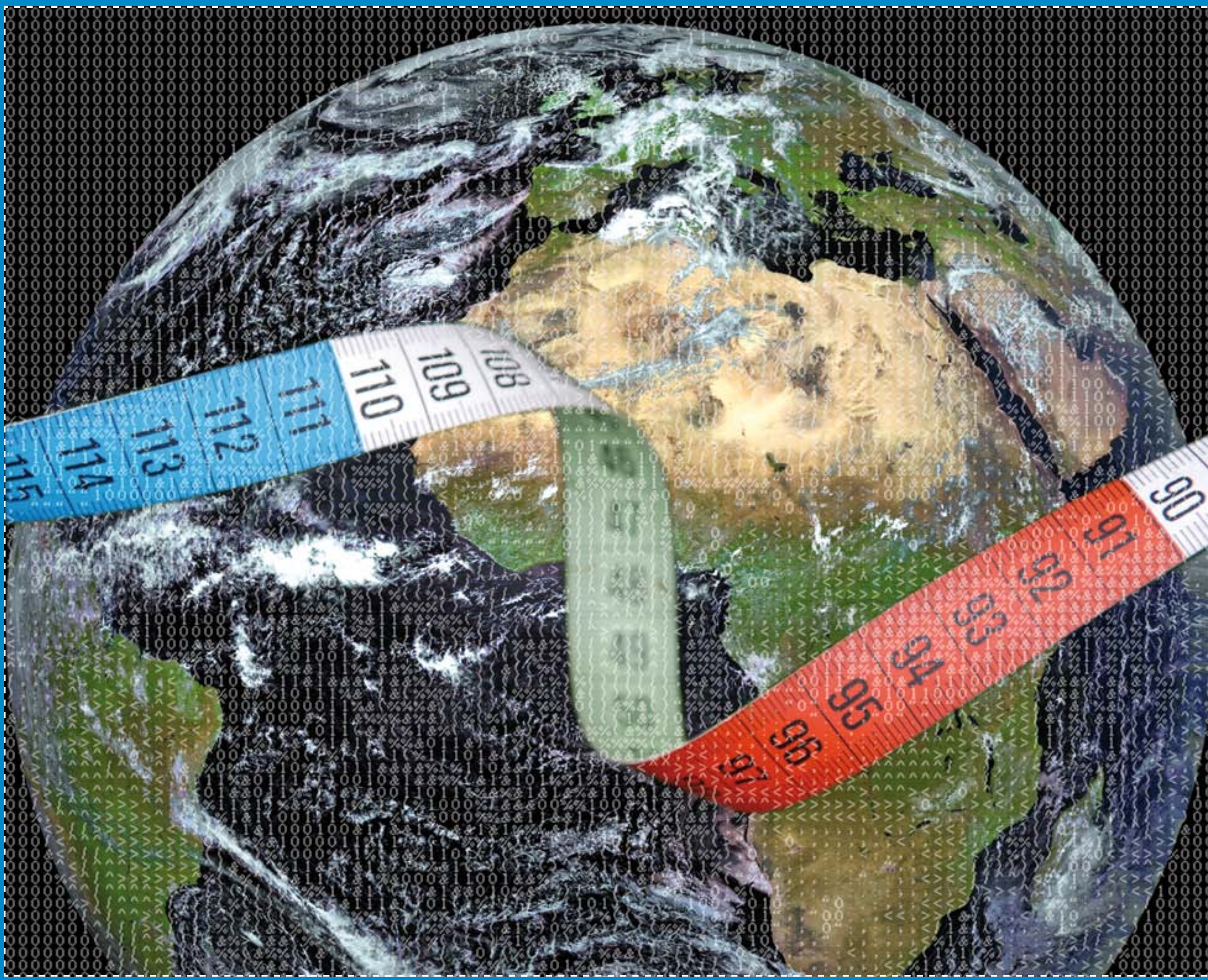
> Environmental Impacts of Swiss Consumption and Production

A combination of input-output analysis with life cycle assessment



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> Abstracts

There is a need for information on total environmental impacts of Swiss consumption and production as a complement to economic information. This research project investigated for the first time the total environmental impacts due to Swiss consumption and production. About 60% of environmental impacts that are caused by final demand occur abroad as a result of imported goods and services. The most important area of consumption is nutrition that accounts for about 30% of total impacts, followed by housing and mobility of private households. Within this study, input-output analysis and environmental data are combined in order to get a true and fair view on total environmental impacts of consumption and production.

Keywords:
Environmentally Extended Input-Output-Analysis
Life Cycle Assessment
Environmental Impacts
Consumption and Production

Heute fehlen Informationen zur gesamten Umweltbelastung von Konsum und Produktion der Schweiz als Ergänzung zu ökonomischen Informationen. Im vorliegenden Forschungsprojekt wurden erstmals die gesamten Umweltbelastungen durch Konsum und Produktion der Schweiz untersucht. Etwa 60 % der durch die Endnachfrage verursachten Umweltbelastungen fallen im Ausland durch Importe von Gütern an. Der wichtigste Konsumbereich ist die Ernährung mit knapp 30 % Anteil an den Gesamtbelastungen gefolgt von Wohnen und Mobilität. Im Rahmen dieses Forschungsprojektes wurde mit der Kombination von ökonomischen Input-Output-Tabellen und verschiedenen Umweltdaten erstmals eine Datengrundlage zur Analyse der gesamten Umweltbelastungen von Konsum und Produktion aufgebaut.

Stichwörter:
Ökologische Input-Output-Analyse
Ökobilanz
Umweltbelastungen
Konsum und Produktion

A l'heure actuelle, nous manquons d'informations sur l'impact environnemental global de la consommation et de la production suisses, pour compléter les informations économiques dont nous disposons. Le présent projet constitue la première investigation du bilan des atteintes à l'environnement générées par la consommation et la production de la Suisse. Quelque 60 % des atteintes générées par la demande finale sont causées à l'étranger par les biens importés. L'alimentation est le secteur ayant l'impact le plus lourd, avec 30 % de la charge écologique totale, suivie du logement et de la mobilité. Le projet de recherche a croisé des tableaux entrées-sorties économiques avec diverses données environnementales pour constituer le premier socle de données permettant d'analyser l'impact environnemental global de la consommation et de la production.

Mots-clés:
analyse écologique des entrées et des sorties
analyse de cycle de vie
atteintes environnementales
consommation et production

Ad oggi mancano informazioni sull'impatto ambientale globale dei consumi e della produzione della Svizzera che completino i dati economici. Il presente progetto studia per la prima volta questa tematica. Circa il 60 per cento dei carichi ambientali della domanda finale è generato all'estero con la produzione di beni poi importati. Tra i consumi, il settore alimentare ha il maggiore impatto, ossia quasi il 30 per cento del carico ambientale complessivo, seguito dal consumo energetico e dalla mobilità delle economie domestiche. Nel quadro della presente ricerca è stata costituita per la prima volta una base di dati con cui analizzare l'impatto ambientale globale dei consumi e della produzione, combinando tabelle sulle entrate e le uscite economiche con diversi dati ambientali.

Parole chiave:
analisi ecologica delle entrate e delle uscite
ecobilancio
carichi ambientali
consumi e produzione

> Foreword

Are we moving in the direction of a resource-conserving and ecologically sound, that is, green economy? The more we see the finite nature of the natural resources of our planet, the more urgent this question becomes. It is at least as important as the question of whether our economic activities – measured in gross domestic product (GDP) – are in line for growth. Within the framework of a decision for a green economy The Federal Council tasked the administration at the end of 2010 with complementing the GDP with suitable indicators for social, economic and environmental developments. This pilot study aims to help create measurements for the future which show the absolute environmental progress of a country. In this way it makes a contribution to the national and international discussion.

The present study is directed towards experts from environmental policy and the economy and towards people who are concerned with indicators for a green economy or with life cycle assessments. It gives for the first time an overall picture of the environmental impacts which are caused by Swiss consumption and Swiss production. This is made possible through the combination of economic data and environmental data with an approach that includes the whole life cycle of products and services.

The investigations carried out within the framework of this study provide an important basis for environmental policy. For example, they show that nutrition, housing and mobility cause a high proportion of the total environmental impacts. We must therefore work in these sectors if we want to reduce the total impact to an acceptable proportion.

Also evident is the considerable significance of environmental impacts that our consumption of imported goods causes in other countries. From this we see on the one hand our shared responsibility for the global environmental situation and on the other hand also our dependence on natural resources from abroad.

Economic growth has understandably a high priority in politics today. Economic development must however take place within the boundaries that are defined by the finite nature of our planet. It is therefore not sufficient if environmental impact is growing more slowly than the gross domestic product (relative progress). The environmental impact must fall overall (absolute progress), and indeed to a level that is environmentally acceptable.

Bruno Oberle
Director
Federal Office for the Environment (FOEN)

> Extended summary

A brief overview

For the first time a comprehensive data base on environmental impacts caused by Swiss consumption and production has been set up in this project. Based on economic input-output tables and environmental data, a series of informative assessments of environmental impacts generated by consumption and production has been made possible.

Most environmental indicators published by the FOEN focus on domestic environmental impacts. The present study shows the significance of the various sectors of the economy and also of imports with regard to their contribution to total environmental impacts. It becomes clear that foreign trade is important in the analysis of environmental impacts arising from Swiss consumption.

Imports to Switzerland account for around 60% of the total environmental impact

The study also shows that in order to obtain a *true and fair view* it is necessary to take into account a large number of relevant emissions and resource uses. Simplified indicators such as greenhouse gas emissions, energy consumption, water consumption or the current method of calculating an ecological footprint are not sufficient to give a comprehensive picture of environmental impacts.

All relevant emissions and resource uses must be taken into account

The average consumption pattern of Swiss households was analysed with regard to the most environmentally relevant sectors at the present time. Food, energy consumption and mobility generate a large proportion of the environmental impacts and thus represent important areas for action.

Food, energy consumption and mobility as most important consumption domains

Studies with similar objectives have also been carried out in other countries. There are however still many differences as regards data bases, procedures, evaluation indicators and results. The approach that is developed here is helpful for countries for which foreign trade plays an important role. The methodological approaches, such as the method of calculation of environmental impacts through imports, are to a large extent transferable to other countries. In this way, the study can make an important contribution to the discussion on methodology and possible harmonisation on an international level.

Transferability of the findings and methodological approaches to other countries

The next ten pages summarise the objectives, the methodological procedure, the results, methodological findings and conclusions.

Contents of the summary

Initial position and objectives

Sustainable consumption necessary

The goal of responsible environmental policy is to ensure that environmental impacts do not exceed a level that is sustainable in the long term. In recent decades environmental impacts have been significantly reduced in some sectors through political measures (e.g. with selected air or water pollutants). In other domains (e.g. CO_2 emissions and resource uses) regulation and efficiency improvements have indeed led to a certain relative decoupling of environmental pollution from economic growth. Economic growth has however to a large extent neutralised the relative improvements so that the environmental goals that were set have not yet been achieved. On the whole therefore the question of how the increasing consumption of goods (material goods and services) can be made more environmentally sound has taken centre stage in environmental politics. For this purpose it is necessary to take an integrating view of production and consumption patterns in society that can be termed "ecologically sustainable consumption and production".

Investigate interaction of consumption and production

Environmental statistics can describe the direct environmental impact that is associated with consumption in households and production in companies. However, in order to set the right priorities for a sustainable policy, the political decision-makers need a comprehensive overview of the interactions between consumption patterns, production activities and environmental impacts. The extreme complexity of the economic and ecological systems requires the use of simplifying models. A central requirement is to capture adequately the diversity of consumption and production activities in a national economy, their most important interactions and the most important environmental impacts. At the same time this task is becoming easier because more and more environmentally relevant data are being made available at various levels, whether in official environmental statistics, environmental information from companies or product-related environmental information.

Project goal: comprehensive analysis of environmental impact of consumption and production in Switzerland

The aim of this pilot project was to provide a comprehensive analysis of the environmental impacts in Switzerland that arise from consumption and production and their most important driving forces. The following questions were addressed:

> How can the total environmental impact caused by Switzerland be determined?
> Who are the direct initiators of environmental impacts in Switzerland? Which sectors are important and how large are the emissions from private households? Which environmental impacts are they responsible for?
> Which consumption domains relating to private households are the driving forces for environmental impacts if the supply chains for the production and distribution of goods are included alongside direct emissions? How environmentally intensive are the various domains of private consumption?

Assessment of all environmental impacts necessary

While existing studies in Switzerland were limited to partial aspects such as greenhouse gases or material consumption, the present study attempts to be as comprehensive as possible in taking into account environmental impacts. In addition, environmental impacts that are generated in other countries during production of goods and services that are imported into Switzerland are also included. The models and data bases needed for this were developed and evaluated as a pilot project.

True and Fair View

The chosen approach is meant to record environmental impacts of the national economy in an aggregated form and according to the requirements of a "true and fair view". The two central requirements of a true and fair view are the relevance for decisions and the significance of all relevant environmental impacts over the whole life-cycle. The information that can be made available with the new calculation approach is meant to serve the following superordinated aims:

> A better information basis for (environmental) policy decisions
> A comparison of environmental impacts in consumption and production over time (performance measurement)
> The provision of a data base for the calculation of the environmental impact of various consumption developments.

The present study contains the basic information necessary for determining a pilot indicator for the total environmental impact in Switzerland. The data base are compatible and comparable with reporting on other levels (business, product and international levels).

Methodological procedure and data bases

Environmentally-extended input-output-analysis

A so-called ecological input-output analysis (Environmentally-Extended Input-Ouput-Analysis: EE-IOA) was chosen as a methodological approach, supplemented by life-cycle inventory data to evaluate the environmental impact associated with imports. EE-IOA is a method used in investigating the environmental impacts of production and consumption patterns of the national economy. It extends the economic input-output analysis with environmental data for the different economic sectors and private households. The input-output table is an economic data base depicting both the supply of goods between the sectors and also the supply to private households and the remaining areas of final demand. It shows for every sector the goods it procures from the other sectors of the national economy in order to manufacture its own products, and the destinations of these products. An input-output model based on this information can calculate how much the separate sectors produce and how many goods are imported so that a certain number of final products can be delivered to the households. This also includes upstream production in the supply chains. If the environmental impact associated with production is known for every sector, then the (direct and indirect) environmental impact generated by the various consumption domains can be assessed. Since household consumption is subdivided in the IO table into various consumption domains (e.g. housing, mobility, health), it is possible to ascertain through the ecological IO analysis the direct and indirect environmental impacts generated by these consumption domains.

Combination with life cycle inventory data for estimate of environmental impact of imports

A simple EE-IOA model is limited in its capacity to adequately estimate the environmental impacts associated with imports. To do this one would have to assume that imported goods are manufactured abroad with the same production technology and the same specific environmental impact as domestically produced goods. This is not realistic for Switzerland since the country is principally a location for service and light industries that are less environmentally intensive, while the environmentally intensive products (e.g. basic chemicals or metals) are likely to come from abroad. In the present study the ecological IO analysis is therefore supplemented with life cycle inventory data. When the IO model has been extended like this it can adequately capture the environmental impact of imports.

Data bases

One of the first steps was to compile the necessary data bases. As a central data base for the IO model the current Swiss Input-Output table for the year 2005 was used. A large number of different sources were drawn on for the allocation of environmental impacts to households and economic sectors. Data on greenhouse gas emissions and energy consumption were made available by the Federal Statistical Office. They were generated within the framework of a project for the compilation of a so-called NAMEA[1] Air (within the context of environmental accounting). Greenhouse gases and energy consumption are allocated here to economic actors. Further important noxious emissions and resource uses have been attributed in this study for the first time to the directly responsible sectors and households. In addition, a large number of other sources were evaluated.

Environmental impacts from the production perspective

This model analysed environmental impacts in Switzerland from two perspectives, the production perspective and the consumption perspective (cf. Fig. 1). From a production perspective the environmental impacts that arise domestically are charged to Switzerland. In a similar way, the directly caused environmental impacts are attributed to the individual economic actors – companies and households. The production perspective makes it possible to identify the direct initiators of environmental impacts.

Environmental impacts from the consumption perspective on the basis of final demand

From the consumption perspective, the environmental impacts attributed to Switzerland are those that have been triggered by the domestic final demand for goods and services both in Switzerland and abroad. The domestic final demand comprises chiefly the consumption of private households, the final demand of the government and investments. From this point of view the environmental impacts that arise from the manufacture of imported goods are also attributed to Switzerland. Likewise the domestic environmental impacts generated by the manufacture of exported products are not attributed to Switzerland.

Check on the results using a second accounting method (foreign trade statistic & LCA)

Along with the accounting method described above with its ecological input-output model, the total environmental balance was also calculated on the basis of data from the foreign trade statistics for goods and life cycle inventory data. The greatest differences are in the calculation of the environmental impacts for exports. This second accounting method does not however permit a detailed evaluation for the separate economic sectors and consumption domains.

1 NAMEA = National Accounting Matrix with Environmental Accounts

Fig. 1 > Environmental impacts in the production and consumption perspective

The graph shows the link between the production and the consumption perspective in recording a country's environmental impact. In the production perspective only domestic environmental impacts are considered. In the consumer perspective the environmental impact triggered by domestic final demand as a whole, both domestically and abroad, is calculated.

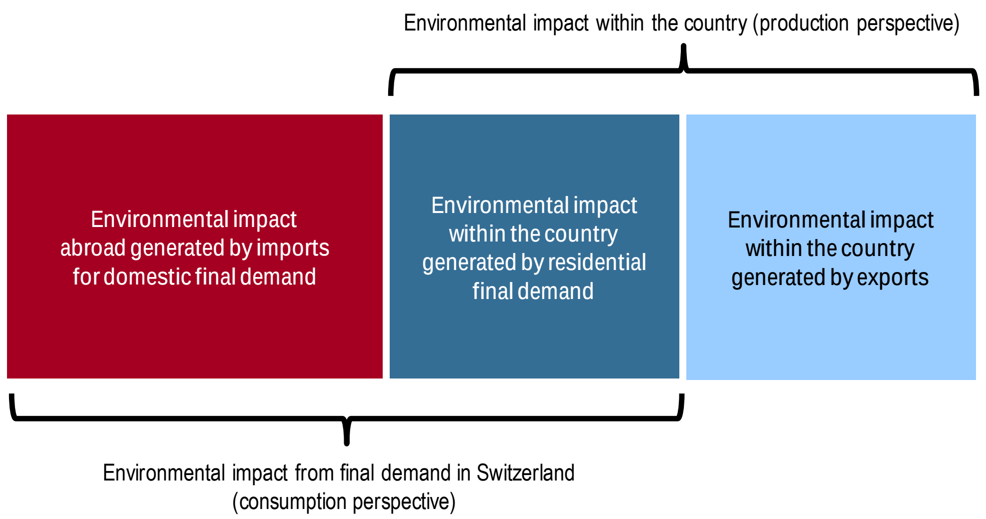


Diagram: ESU-services Ltd. and Rütter+Partner

Results of the study using the assessment method of ecological scarcity

Perspectives used in evaluation

Fig. 2 gives first of all an overview of the total environmental impact of consumption and production in the Swiss national economy. The analysis is geared to the two perspectives discussed above, the consumption and the production perspective.

Assessment of environmental impacts using the method of ecological scarcity

In order to calculate the results the particular emissions and resource uses are weighted using the method of ecological scarcity (eco-points) (Frischknecht et al. 2008). This method offers a comprehensive picture of emissions from a whole series of pollutants and the use of various resources that are relevant from the point of view of Swiss environmental policies. It is often used in Switzerland for product life cycle assessments.

Environmental impact in Switzerland (production perspective)

The first column in Fig. 2 shows the assessment of emissions and resource uses that occur in Switzerland and are generated by households or businesses (production perspective). Around 30 percent of direct environmental impacts in Switzerland are generated by the agriculture and forestry sector. A series of environmental impacts arising from the use of pesticides and fertilisers for instance, play an important role here. The waste management industry and transport services are also important for the environmental impacts in Switzerland.

The environmental impacts that are caused by goods and services imported into Switzerland (2nd. column in Fig. 2) are about twice as high as the direct impacts within Switzerland. The environmental impacts associated with exports of goods and services (3rd. column in Fig. 2) cannot be attributed to Swiss consumption. They must therefore be deducted in the consumption perspective from the Swiss environmental account. It is worth noting that a large part of the environmental impact of exports occurs in other countries. This shows that the Swiss export industry largely carries out "refining services". It is therefore a case of imported environmental impacts that are later re-exported.

Trade is important for the total environmental impacts

Fig. 2 > Overview of the environmental impacts of consumption and production in the Swiss national economy

In this diagram the environmental impacts in the year 2005 are assessed using the method of ecological scarcity. The average value of the two calculation approaches and the deviation between the two results are illustrated as the range. Imports make an important contribution to the total impacts from the Swiss final demand.

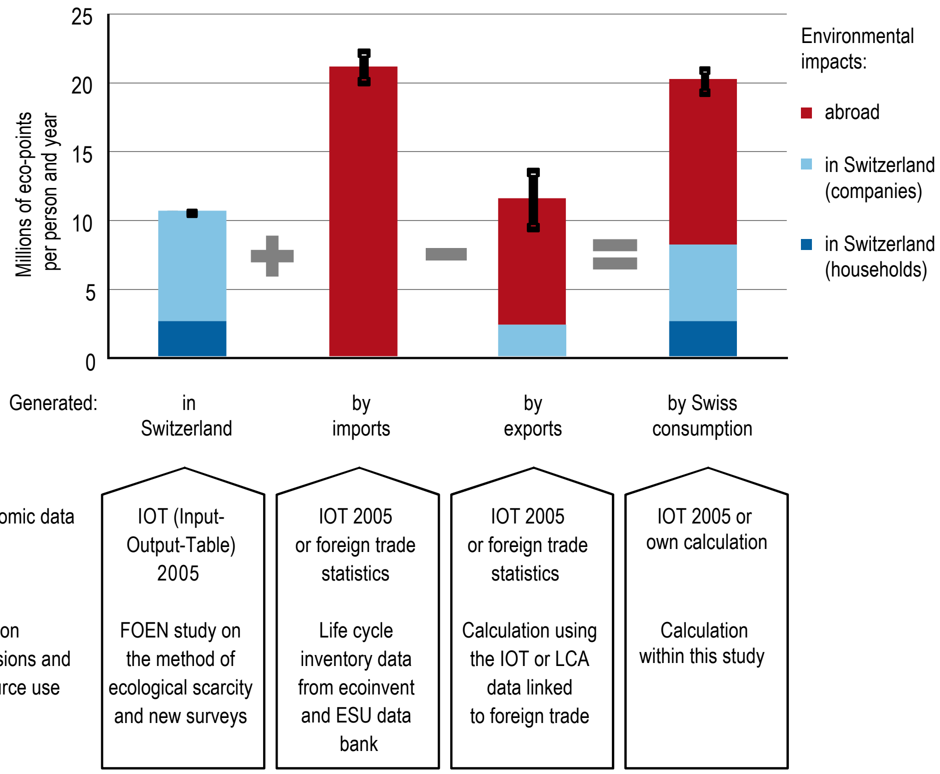


Diagram: ESU-services Ltd. and Rütter+Partner

The environmental impact generated by consumption in Switzerland is then calculated as direct emissions plus imports minus exports (consumption perspective, 4th. column in Fig. 2). This amounts to about 20 million eco-points per year and person and is thus about twice as high as the impacts generated directly within Switzerland. Around 60% of the total environmental impact arising from the final demand in Switzerland accumulates in other countries. For a true and fair picture of the environmental impact of Swiss consumption therefore, the environmental impact of imports must be added to

Consumption generates around 20 million eco-points per person (consumption perspective

Switzerland's environmental account and the environmental impact of exports must be deducted from it. In the case of the environmental impact of exports in particular, the second accounting method (foreign trade statistics & LCA) leads to an approximately 25% lower result than the first accounting method (EE-IOA), even though the importance of the environmental impacts of imports and exports as a whole is undisputed.

Consumption domains

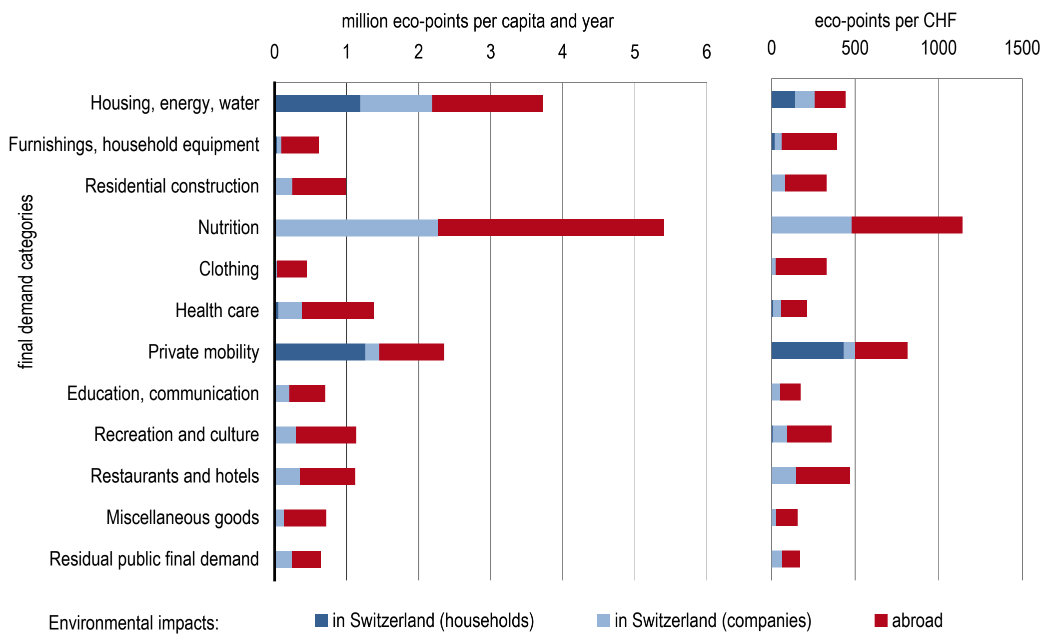
The environmental impacts generated by Swiss consumption are evaluated on the basis of the established data bases (Fig. 3 and Fig. 4). Various consumption domains such as housing, food or mobility are investigated with regard to their share of the total impact. In addition, the extent of environmental impacts per CHF of consumer expenditure in households is shown. In this way it is possible to estimate, for example, how a future alteration in consumer expenditure could change the environmental impacts.

Fig. 3 > Environmental impact of the different consumption domains (eco-points per person in 2005)

The supply of foodstuffs causes almost 30% of environmental impacts and is therefore the most important domain of final consumption, followed by housing and the demand for mobility. The direct environmental impact in the consumption domain of "housing, energy, water" can be attributed to the electricity and heating energy consumption in households, and that of the consumption domain of "private mobility" mainly to fuel consumption for private vehicles.

Fig. 4 > Environmental intensity of the different consumption domains (eco-points per CHF in 2005)

Expenditure on food has also the highest environmental intensity per CHF. The diagram shows that one Swiss franc spent on mobility has greater environmental impacts than the same money spent on housing.



Diagrams: ESU-services Ltd. and Rütter+Partner

The environmental impact in the consumption perspective can also be shown from the point of view of the goods demanded rather than the consumption domains (cf. Fig. 5 and Fig. 6). Every consumption domain consists of a variety of goods that are used for a defined purpose. Fig. 5 and Fig. 6 show the total environmental impacts that are generated by domestic final demand for these goods. They distinguish between environmental impacts generated within the country and abroad.

Final demand in goods

Fig. 5 shows the environmental impacts of the individual groups of goods per capita. The direct environmental impacts of households are listed for comparison. A large proportion of the environmental impact is generated by agricultural/forestry goods, foodstuffs and the services of restaurants and hotels. Further important categories of goods are the energy sources electricity and gas, and construction services.

Food supply is important

Fig. 5 > Total environmental impact induced by final demand in Switzerland, in categories of goods, in 2005

This illustration shows the total environmental impacts arising from domestic final demand (i.e. final demand without exports) per head of the population. Within each category there is a division into impacts in Switzerland and impacts abroad. For comparison the direct environmental impacts of households are also shown.

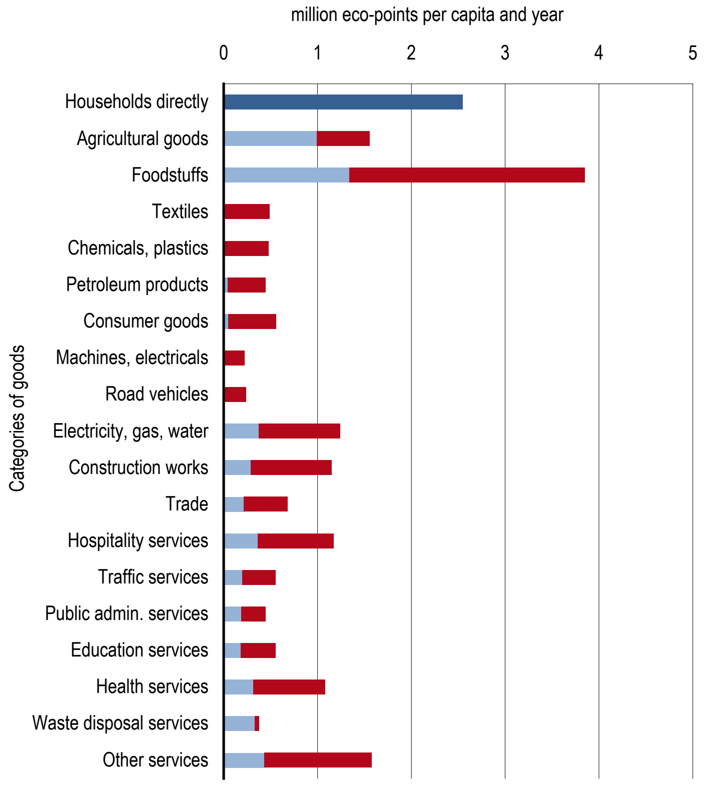
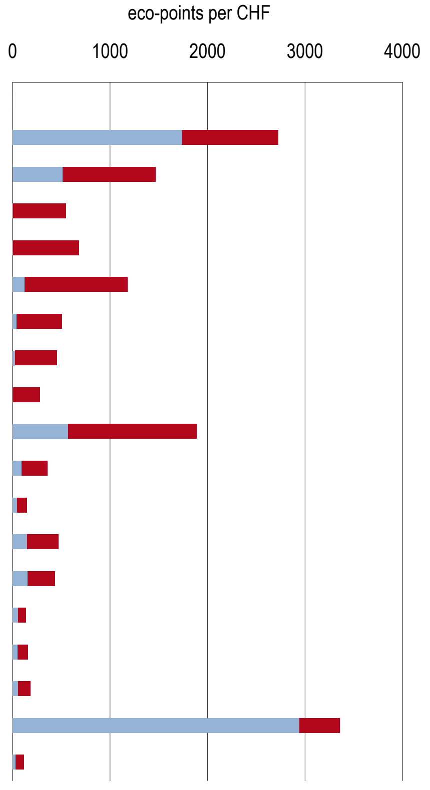


Fig. 6 > Environmental intensity of the categories of goods in domestic final demand, in 2005

This illustration shows for the same categories of goods the environmental impact relating to the money spent on buying the goods (at basic prices).



Environmental impacts: in Switzerland (households) in Switzerland (companies) abroad

Svc: Abbreviation for services. Diagrams: ESU-services Ltd. and Rütter+Partner

A different picture emerges if one looks not at the level of environmental impact but at the specific environmental intensity in relation to the value of the goods demanded. Here the services of the waste disposal industry stand out, followed by agricultural products, foodstuffs and energy sources. Goods have a decidedly higher environmental intensity than services. The final demand for services however makes a considerable contribution to the absolute environmental impact.

For most of the goods relating to final demand the proportion of environmental impacts in other countries is decidedly larger than the domestic proportion. With the exception of foodstuffs this holds true more for goods than for services. The exceptions are disposal services that are strongly anchored in this country and agricultural products.

Comparison of results with different assessment methods

For purposes of comparison, assessments of the total environmental impact were also carried out using other life cycle assessment methods (Fig. 7). The methods used are ecological scarcity (eco-points 2006), ReCiPe, Eco-indicator 99 (H,A)[2], cumulative energy demand (non-renewable energy resources), greenhouse gas emissions and the ecological footprint.

Different weightings

This results in different consumption domains having a different share in the total environmental impact according to the assessment method used. The reason for this is that three of the methods (cumulative energy demand, greenhouse gas emissions, ecological footprint) each only consider individual environmental aspects. So in agriculture in particular they do not assess the diverse types of environmental impacts. The other, more comprehensive assessment methods (eco-points 2006, ReCiPe, Eco-Indicator 99 (H,A)) on the other hand take into consideration a series of different environmental impacts and accordingly have a better claim to being a true and fair view.

Food generates 30% of environmental impacts

Overall it is shown that with all comprehensive assessment methods food consumption generates approximately 30% of the environmental impacts. Emissions (nitrate, phosphate, methane, dinitrogen monoxide, pesticides and heavy metals), and resource uses (land, water) in agriculture play an important role here. Other important domains are the mobility and energy consumption of households.

Political preferences relevant in environmental assessment

The question of which comprehensive assessment method is ultimately preferred depends to a large extent on the value system of the analysts and there is no answer from a scientific point of view. For Switzerland we regard the method of ecological scarcity as the most suitable method since it directly reflects the aims of environmental policy here and allows for amendments concerning relevant environmental topics in the future as soon as they are reflected in legislation.

[2] The latter are two scientific assessment methods developed by Dutch researchers that model and assess damage from environmental impacts. The abbreviation (H, A) stands for the assessment perspective Hierachist and Average. Weighting of the three protected commodities and details on this subject can be found in the scientific background report.

Fig. 7 > The proportion of environmental impact for each domain of final consumption

The proportion of environmental impact for each domain of final consumption was calculated using different impact assessment methods. Food is the most important and is responsible for almost 30% of the total environmental impact.

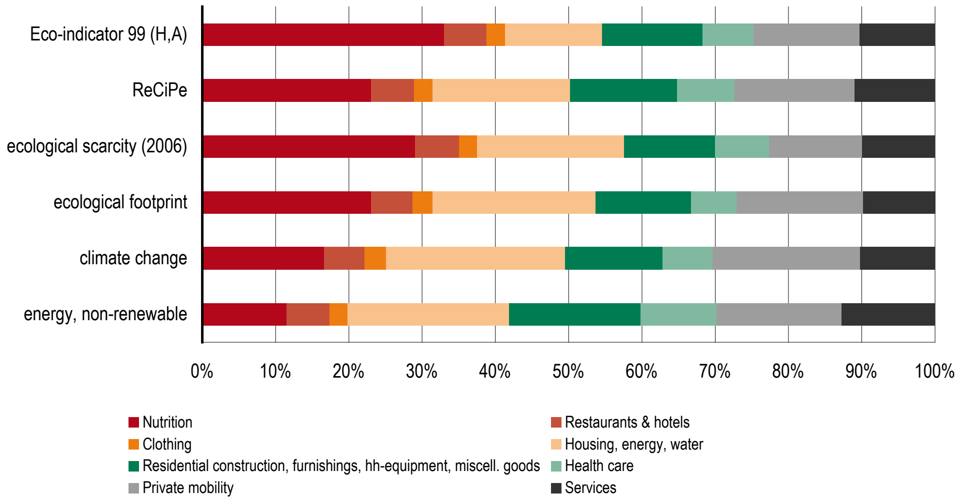


Diagram: ESU-services Ltd. and Rütter+Partner

The results of this study were compared with other, earlier studies for the indicators "greenhouse gas emissions" and "ecological footprint". In these studies very different approaches and data sources from the domains of IOT, life cycle assessment and ecological footprint were used. The methodological approach used here for the first time confirms the importance of foreign trade for total impact, which was established by this study, and also the considerable increase in the total impact when this is included in the environmental balance.

Comparison of results with earlier studies

However, between the total results of the different studies there is a range of 11 to 18 tonnes for greenhouse gas emissions generated by the final demand per person. This is certainly considerably higher than direct emissions in Switzerland of only about 7 tonnes of CO_2-eq. On the basis of the available information the scale of 11–13 tonnes per person for Switzerland is considered realistic. Thus there is a further need for research to compare different approaches and to improve the data base.

About 12 tonnes of CO_2-eq per Swiss consumer

Reduction target

This study also estimated by how much the current environmental impact would have to be reduced in order to achieve Switzerland's political goals. For direct emissions and resource uses in Switzerland a total reduction target of about 40% was calculated using the method of ecological scarcity. This target is derived from political targets for different environmental impacts (e.g. politically agreed reduction targets for CO_2 emissions) based on the method of ecological scarcity. It cannot therefore be scientifically proved or falsified and cannot show the ecologically sustainable degree of resource use and environmental impact as a function of population.

40% reduction as political target in Switzerland for direct emissions

For worldwide environmental impacts, too, (including therefore imported goods and services) there is a need to define the maximum sustainable impact per head of the future world population. Some first considerations on this topic can be found at the end of Chapter 5 of the report.

Methodological findings

Up to now the data bases that have been available in Switzerland have not made it possible to show a comprehensive picture of environmental impacts. In particular there has been a lack of total indicators which take into account the environmental impacts of water pollution, land use or a series of airborne pollutants. This gap can be closed with the accounting approach developed in this pilot study for the total environmental impact of the Swiss economy.

The approach presents a comprehensive picture of the total environmental pollution that is generated by Swiss consumption and production. Special consideration is given to environmental impacts that are generated in other countries. In addition, an analysis by consumption domain and economic sector has been made possible.

Link to National Accounts

The accounting approach with its EE-IOA model makes it possible to create a direct link to the National Accounts (SNA), since the same classification of economic sectors (NOGA/NACE) and consumption domains (COICOP) is used.

Uncertainties

The study also shows however that such an analysis of the total environmental impact has some uncertainties. On the basis of a comparison of two approaches, through the comparison of the results with other studies and through the evaluation of estimated uncertainties in a Monte Carlo Simulation we estimate the uncertainty of the results for total consumption to be of the order of magnitude plus/minus 20–30%. This corresponds to the uncertainties that as a rule also have to be taken into account with life cycle assessment results. Unfortunately the uncertainties are often not quantified in other approaches. The interpretation for the total environmental balance were verified in different ways with literature data and alternative approaches and so can be still considered valid. Furthermore, it must be taken into account that uncertainties for various partial aspects are not independent of one another and so the partial results do not as a rule vary in opposing directions. For comparisons over and above this, of individual economic sectors or the balance of alterations in a time series, the possible uncertainties in an interpretation must also be taken into account. In order to consider the possibilities for improvements to individual products, sectors and consumption domains it is necessary to carry out detailed evaluations on the basis of life cycle assessments. Depending on the specific questions asked, equally secure statements are also possible in this way.

Data base for further evaluations

The provision of an EE-IOA in a format that is commonly used for life cycle assessments makes it possible to use these data in so-called hybrid analyses. In this way missing detailed information is supplemented by the general sector-specific environmental information. Thus sectors and products are identified for which life cycle inventory data need to be established as a priority in order to reduce relevant “blind spots” in life cycle assessments. In addition, the EE-IOA offers various methods of verification for different approaches to accounting for imported environmental impacts. The latter can be considered in depth in follow-up studies.

Conclusions and recommendations

First analysis of total environmental impact for Switzerland
Study analyses overall picture

The methodological approach developed here makes it possible to indicate the significance of different fields of activity or economic sectors within environmental impacts as a whole (e.g. food). This type of analysis however is not suited for deducing *directly* concrete measures (e.g. a change to a low-meat diet in order to reduce environmental impacts) or for comparing individual products with one another. Detailed life cycle assessment are necessary as a basis for decision for specific questions e.g. the possibilities for optimisation in the domain of food. They can then help to put forward suggestions for improvements. In the most important domains of food, energy and mobility there are already a number of relevant life cycle inventories available.

Better coordination of future data collection necessary

Many data sources had to be used for this overall calculation. They are not always brought up to date on a regular basis and are not always available with a suitable structure and nomenclature. For the purposes of regular reporting it is therefore necessary to better coordinate statistical data collection on economic structure, foreign trade, energy use and direct environmental impacts and to liaise in a timely manner with the different federal offices. Because of the complexity and uncertainties of the calculation however, further experience will be necessary before it is actually possible to observe alterations over time.

External review

The study was externally reviewed. According to the review, the pilot study and the various indicators of environmental impacts present a picture that corresponds to the actual situation and thus meet the FOEN requirements for environmental information with regard to a true and fair view. That is, the study fulfils the two key requirements: (1) It provides relevant information for decisions that require input (in the present case political and consumption decisions are involved), and (2) it takes into account all significant environmental impacts, (differentiated according to domestic and foreign impacts), for the whole of the product life. The study also satisfies the conditions for these two requirements: reliability, transparency, comprehensibility, coherence and comparability, availability of information and timeliness.

1 > Introduction

What are the environmental impacts of Swiss consumption and production patterns? Developing and applying a methodology for answering this question is the main topic of this report. This is done by combining national economic and environmental accounts, and foreign trade statistics with life cycle based information for single products in order to calculate and analyse the environmental impacts caused by Switzerland in the year 2005.

1.1 Background

Goal of environmental policy

The main goal of environmental policy is to ensure that the environmental impacts of consumption and production activities do not exceed a sustainable level. In some areas (e.g. critical air or water emissions) policy actions have resulted in significant reductions of environmental impacts. In other areas (e.g. CO_2-emissions, materials use or traffic-related impacts) regulation and efficiency improvement have led to a relative decoupling of environmental impacts from economic growth, though the level of environmental impacts has not reached sustainable levels yet due to economic growth in absolute terms. Thus research questions dealing with increasing consumption as a driving factor for environmental impacts and the quest for sustainable consumption patterns have continuously become more relevant. An integrated view of consumption and production patterns and their environmental impacts has consequently gained in importance in the policy area "sustainable consumption and production (SCP)".

Appropriate environmental statistics and accounts can describe the direct environmental impacts of production patterns. But setting the right priorities for SCP policy measures ideally requires a comprehensive overview of the mechanisms between consumption patterns, production activities and environmental impacts. This overview is difficult to gain due to the high complexity of the economic and the environmental system. One of the main challenges is to capture all the relevant consumption and production activities in the economy, including their interrelations, and all the relevant environmental impacts. This is only possible with simplified models that reduce the complexity of the real economic and environmental system.

The models appropriate for answering the research question should ideally fulfil the following criteria.

> *Life cycle approach:* Consumption activities lead to direct emissions and resource uses (in the following also often referred to only as emissions), but also induce impacts in the production and waste disposal phase of the goods that are consumed. Therefore in the analysis of consumption- related environmental impacts a life cycle or supply chain approach that encompasses all three phases needs to be chosen.
> *Consideration of imports:* In today's globalized world supply chains stretch across country and even continental borders. Thus domestic consumption also leads to environmental impacts in foreign countries. Likewise more sustainable consumption

patterns can lead to a reduction of environmental impacts abroad. For Switzerland – being a service and light industry economy – this is especially important since imported goods are supposed to have a higher environmental intensity than domestic goods. A recent study has shown that imported goods contribute 44% to the total greenhouse potential caused by consumption in Switzerland (Jungbluth et al. 2007). Therefore – to have a complete picture – it is necessary to consider environmental impacts in foreign countries that are induced by imported goods destined for domestic consumption.

> *Comprehensive coverage of environmental impacts:* A comprehensive picture includes several different environmental impacts, encompassing different environmental resources (e.g. air, water, land) and impact categories (e.g. greenhouse effect, acidification, toxic air emissions compromising human health and ecosystem quality). For decision makers in environmental policy some aggregation of these different impacts would be useful in order to have a focus on a limited set of indicators.

1.2 Overview of possible methodological approaches and literature review

In principal the following methodological approaches are available for the required analysis,

> life cycle assessment (LCA),
> material flow analysis (MFA) and
> environmentally-extended input-output analysis (EE-IOA).

In the following paragraphs the three approaches are briefly described and compared in the context of the research question. A more detailed description of LCA and EE-IOA and the approach chosen in this study follows in chapter 2.

Life Cycle Assessment (LCA)

Life cycle assessment (LCA) is a well-established method to analyse the environmental impacts of products (e.g. International Organization for Standardization (ISO) 2006a). The life cycle perspective is an inherent element of this method. LCA is normally used for the comparison of the environmental impacts of specific products (e.g. different kinds of packaging for milk) or as a basis for the improvement of the environmental performance of products. The life cycle of a product includes all processes that are related to the production, consumption and disposal phase (cradle to grave approach). The physical flows between these processes and their emissions and resource uses are recorded in detail. Complex models are used to aggregate the different emissions and resource uses to provide environmental indicators that can be used for decision-making.

LCA is usually applied at the detailed product level. In some cases LCA has been extended to the analysis of aggregate product groups or consumption categories e.g. for nutrition, mobility or housing (Girod & de Haan 2010; Jungbluth et al. 2003; Känzig & Jolliet 2006) or of consumption of private households as a whole (e.g. Biointelligence Services 2003; Dall et al. 2002; Girod & de Haan 2010; Nemry et al. 2002; Noorman et al. 1999). Jungbluth et al. (2007) used LCA data to estimate the global warming potential of Swiss imports and exports.

The studies on the environmental impact of household consumption usually start with detailed survey data on household expenditures for goods and services, convert the monetary values to physical values with price data and then estimate the total environmental impacts of the goods with LCA data. A major challenge of this approach is to adequately model the large variety of goods and services consumed by private households and their respective life cycles. LCA data are mainly available for more basic products such as energy carriers, basic materials, food products or packaging, less so for complex products (e.g. electronics) and services. Therefore in some studies data gaps in the analysis of household consumption and simplifying assumptions have impaired the quality of the results (Tukker et al. 2006).

A major advantage of the LCA approach is the low aggregation level (products) and the comprehensive inclusion of all relevant environmental impact categories. Yet the low aggregation level is also its main disadvantage for application to the complete economy, since data requirements and modelling complexity which would adequately capture all the goods consumed and the supply chains to produce these goods would be enormous. Furthermore LCA data usually do not distinguish between domestic and foreign production in the supply chains, making it difficult to separate them in the analysis.

Material Flow Analysis (MFA)

Material flow analysis is closely related to LCA with regard to the methodological approach and the data used. It is generally used for the depiction and improvement of material flow systems within regions, countries or even across countries. Similarly as with LCA, a system of production, consumption and disposal activities (or processes) that are connected by physical flows is set up as a basis for the analysis (Baccini & Bader 1996). Often MFA focuses on certain basic materials (e.g. wood-based materials or metals). The level of aggregation is usually higher than in LCA. Environmental impacts are usually less comprehensively included in comparison to LCA, e.g. only as material flows (Rubli et al. 2005). Due to regional system boundaries the location of processes is known. As with LCA, data at the process level, especially with regional information, are not available to a sufficient extent to be able to comprehensively capture the complexity of economic systems.

Environmentally-Extended Input-Output-Analysis (EE-IOA)

In the economic field environmentally extended input-output-analysis (EE-IOA) is a well-established method for analysing the environmental impacts of consumption and production patterns of an economy. This method combines economic input-output-analysis with environmental data. The main economic database is the input-output table that records the supply of goods between industries and from industries to private households and other sectors of final demand. All flows are recorded in monetary units. The use of input-output modelling enables the level of production and imports caused by consumption or final demand in an economy to be calculated. The combination with environmental data enables the environmental impacts related to consumption and production to be calculated. With regard to the consumption of private households, various consumption categories (e.g. housing, mobility, health, education) can be distinguished. Compared to LCA and MFA, the level of aggregation is higher in EE-IOA (industries instead of products). On the other hand, consumption and production activities in the economy are comprehensively depicted. EE-IOA thus enables the environmental profile of private consumption and the final demand of an economy to be estimated at a mesoeconomic (sectoral) level. Its use in scenario analysis enables analysts to estimate the environmental impacts of different consumption patterns. Up to now the general method has been applied for several countries.

We can distinguish between single country and multiregional IO models. In single country IO models imports are either ignored or it is assumed that imported goods are produced in the domestic economy, implicitly assuming domestic economic structures and emission intensities. Multiregional IO models link several single country models to each other via trade flows between countries. Thus with some simplifying assumptions it is possible to calculate the impact of additional consumption in one country on production in all other countries included in the model.

Single country Input-Output (IO) models

Applications of single-country EE-IO models to the analysis of energy use date back to the 1970s (e.g. Bullard & Herendeen 1975, or Knoepfel 1995 for Switzerland). Analysing the impact of consumption patterns on greenhouse gas and other air emissions has also become a standard application (e.g. Munksgaard et al. 2001; Weber et al. 1996). By contrast only a few studies have included other environmental impacts in EE-IOA (e.g. Moll & Watson 2009). With regard to import-induced energy use or emissions these studies mostly assume domestic production of imported goods. The possible level of detail depends upon the sectoral disaggregation in the respective IOT and the availability of sectoral environmental data. Usually the level of sectoral aggregation is quite high in terms of environmental analysis. Tukker et al. (2006) present an approach aimed at overcoming the aggregation problem which they apply to the EU. Since at the time of the study comparable IO tables for the EU countries only distinguished 25 production sectors and environmental data were restricted, the EU table was disaggregated with data from the US IOT, which distinguishes approximately 500 economic sectors. Sectoral environmental pressures[3] were also taken from a US database and adjusted to EU aggregate data. In this way it was possible to do the calculations at a lower aggregation level and for a large number of environmental pressures. Yet questions remain with regard to the quality of the database and the results, since US data were used to a large extent.

The above-mentioned studies show the analytical strength of the EE-IOA approach, since it helps to identify the environmental hotspots of consumption and production in the various countries. However in most of the existing studies the environmental impacts were limited to a few impact categories. Mostly energy use, greenhouse gases, air emissions or materials use were analysed due to the lack of data for other emissions and resource uses. Only a few countries have a comprehensive set of sectoral emissions and resource use data that is compatible with IO tables.

Multiregional Input-Output (IO) models

The use of multiregional EE-IO models gained momentum with the setup of databases including comparable IO tables for a larger number of countries and trade flow data compatible with IO tables, especially by the GTAP project (Global Trade Assessment Project), the OECD IOT and trade databases and data from Eurostat. Due to restrictions with regard to comparable environmental data across countries these studies so far have been restricted to energy use and greenhouse gas emissions (e.g. Ahmad & Wyckoff 2003; Hertwich & Peters 2009; Nathani 2007; Nijdam & Wilting 2003).

[3] The term “environmental pressures” is used in this scientific community dealing with IOT similarly to the term “emissions and resource uses” in the LCA community.

Summary of approaches

The various approaches can be summarised as follows. The LCA approach principally enables the environmental impacts of consumption to be captured with a high level of detail. But comprehensive coverage of the economic system is usually lacking. Furthermore as a stand-alone approach it does not allow distinctions between domestic emissions and emissions in foreign countries. The high level of detail makes the LCA approach data-, time- and resource-consuming.

The MFA approach would in principal also allow for a high level of detail and additionally for distinctions between domestic and foreign emissions and resource uses. Since for most countries the necessary data are only partly available, in a first step a huge effort would have to be made to generate the database.

With the EE-IOA approach the economic system is comprehensively captured, though at a rather high level of sectoral aggregation. Whereas the economic data are available in the IO tables, the main challenge is to allocate domestic emissions and resource uses to the economic sectors and private households according to the conventions of national and environmental accounting. The life cycle approach is followed with some limitations regarding the waste disposal of consumer products.

Environmental impact of imported goods

In single country IO models imports can be assumed to be produced domestically, which for some countries may introduce significant error. Another possible way of estimating the environmental impact of imported goods is to combine the import data from trade statistics with LCA data, as done in Jungbluth et al. (2007). In multiregional IO models the environmental impacts of imports can be directly calculated. The sectoral aggregation level is often higher than in single country IO models. In the existing multiregional EE-IO models the environmental indicators are limited to energy use and greenhouse gases. At the present time a large-scale EU project (EXIOPOL) is being carried out with the aim of building a multiregional EE-IO database for the EU countries that also includes other emissions and resource uses (reference year 2001).

General approach chosen in this study

The existing studies show that EE-IOA is a suitable method for analysing the environmental impacts of consumption and production patterns at a mesoeconomic (sectoral) level and to understand the relevant driving forces. This approach is also chosen for the study at hand, since it allows for a comprehensive overview with a reasonable input of time and manpower. Although the analysis of Swiss consumption and production patterns with an EE-IOA can build on existing work, some important elements are missing. For Switzerland an economic input-output table (IOT) has been estimated for the year 2005 (Nathani et al. 2008). Data on greenhouse gas emissions by industries and private households, that are compatible with the IOT, were made available by the Swiss statistical office (BFS 2009; 2011). For other emissions and resource use categories, data on the absolute level of emissions and resource uses is available (Frischknecht et al. 2009; Rubli et al. 2005), but the allocation to industries and private consumption has not yet been carried out.

A major weakness of the single-country IO approach, especially for a country like Switzerland, is that the environmental impact of imports cannot be captured adequately. Such an approach would significantly underestimate the impacts, since a whole range of emission- intensive production activities (e.g. extraction of raw materials, basic industry) are not located in Switzerland and their products are largely imported. Therefore the assumption is sound that the production pattern of the Swiss economy does not represent the production pattern of Swiss imports well enough.

This kind of comprehensive study covering the relevant environmental impact categories has not yet been carried out for Switzerland. Here a combination of EE-IO with LCA data seems reasonable. Furthermore – as far as the authors know – the combination of an EE-IOA with LCA data for the estimation of import-induced impacts is being carried out for the first time.

1.3 Goal of this study

Analysing environmental impacts

The first aim of this study is to develop an approach that enables the environmental impacts of consumption and production patterns in Switzerland and its main drivers to be analysed in a comprehensive way. The analysis is carried out from a mesoeconomic perspective with economic sectors and product groups as smallest units. As an analytical tool we use an environmentally extended IO analysis that is combined with LCA data for estimating the environmental impacts of imported goods.

Pilot study

Since this kind of study is being carried out for the first time for Switzerland, it should be considered as a pilot study. Due to restricted resources and data availability rough estimations are necessary in several cases. Further refinements of the methodology and database are outlined in sub-chapter 7.1 and left to future projects.

Comprehensive database

A major goal is to resolve the relevant methodological issues and to establish an environmental database for Switzerland, in which the emissions and resource uses are allocated to industries and households. This database should not only cover domestic emissions in Switzerland, but also emissions due to trade with other countries. It can be used for the analysis of environmental impacts in Switzerland, in combination with expenditure statistics for households or companies, as well as for hybrid-analysis in combination with LCA data.

Consistency with national accounts

The approach should be consistent with existing statistics about environmental impacts in Switzerland. Additionally, it should also be comparable to studies in other countries or regions. This should allow comparisons between Switzerland and other countries.

Covering a range of environmental impacts

Compared to most other similar studies, a more comprehensive view of environmental impacts is taken in this study, which considers a large range of environmental aspects such as e.g. water pollutants, land occupation or energy resources.

Support of environmental politics

The results of this study should help to support Swiss environmental policy in the following fields:

- Support political decisions concerning priority areas of economic sectors and private consumption.
- Monitor environmental impacts of consumption and production on a macro-economic level over time. Evaluate the importance of different economic sectors for the total environmental impacts caused by Swiss consumption.
- Evaluate the relevance of different types of emissions and resource uses by means of life cycle impact assessment.

> Supplement existing environmental accounts on the level of companies and single products to the level of national consumption and production.
> Facilitate international comparisons.
> Identify potentials for the reduction of environmental impacts.

1.4 Different perspectives on environmental impacts

Environmental impacts are investigated from two perspectives.

Production perspective

In the production perspective a country is responsible for its domestic emissions. For each economic actor (households and enterprises) only the emissions and resource uses directly generated during the economic activity are taken into account. The production perspective thus makes it possible to identify the most important direct polluters. Furthermore it is possible to analyse different sectors with regard to their direct emission intensities. This analysis can be done on the basis of environmental statistics or environmental accounts that allocate emissions and resource uses to the economic actors (industries and households).

Consumption perspective

In the consumption perspective a country is responsible for the emissions caused by its domestic final demand[4]. This includes emissions in other countries for the production of goods imported into Switzerland and excludes domestic emissions for the production of goods exported to other countries. Thus emissions allocated to final demand cover direct emissions of households and indirect emissions from production of goods and waste management within and outside the country. Indirect emissions include all supply chain activities. The consumption perspective identifies consumption patterns as drivers of environmental impacts.

The following figure clarifies the difference between the two perspectives:

Fig. 8 > Environmental impacts in the consumption and production perspective

This figure compares the production and the consumption perspective. Reading example: In the production perspective domestic environmental impacts induced by domestic final demand are included. Environmental impacts abroad induced by domestic final demand are not included.

Production perspective

	induced by:	
	Domestic final demand	Exports
Domestic environmental impacts		
Environmental impacts abroad		

Consumption perspective

	induced by:	
	Domestic final demand	Exports
Domestic environmental impacts		
Environmental impacts abroad		

Source: Rütter+Partner

[4] Final demand includes consumption of private households, final demand of government, investment and exports. Domestic final demand excludes exports.

Territorial principle

There are different accounting principles. The United Nations Framework Convention on Climate Change (Climate Convention, UNFCCC) requires its member states to prepare national greenhouse gas inventories on an annual basis (IPCC 1997; Liechti 2000). The inventories list the emissions within each country's territory (territorial principle). Emissions from manufacturing and transport of commercial goods are assigned at the point at which they are released to the atmosphere, irrespective of where the goods are consumed. The UNFCCC approach enables the emissions to be clearly attributed to individual countries and helps to avoid overlapping entries and gaps in the national inventories.

Residence principle

The allocation of resource use and emissions in economic and environmental accounts follows the residence principle of national accounts. This means that each resident economic unit (enterprises and households)[5] is responsible for the direct emissions stemming from its economic activity, comprising emissions within and outside the resident country. The allocation of emissions according to the residence principle is explained in chapter 2.1.

Embodied emission

Yet to obtain the total amount of emissions and resource uses associated with the products that the people of a country consume, the so-called 'embodied' emissions and resources uses must be determined based on knowledge about goods and services exchanges between countries. The balance of these emissions and resource uses can be added to the domestic emissions and resource uses according to the territorial or residence principle.

Mix of principles

To be compatible with the system boundaries of the input-output table used as a core analysis tool, the aim is to follow the residence principle in this study as far as possible. But, since most data in environmental statistics are only available according to the territorial principle, an unintended mix of these principles is unavoidable.

Embodied or indirect

The term "embodied" (or "indirect") energy use (or emissions) has been used by several authors to distinguish the indirect energy uses for the production of goods in contrast to the direct energy uses. Van Engelenburg et al. (1994) used the term while investigating the indirect energy uses of households due to the consumption of goods and services. Coley et al. (1997) investigated the embodied energy of food products. The term has also been used to investigate the emissions that take place outside a country and which are embodied in products consumed at the place of analysis (e.g. Subak 1995).

This study focuses on the environmental impacts that are caused by Swiss consumption patterns. Emissions by Swiss companies which are due to exported products or services are subtracted from the balance. Thus embodied refers here to the emissions by non-Swiss companies in contrast to the direct emissions caused by Swiss companies. Fig. 9 and Fig. 10 shows the distinction of embodied emissions released by production abroad (grey) and *domestic* emissions released by production processes in the country (white).

[5] See UN et al. 2003 for the definition of a resident economic unit. The term resident means that an enterprise is registered and economically active in the country of residence or that the members of a private household live in that country.

In the analysis of emissions from a production perspective we use the term direct for direct emissions of industries or households. In the analysis from a consumption perspective we use the term direct for direct emissions from households and the term indirect for emissions stemming from the production of goods and services that are consumed. These emissions from domestic industries or industries in foreign countries are attributed to the categories of final demand and are thus called indirect.

Fig. 9 > Distinction of embodied and domestic emissions and resource uses due to processes in the life cycle of a consumer good purchased in Switzerland

The grey boxes represent companies producing outside Switzerland and not Swiss-owned. In any case these emissions and resource uses are termed as embodied. The yellow box is an example for a Swiss-owned company. Emissions and resource uses would be included in the Swiss balance according to the residence principle, but excluded according to the territorial principle. The green box shows a company not Swiss-owned and thus treated as foreign in the residence principle, but domestic in the territorial principle. All white boxes stand for Swiss-owned companies thus accounted for as domestic in any case

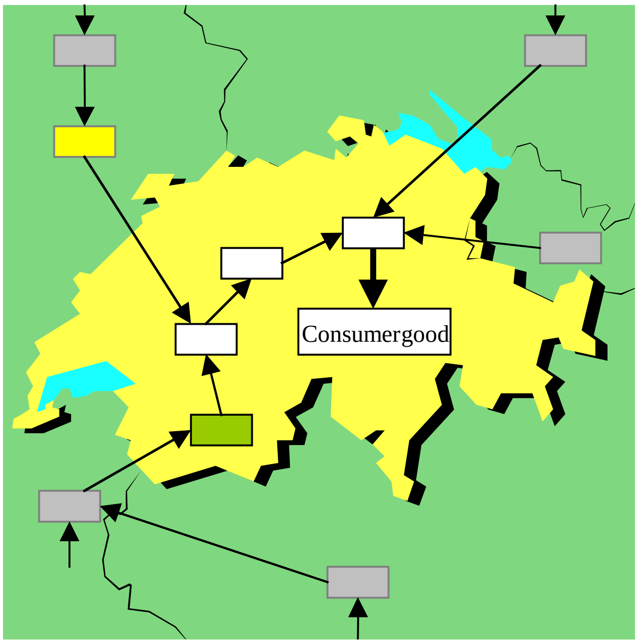
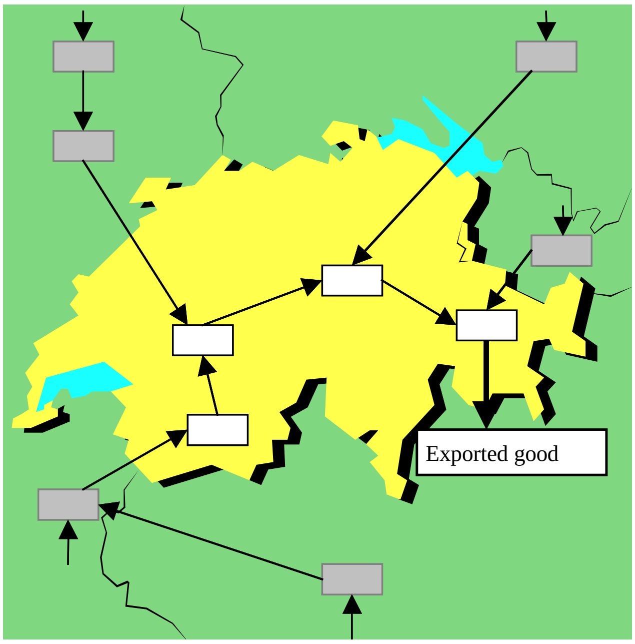


Fig. 10 > Distinction of embodied and domestic emissions and resource uses due to processes in the life cycle of a consumer good exported from Switzerland

The calculation for exported goods includes all emissions and resource uses by Swiss companies as well emissions and resource uses due to the import of goods and services.



Source: ESU-services Ltd.

2 > Methodologies used in this study

In principle there are two main methodologies for investigating environmental impacts of economic activities in a life cycle perspective. These are the economic-based environmentally extended input-output analyses and the physical process chain analysis known as life cycle assessment. This chapter gives a detailed description of these basic methodologies and shows how they are linked to the framework for this study.

2.1 Environmentally extended input-output analysis

Input-output analysis

Input-output (IO) analysis is a standard methodology for economic impact analysis. Its main strengths are its ability to calculate indirect impacts in the supply chains triggered by the demand for goods and the relatively low level of sectoral aggregation (by macroeconomic standards). Thus e.g. it is possible to calculate total production in all sectors of the economy that is triggered by an additional demand for residential buildings. Given this additional demand, an input-output model is able to calculate production in the economic sectors of a country that is directly and indirectly related to this demand. This includes e.g. the construction of the building, manufacturing of concrete and cement, of doors, windows, heating boilers back to the basic materials (wood, glass, steel etc.) and raw materials, in other words the complete supply chain of buildings. Apart from domestic production the IO model also calculates the necessary imports.

Complemented with environmental data, input-output analysis can be used for analysing the environmental consequences of economic activities. In principle this approach is similar to the life cycle inventory approach described below. The main differences are the higher level of aggregation (industries instead of products) and the use of monetary units instead of physical units to describe the flow of goods or the transactions between the economic actors.

Input-output tables

Input-output tables (IOT) are the main data basis of input-output analysis. They show the flow of goods among the industries of an economy (intermediate demand) and from the industries to final demand. Final demand includes consumption of private households, non-profit institutions and government, capital formation (investment), inventory change and exports. Since for each industry the demand for intermediate inputs from all other industries needed to produce its own goods is known, it is possible to calculate the total production triggered by an arbitrary demand for goods across all levels of the supply chain.

In most countries the statistical offices compile input-output tables. In Switzerland this is not the case, since some basic statistics needed for the compilation of IO tables do not exist (e.g. commodity statistics, statistics on company cost structures). Therefore IO tables for Switzerland have been estimated by using national statistical data and data from foreign country IO tables. The most recent Swiss IO table was estimated for the year 2005 (Nathani et al. 2008). Due to the data situation and the estimation process, data uncertainty in the Swiss IO table is larger than in other countries' IO tables.

Two different types of input-output tables can be distinguished, first supply and use tables (SUT) and second symmetric input-output tables (SIOT).[6] Usually symmetrical input-output tables are used for environmental IO analysis since the economic sectors are more homogenous than in supply and use tables. For the same reason we use the SIOT in this analysis.

The ability to calculate indirect impacts enables total production in an economy to be allocated as well as imports to final demand. Thus it is possible to estimate the level of sectoral production or imports triggered by e.g. private consumption, capital investment or exports. This is an essential feature for estimating environmental impacts in an economy from a consumption perspective.

Environmentally extended IOT

An environmentally extended IO table (EE-IOT) combines the economic data of input-output tables with data on resource use or emissions in physical units (e.g. kg CO_2 emissions or use of natural gas in TJ). The environmental data is organised according to the structure of the IO table thus showing the direct resource use and emissions of industries and private households.

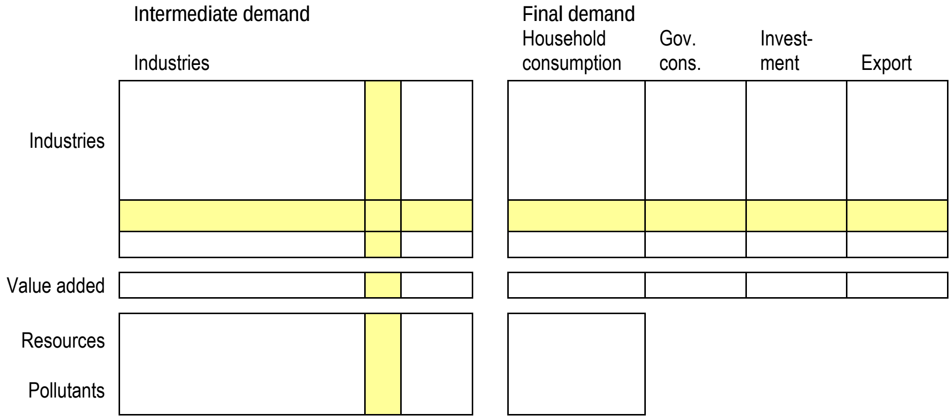
Fig. 11 shows a scheme of an EE-IOT. The upper table is the usual economic input-output table. Each row contains the supply of a product (group) to the other industries or to final demand. For the industries each column of the IOT shows the use of inputs from other industries as well as the use of primary inputs. The latter especially include the components of gross value added, consisting of compensation of employees, net production taxes, depreciation and operating surplus. The transactions in the input-output table are recorded in monetary units.

The lower table contains the environmental extension of the input-output table. It records for each industry and private households the direct use of resources and emission of pollutants related to consumption and production activities.

6 see e.g. Miller/Blair (1995) for an explanation of different types of IO tables

Fig. 11 > Scheme of an environmentally extended input-output table

Simplified overview of an IO table extended with environmental indicators. The yellow row and column illustrate the data of an economic sector.



Source: Rütter+Partner

System boundaries and accounting principles

The combination of an input-output table with environmental data has to make sure that the system boundaries and accounting principles are compatible. The relevant definitions and accounting principles are internationally harmonised in the SEEA handbook on environmental accounting (United Nations et al. 2003) and ensure that national accounting and environmental accounting follow the same principles. In environmental accounting the combination of IO tables with data on emissions or other environmental indicators are called NAMEA (national accounting matrix with environmental accounts). For the compilation of a NAMEA on air emissions, Eurostat has recently published a specific handbook (Eurostat 2009).

Some important principles of compiling emission accounts that are compatible with the IOT are mentioned in the following.

> The allocation of resource use and emissions should follow the residence principle of the input-output-table, meaning each resident economic unit (enterprises and households) is responsible for the direct emissions stemming from its economic activity, comprising emissions within and outside the resident country. This allocation rule differs from the allocation rule in energy statistics, which usually follow the territorial principle or in emission inventories, which exclude emissions from certain international transport activities. The main differences concern transport-related emissions. Transport companies generally are responsible for emissions of their fleet in the resident country as well as abroad. Private households are also responsible for their vehicle emissions in other countries (e.g. as tourists). On the other hand direct emissions caused by tourists within the resident country are not counted if the assessment is based on the residence principle.
> The balance principle ensures that for each emission the source and destination are recorded.
> Only emissions and resource uses caused by economic actors are included. Thus e.g. emissions from nature are not recorded (e.g. volcanic eruptions, decomposing or

organic matter in alpine regions). Cultivated land, such as agricultural land or forests, is considered as part of the economic system, as are e.g. controlled landfills.
> Emissions remaining in the economic system are not recorded, e.g. waste destined for treatment.
> In the IO table the treatment of waste is treated as a service offered by the waste treatment plants to the waste producers (enterprises or households).

Calculation procedures

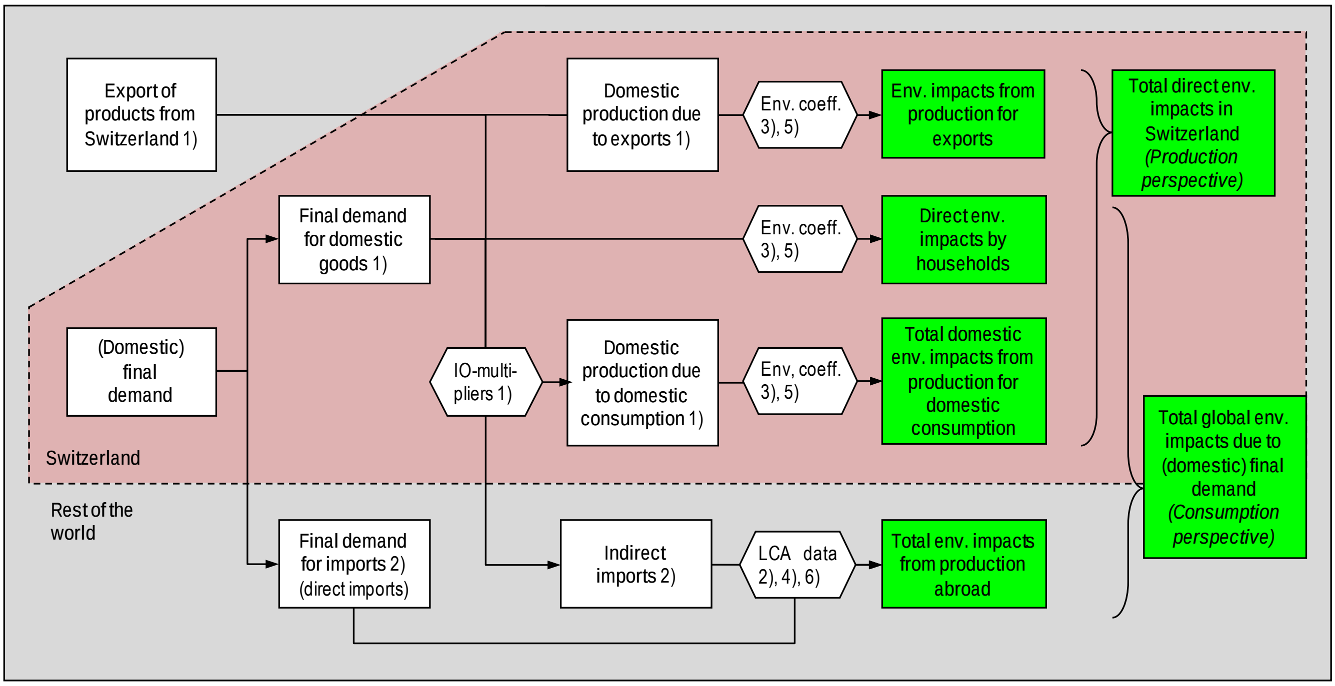
The calculation of emissions and resource uses related to final demand usually includes the following steps (see e.g. Miller & Blair 1995):

1. Starting point is final demand for goods, which can be further differentiated (e.g. to domestic final demand and exports or by consumption category in the case of private households).
2. In a first step the goods of final demand that are directly imported are separated from the domestically produced goods.
3. By multiplying the domestic final demand matrix with the so-called Leontief inverse, we obtain total output triggered by final demand in each sector of the economy. The Leontief inverse is calculated from the intermediate inputs matrix of the IO table and contains multipliers showing total direct and indirect output in each economic sector necessary to supply one unit of a final demand product.
4. By then multiplying total output with a matrix of imported intermediate input shares, we obtain the total of imported goods used as intermediate inputs in domestic production activities.
5. Total imports triggered by final demand are then obtained as the sum of imported final demand goods and imported goods for intermediate use.
6. In the next step the emissions and resource uses related to the domestic consumption and production activities are calculated. Consumption-related environmental impacts can be calculated with the direct emissions and resource uses of private households. They are recorded in the EE-IOT. Environmental impacts related to production are calculated by multiplying total output (induced by final demand) with direct emission coefficients that show for each industry the ratio of direct emissions to gross output.
7. Emissions and resource uses related to imported goods could be estimated by assuming domestic emission coefficients. For a small and open country like Switzerland this would lead to a significant underestimation of environmental impacts, since a large share of emission-intensive goods (e.g. basic materials) are not produced in Switzerland. In this study we therefore estimate emissions related to imported commodities by using LCA data (see following chapter).
8. The sum of direct and indirect emissions induced by final demand consists of direct emissions by private households, emissions from domestic production and emissions from production of imported goods outside Switzerland (green boxes in the figure shown below).

An overview of the calculation procedure is shown in the following figure.

Fig. 12 > Procedure for calculating total emissions induced by final consumption

Starting with final demand this figure gives an overview of the procedure for calculating total emissions induced by final demand. Domestic emissions are calculated with EE-IOA, while foreign emissions are calculated with LCA data.



Data sources:
1) IOT 2005 (Nathani et al., 2008)
2) Trade data (Eidg. Oberzolldirektion, 2005)
3) Frischknecht et al., 2009
4) ecoinvent Centre 2010
5) NAMEA Air (BFS 2009; 2011)
6) ESU-services, 2010

Legend:
IO-multipliers: multipliers from the IO-model showing total domestic production and imports in each sector of the economy directly and indirectly caused by each unit of final demand
Env. coeff.: Emissions and resource uses per unit of gross output [e.g. CO_2-emissions in kg/CHF]

Source: Rütter+Partner

Capital investment

A disadvantage of this procedure is that capital investment as a part of final demand is considered exogenous. Thus the causal link between production, the use of the capital stock and the demand for new investment goods does not become visible. Therefore we partly exclude capital investment from final demand and link it to production. We distinguish between the use of domestic and imported investment goods. Two matrices with specific investment demand are calculated by relating investment demand to sectoral gross output.

In our calculations domestic investment demand is included in the calculation of multipliers. Before calculating the Leontief inverse (step 3), they are added to the intermediate inputs matrix. Likewise the imported investment goods matrix is used in the calculation of indirect imports (step 4).

2.2 Life cycle assessment (LCA)

LCA

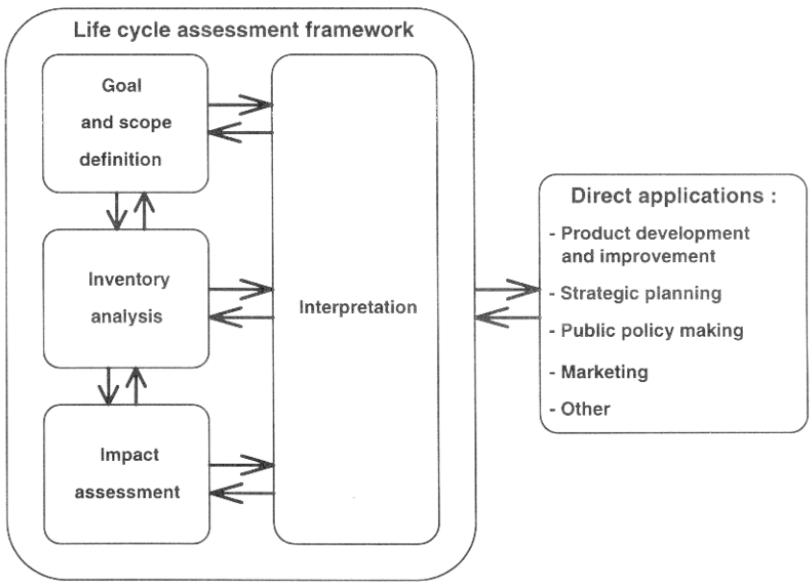
The method of life cycle assessment (LCA) (some authors use the older term life cycle analysis or ecobalance, the latter is derived from the German "Ökobilanz") aims to investigate and compare environmental impacts of products or services that occur from cradle to grave. This means that the whole life cycle from resource extraction to final waste treatment is investigated.

The method has been developed starting from cumulative energy requirements analysis and including more and more emissions of pollutants and consumption of resources. The International Organization for Standardization (ISO) (2006a; b) standardizes the basic principles. LCA is used for the analysis of hot spots for environmental impacts, product or process improvement and development, comparative assertion, marketing and environmental policy.

The "Goal and scope definition" describes the underlying questions, the target audience, the system boundaries and the definition of a functional unit used in the comparison of different alternatives (see Fig. 13). The inputs of resources, materials and energy as well as outputs of products and emissions are investigated and recorded in the "Life cycle inventory analysis". Its result is a list of resources consumed and pollutants emitted. These elementary flows (emissions and resource consumptions) are described, characterised and aggregated during the "Impact assessment". Conclusions are drawn during the "Interpretation". The different phases of an LCA are not necessarily executed in a step by step procedure, but they might be refined in an iterative manner throughout the study.

Fig. 13 > Phases of an LCA (life cycle assessment)

The LCA method distinguishes four main phases, namely (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation.



International Organization for Standardization (ISO) 2006a

2.3 Life cycle inventory analysis

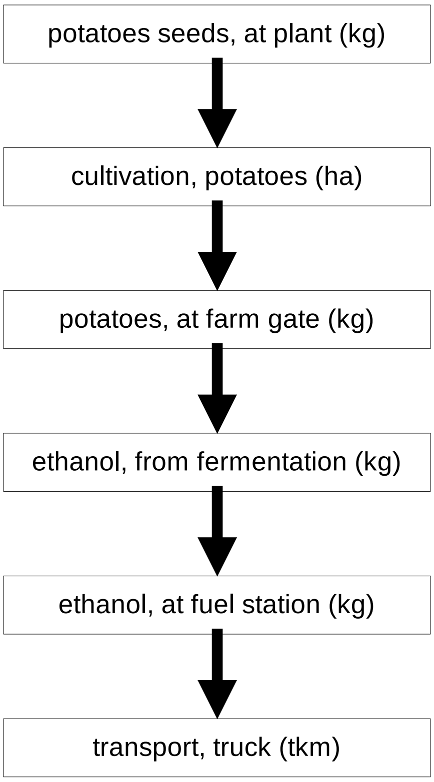
The second stage of an LCA is the life cycle inventory analysis (LCI) or short inventory analysis. Here the main differences can be found in comparison to the EE-IOA and thus this stage is described in more detail. The LCI involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. An intermediate result of an LCA is the life cycle inventory analysis result with cumulative data for the emission of hundreds of individual substances and for many resource uses. These data constitute the input to the life cycle impact assessment (see chapter 2.6).

Normally, data investigation is the most time consuming step of an LCA. In the last years, the situation has been continuously improved due to the setup of standardized background databases (e.g. ecoinvent Centre 2010) and LCA software products that include these background data (PRé Consultants 2010).

Unit process as smallest part of investigation

Fig. 14 > Product system from well to wheel for truck fuelled with ethanol from potatoes that is divided into unit processes

The unit process describes the smallest portion of a product system for which data are collected when performing a life cycle assessment. The figure shows the main processes of the product system for the transportation with a truck that uses ethanol. The product system is divided into unit processes, e.g. potatoes production or fermentation to ethanol, in order to facilitate and structure the further analysis.



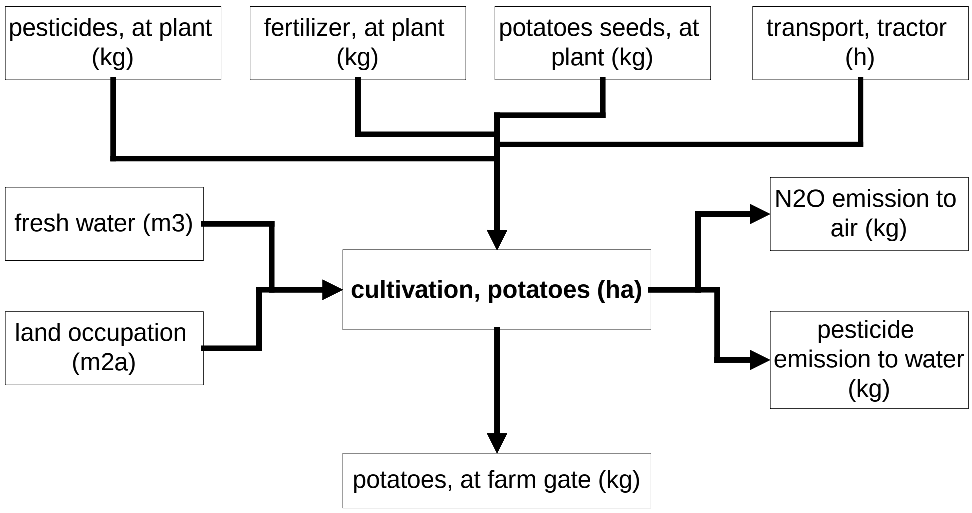
Source: ESU-services Ltd.

Unit process inventory

The unit process inventory is an inventory of energy and material flows (in- and outputs) which are used or emitted by a unit process. It is also termed unit process raw data. There are two classes of inputs and outputs: technosphere flows and elementary flows. Technosphere flows take place between different processes, which are controlled by humans, e.g. the delivery of ethanol from the plant to the fuel station. They can be physical or service inputs (e.g. electricity, fertilizer or seeds) or outputs (e.g. the product or wastes that have to be treated). Elementary flows in this context are all emissions of substances to the environment (output) and resource uses (inputs, e.g. of fresh water or land). An emission is a single output of a technical process to the environment, e.g. the emission of a certain amount of SO_2.

Fig. 15 > Unit process for the cultivation of potatoes including some examples of inputs and outputs

The figure shows the unit process for potato cultivation with some inputs and outputs as an example. Potato seeds are the direct input; potatoes are the major output (product or reference flow) of this unit process. Besides, further inputs, e.g. fertilizer, machinery hours or pesticides are necessary. The unit process causes also some emissions, e.g. pesticides to water or N_2O to air.



Source: ESU-services Ltd.

Unit process raw data

Tab. 1 > Example of unit process raw data for the production of 1kg potatoes in Switzerland with integrated production technology

The table shows some unit process raw data for the production of 1kg potatoes in Switzerland with integrated production technology. One can first see some examples for the input of fertilizers, pesticides and transport services. These technosphere inputs are linked to other unit processes that are described in similar tables. Then resource uses of carbon dioxide and land are recorded (input flow from nature). Emissions are distinguished according to the compartments (air, water, soil) and sub compartments (e.g. river, groundwater). They are recorded for different outputs. Finally the technosphere output or reference flow of the process is defined as 1kg potatoes from integrated production in Switzerland. This inventory table provides also information on the uncertainty for the recorded amount of the flows. In this case the uncertainty type 1 means a lognormal distribution. The standard deviation records the square value for the 95% percentile. The mean value multiplied or divided by the 95% standard deviation gives the 97% maximum or the 2.5% minimum value, respectively.

Explanations	Name	Location	Infrastructure-Process	Unit	potatoes IP, at farm	uncertaintyType	StandardDeviation95%
	Location				CH		
	InfrastructureProcess				0		
	Unit				kg		
Technosphere	ammonium nitrate, as N, at regional storehouse	RER	0	kg	4.4E-4	1	1.07
	[sulfonyl]urea-compounds, at regional storehouse	CH	0	kg	2.7E-7	1	1.13
	potato seed IP, at regional storehouse	CH	0	kg	6.8E-2	1	1.07
	fertilising, by broadcaster	CH	0	ha	8.1E-5	1	1.07
	harvesting, by complete harvester, potatoes	CH	0	ha	2.7E-5	1	1.07
	transport, lorry 28t	CH	0	tkm	1.6E-3	1	2.71
resource, in air	Carbon dioxide, in air			kg	3.4E-1	1	1.07
resource, biotic	Energy, gross calorific value, in biomass			MJ	3.9E+0	1	1.07
resource, land	Occupation, arable, non-irrigated			m2a	1.3E-1	1	1.77
	Transformation, from arable, non-irrigated			m2	2.7E-1	1	2.67
	Transformation, to arable, non-irrigated			m2	2.7E-1	1	2.67
air, low population density	Ammonia			kg	4.4E-4	1	1.3
	Dinitrogen monoxide			kg	1.3E-4	1	1.61
soil, agricultural	Cadmium			kg	2.6E-8	1	1.77
	Chlorothalonil			kg	8.8E-5	1	1.32
water, ground-	Nitrate			kg	9.4E-3	1	1.77
	Phosphate			kg	3.1E-6	1	1.77
water, river	Phosphate			kg	1.1E-5	1	1.77
Outputs	potatoes IP, at farm	CH	0	kg	1.0E+0		

RER – Europe; CH – Switzerland; IP – Integrated Production

Excerpt from Nemecek et al. (2004). Only a part of the recorded 67 inputs and outputs is shown in this table.

2.4 Important differences in accounting principles

The accounting principles and methodological approach of EE-IOA and life cycle inventory analysis are generally quite similar. Both follow up environmental impacts of production patterns in a life cycle perspective. Nevertheless there are some general differences, which are described in Tab. 2. Both have their specific advantages and shortcomings. The data basis for the methods is also different. Therefore in this project they are combined in order to profit from both approaches. The resulting inconsistencies from combining different methodologies are considered as a weak point of this approach. Nevertheless, this combination seems to be currently the only feasible approach for investigating environmental impacts of Swiss consumption and production. It was not possible to quantify and assess the importance of these inconsistencies on the final results. Therefore extensive scenario analysis would be necessary.

Tab. 2 > Main differences in accounting principles of EE-IOA and LCA

There are several differences in accounting principles between the two methods. These make a comparison of results and a combination of methods difficult to apply in some cases. In many cases it is even not possible to judge which method would provide "more correct" results.

	EE-IOA	LCA / LCI
Time horizon	One year of consumption and production	Life cycle of a product with possible inputs produced in former years (e.g. infrastructure) and services needed in the future (e.g. waste treatment of products used over several years).
Reference units	Monetary value of products (Swiss Francs)	Physical flows e.g. kg, MJ
Investment goods	Production only covered for reference year and not for past provision or future use. Provision of investment goods kept separately and not assigned to the production patterns.	Investment goods are depreciated over their full life cycle to the production volume in this time.
Disposal services	Only included in the reference years. Thus, falsification if stocks of goods are built up.	Included as far as possible, but future or past disposal assumed to be the same as today and thus possible developments are not considered.
System boundaries	In principle all inputs and outputs are considered.	Cut-off criteria allow truncation of inputs or outputs, which are considered to have a minor contribution in the life cycle. Also inputs that are difficult to assign to a specific product are often neglected. Thus, e.g. business travel or research might often not be included in the assessment of single products.
Allocation principle	Environmental impacts are allocated by the value of products provided by a certain sector. No subdivision going deeper than the sectors distinguished.	Different principles might be applied. Where possible, joint production processes are subdivided in order to allocate environmental impacts to single products.
Sectors and products covered	All economic sectors and thus all products are in principle investigated. But, the analysis addresses the whole production sector and not single products or services.	Focus on products and services with environmental relevance and large production volumes. Not so much knowledge on specific consumer products and services.
Stocks of goods	Production of stocks of goods not sold in the particular time horizon is considered separately.	Change of stocks is not included in the assessment. It is assumed that products produced by a company enter the market immediately.

Source: ESU-services Ltd. and Rütter+Partner

2.5 Combining different data sources for calculation in the LCA software

Within this study the two main methods (LCA and EE-IOA) are combined in order to calculate the overall environmental impacts of Swiss consumption and production patterns in the LCA software. There are two ways of combining different data sources in order to calculate the total environmental impacts:

> In option 1, the total of an economic sector is the sum of domestic and imported environmental impacts of this sector (environmental impacts of exports are deducted

according to the balance of imports and exports in Swiss francs). Thus, the dataset for one sector has two inputs.

> In option 2, the total is modelled as one dataset without separate links to datasets for domestic or imported production. It includes the total economic IOT relationships, the direct emissions per total CHF value and the imported goods per total CHF value. Thus, the dataset for one sector has more than a hundred inputs.

Option 1 would allow evaluating in detail the importance of imports for the emissions caused by a specific sector or final demand.

This method would not fit well with the general idea used in LCA for modelling of life cycles. In this study we analyse all inputs and outputs of an economic sector together as one unit process. Therefore we apply the second option. However, this does not make it easy to calculate the share of imported goods and services for the total results in a specific production sector or consumption domain.

Tab. 3 > Two options for calculating the total impacts of consumption and production in an LCA software

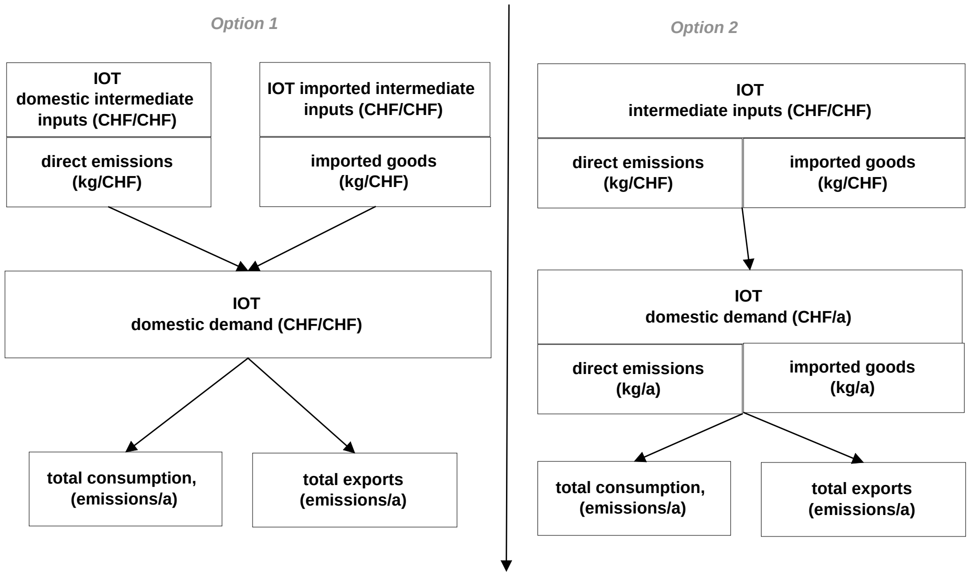
The calculation of datasets for total environmental impacts of consumption and production can be elaborated in two ways. In the first option, total impacts are calculated with the two datasets for domestic and imported goods. The second option starts directly from the IOT for domestic and imported intermediate inputs. Both tables are directly combined first and then transferred into the EcoSpold format.

	Option 1	Option 2
Principle	The total of one economic sector is the sum of one dataset for domestic and one for imported products in this sector according to the share of Swiss francs between imports and exports. Thus, one datasets has two inputs.	The total is modelled as an own dataset without separate links to datasets for domestic or imported production. It includes the total economic IOT relationships, the direct emissions per total CHF value and the imported goods per total CHF value. Thus, one dataset has more than a hundred inputs.
Example	-	IOT for Denmark in the LCA-Software tool 'SimaPro')
Workload for datasets	Three times the number of sectors	Easy. One dataset per sector
Showing share of imported impacts for total	Easy to evaluate for each single sector.	Nearly impossible because emissions of all dataset for imported goods have to be added up.
Evaluation of contribution of other sectors to the total in one sector	Not easy because always split up into two parts (dom/imp) that have to be added.	Only one relation to each other sector, thus easy to evaluate.
Usefulness of datasets	The split datasets are a virtual calculation without a real-world meaning. They should not be used e.g. in Hybrid analysis	Datasets shows relationship and emissions of the sector as it is.
Summary	Easy and better view on share of imports vs. domestic	Higher workload and better estimation for the total in one sector and contribution of other sectors to this total.

Source: ESU-services Ltd. and Rütter+Partner

Fig. 16 > Two options for calculating the total impacts of consumption and production

The two options for calculating the total impacts are shown in the following figure. Each bigger box would represent one set of datasets in the LCA software. In option 1 domestic and imported production sectors are kept separate while they are combined in option 2.



Source: ESU-services Ltd.

The following paragraphs describe the procedure (option 2 in Tab. 4 and Fig. 6) that is implemented for calculations in the EcoSpold format. This procedure follows the principles of LCA.

The EE-IOA is used for analysing domestic environmental impacts. Therefore the basic economic IOT is extended for the emissions and resource uses caused in Switzerland. These are assigned to single economic sectors and final demand. There is no direct link between the LCA database for imports and the EE-IOA for domestic consumption and production.

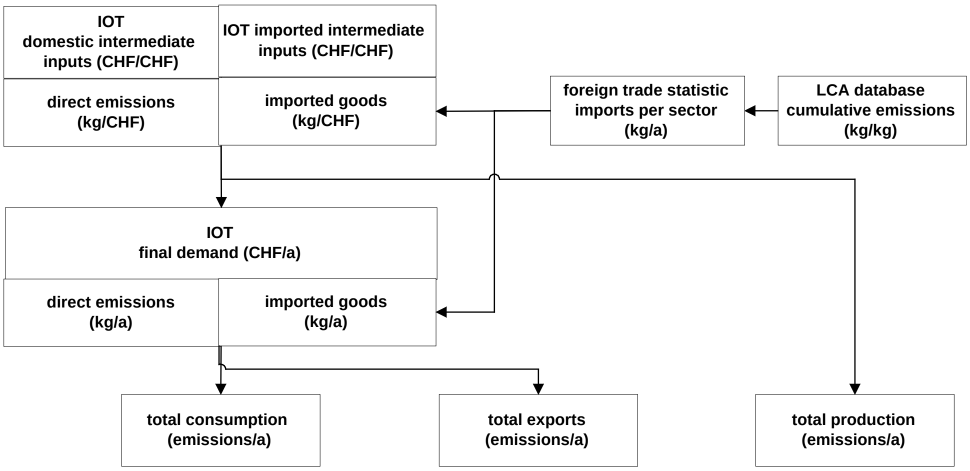
LCA data are used for estimating the environmental impact caused by the production of imported goods. Therefore environmental impacts for sectors as distinguished/listed in the foreign trade balance are calculated directly with LCA data. These impacts are then assigned to the sectors of production or consumption in the IOT. The IOA is then used to reallocate the impacts of these imported goods to the provision of goods and services in a certain sector.

The final datasets for the production sectors thus include economic information about inputs from other sectors, direct emission intensities per CHF of production and imports of goods per CHF used by this sector.

The combined EE-IOA for domestic and imported production patterns is used in order to calculate the impacts of exported goods and services or provide them for final demand. The domestic consumption categories include again also direct emission per year and the direct import of goods and services for final demand.

Fig. 17 > Simplified flow sheet of calculations in this study

The figure shows the linkage between different data sources and the calculations within this study for the EcoSpold format. The three principle data sources IOT, LCA and foreign trade statistic are combined in order to calculate the total environmental impacts of production, consumption and exporting of goods and services. They are supplemented with information about domestic emissions in the consumption and production sector.



Source: ESU-services Ltd.

Within this study we apply a second calculation procedure as described in chapter 2.1 for the modelling of greenhouse gas emissions and partially for total environmental impacts. It enables the importance of imports for the emissions caused by final demand to be evaluated in detail. The two approaches also serve as checks for each other, since the implementation of the EE-IO model is complex. The second calculation procedure is implemented with the mathematical software tool Matlab. The results of the calculations are available as EXCEL tables.

2.6 Impact assessment methods

Assessment of environmental impacts

The life cycle impact assessment (LCIA) phase of the LCA aims at evaluating the significance of potential environmental impacts using the results of the LCI analysis. This procedure involves associating inventory data (emissions and resource uses) with specific environmental impacts and attempting to understand those impacts. The level of detail, choice of impacts evaluated and methodologies used depend on the goal and scope definition of the study (International Organization for Standardization (ISO) 2006a). The term impact assessment is used for all steps of aggregation. Within this study, impact assessment methods, which are developed in the framework of the LCA method, are used for the impact assessment of inventory data calculated with the EE-IOA.

It is necessary to choose appropriate impact assessment methodologies with regard to special emissions in the life cycle (e.g. agricultural chemicals), the region under study (e.g. Europe), and the decision-makers addressed. Often LCA studies use different impact assessment methodologies simultaneously in order to analyse and discuss differences in the outcome.

Every LCIA involves some subjectivity such as choice, modelling and evaluation of the impact categories. Therefore, transparency is critical for LCIA to ensure that assumptions are clearly described and reported.

“True and Fair View” criteria

Consideration of the following “True and Fair View” criteria for comprehensive and reliable environmental information has influenced the selection of LCIA methods in this study[7]:

- Relevance for the decisions to be influenced (e.g. by the results calculated with the respective method)
- Total picture in focus: Transmission of a true and fair view of the actual situation, therefore it should consider all relevant environmental impacts,
  - along the whole life cycle of products and services and
  - if possible at the place they occur
- Reliability
  - Trustworthiness (e.g. external assurance)
  - Scientific soundness
- Transparency
  - Traceability
  - Verifiability (e.g. separation of scientific modelling and weighting based on societal or political decisions)
- Comprehensibility
- Coherence and comparability
  - Coherence (consistency)
  - Continuity
  - Scalability
  - Standardisability, expandability and connectivity
- Availability of information (sources)
- Information and data are up to date

According to Jungbluth et al. (2011b) the methods should further:

- Be suitable for the national level, company level and all types of products,
- being useful on a regional and a national level, and it should be transferable to the international level,
- provide an individual indicator (single-score),
- be known in Switzerland

Selection of LCIA methods

The selection of LCIA methods has been made according to the criteria for a True and Fair View on information about environmental impacts by recognizing only methods that provide an individual indicator (single-score), are known in Switzerland and cover a range of environmental impacts. The following LCIA methods are used:

7 These criteria were transferred by Infras from the general norm of financial accounting “True and Fair View” (Schwegler et al. 2011).

- Ecological scarcity method 2006 (Frischknecht et al. 2009): The development of this method has been commissioned by the Swiss FOEN. This method reflects best the goals of environmental policy in Switzerland. This method is used as the lead method in this report. The main reason is the complete availability of emission and resource use data. It has to be noted that it was not possible to differentiate water consumption with regional factors because such a detailed LCI was not available.
- Eco-indicator 99 (H,A) (Goedkoop & Spriensma 2000): Developed in a Dutch – Swiss cooperation and based on natural and social sciences. This method allows three social perspectives for the weighting of environmental impacts. Here only the Hierarchist perspective is used because this is considered in most studies to reflect the perception of scientists and an average weighting scheme is applied. Long-term emissions are excluded from the analysis, because data would only be available for imported goods, but not for domestic emissions.
- ReCiPe (Goedkoop et al. 2009), successor of Eco-indicator 99 (H,A) (Goedkoop & Spriensma 2000): The development of this method has been commissioned by the Dutch Ministry of Housing, Spatial Planning and Environment. The method enables different assumptions for normalisation[8] and weighting[9] to be used. Again the Hierarchist perspective is used. For normalisation we show the differences between using only European emissions and resource uses and global ones.

For comparison, results are also calculated using the following methods although they cover only one or two relevant environmental aspects:

- Ecological footprint: The ecological footprint has been applied according to the new guidelines, it does not include nuclear energy (Global Footprint Network 2009).
- Carbon Footprint, CO_2-emissions, Global Warming Potentials, etc. (only climate change). See chapter 5.1 for further information about the applied characterisation factors.
- Cumulative energy demand: This indicator describes the use of fossil, nuclear and renewable resources (Frischknecht et al. 2007c). It covers only one environmental aspect, but is well known and suitable for comparison with other studies.

Readers who are not familiar with LCIA methods can refer to the cited literature providing more detailed descriptions of the environmental impacts covered, weighting procedures applied and possible differences (Frischknecht 2009; Jungbluth et al. 2011b).

Tab. 4 shows a summary of the coverage of environmental problems in different methods for assessing aggregate environmental impacts. The four methods on energy (CED), resources (MIPS), climate change (CF) and ecological footprint can cover only a very limited list of environmental problems. Thus, according to the criteria used in this study we recommend they are not used for decision-making as several other environmental problems cannot be evaluated.

[8] Division by total emissions in one region e.g. Europe or World.
[9] Stage where different types of environmental impacts are summarized and that cannot be based on natural science alone. E.g. weighting human health effects versus ecological damages.

The LCIA methods cover a much larger range of environmental indicators. A clear difference between LCIA methods only according to the impact categories is difficult to set. The selection depends also on personal preferences concerning the weighting of different environmental issues. All existing LCIA methods have gaps concerning impact categories, which are not yet integrated.

It has to be noted that the list of impact categories is not complete and might be revised in future if new environmental problems are better investigated or if political goals are set for such problems. Some examples of impact categories so far not covered very well are salinisation, erosion, littering or depletion of biotic resources such as fish. It will never be possible to model the complexity of environmental problems entirely, thus LCIA method can only cover the most important environmental impacts.

There are also certain types of impacts, which are not very well covered by thinking of product life cycles. Examples are fires caused by accident or several illegal activities such as burning of household waste as well as semi-natural emissions such as VOC from plants.

It is assumed that all LCIA methods in right part of Tab. 4 fulfil the criterion of being meaningful concerning the environmental impacts covered. All methods, with exception of the Impact 2002+ provide clear recommendations for the calculation of a single score as a result. None of the methods can really cover all environmental impacts, but all cover at least a range of important topics.

Tab. 4 > Comparison of different life cycle impact assessment methods aggregating emissions and resource uses and the impact categories they cover

Summary of the coverage of environmental problems in different methods for aggregate emissions and resource uses to environmental impact categories.

		One environmental issue			Aggregation of several environmental issues				
	LCIA method: Impact category	Cumulative Energy Demand	MIPS	Carbon footprint	Ecological footprint	Ecological scarcity 2006	Impact 2002+	Eco-indicator 99	ReCiPe 2009
Resources	Energy, fossil	√	√[2]	∅	∅	√	√	√	√
	Energy, nuclear	√	√[2]	∅	∅[10]	√	√	∅	√[4]
	Energy, renewable	∅	√[2]	∅	∅	√	∅	∅	∅
	Ore and minerals	∅	√[2]	∅	∅	√[7]	√	√	√[4]
	Water	∅	√[2]	∅	∅	√	∅[12]	∅	√[1]
	Biotic resources	∅	√	∅	∅	∅	∅	∅	∅
	Land occupation	∅	∅	∅	√	√	√	√	√
	Land transformation	∅	∅	∅	∅	∅	∅	√	√[11]
Emissions	CO_2	∅	∅	∅	√	∅	∅	∅	∅
	Climate change	∅	∅	√	∅	√	√	√	√
	Ozone depletion	∅	∅	∅	∅	√	√	√	√
	Human toxicity	∅	∅	∅	∅	√	√	√	√
	Particulate matter formation	∅	∅	∅	∅	√	√	√	√
	Photochemical ozone formation	∅	∅	∅	∅	√	∅	√	√
	Ecotoxicity	∅	∅	∅	∅	√	√	√	√
	Acidification	∅	∅	∅	∅	√	√	√	√[3]
	Eutrophication	∅	∅	∅	∅	√	√	√	√
	Odours	∅	∅	∅	∅	∅	∅	∅	∅
	Noise	∅	∅	∅	∅	∅[9]	∅	∅[9]	∅
	Ionizing radiation	∅	∅	∅	∅	√	√	√	√
	Endocrine disruptors	∅	∅	∅	∅	√	∅	∅	∅
Others	Accidents	∅	∅	∅	∅	∅	∅	∅	∅
	Wastes	∅	∅	∅	∅	√[5]	∅	∅	∅
	Littering	∅	∅	∅	∅	∅	∅	∅	∅
	Salinisation	∅	∅	∅	∅	∅	∅	∅	∅
	Erosion	∅	∅	∅	∅	∅	∅	∅	∅

1: Only summation of all water uses
2: Quantified according to moved masses for extraction
3: Only terrestrial acidification
4: Including uranium as a mineral resource
5: Includes radioactive wastes and hazardous wastes stored underground
6: Not including uranium
7: Eco-factor for gravel
8: Part of assessment of working environment
9: Supplementing proposal made by Doka (2009) for traffic noise
10: Nuclear electricity was included in the original version (Wackernagel et al. 1996, but is according to revised guidelines published in 2009 not included anymore (Global Footprint Network 2009)
11: Only transformation of forests
12: Under development

Source: ESU-services Ltd.

An extensive and up-to-date description of several LCIA methods has been elaborated by the EU (European Commission 2009). Furthermore, a more detailed description of different methods has been made e.g. by Frischknecht (2009). A second report describes the framework and requirements for Life Cycle Impact Assessment (LCIA) models and indicators (Hauschild et al. 2009). The report includes a detailed description of the areas of protection and impact categories. Assessments including a final weighting into one score are not part of this evaluation. These reports are currently in public consultation. Finally, the work should lead to recommendations for best practice in the EU. Such final recommendations are not yet available.

The ecological scarcity 2006 method is designed to represent the assessment of environmental problems from a Swiss perspective. It covers many environmental problems and the method can be adapted to cover further environmental topics (e.g. more regionalized assessment of water use, noise, other environmental issues which are decided on the political agenda) as soon as political goals are established. The method is suitable for all types of products and can be used on a regional or national level.

ReCiPe is considered as the second best option, but so far there is not much experience with this method. The fact that the evaluation of nuclear energy is not possible with ReCiPe might be seen as a shortcoming from a Swiss perspective. The weighting is not based on a formal European consensus finding, but on preferences of some selected scientists.

3 > Basic economic and LCA data

This chapter describes the basic economic and environmental data used for this study. The current Swiss input-output table for the year 2005, which was estimated for the Swiss Federal Office of Statistics, is an important economic data source for the present study. Additionally data from the Swiss trade statistics are used for the estimation of environmental impacts related to imported and exported products. Therefore these trade statistics are combined with LCA data. Chapter 3 presents data sources and discusses data quality in more detail.

3.1 System boundaries

Reference year 2005

The reference year for all calculations is the year 2005. Sometimes older or newer data had to be used. So far it is not possible to calculate full time series, such as for each year or each five years, with the available data.

Swiss perspective

The goal of the study is to investigate the environmental impacts due to the consumption and production patterns of Swiss enterprises and people living within the national boundaries of Switzerland. With people we assume here the private consumption of inhabitants and their households. In terms of national and environmental accounting this is called the residence principle, including all resident economic units of a country (see chapter 2).[10]

7 459 128 inhabitants

The Swiss population in 2005 is given as 7 459 128. This figure is used for the calculation of per capita emissions (BFS 2006).

3.2 The Swiss input-output table (IOT)

43 industries, 20 final demand categories

For the present study we use the most recent Swiss IOT for the year 2005 (Nathani et al. 2008). In technical terms the symmetric IOT is used due to the larger homogeneity of the economic sectors. In the Swiss input-output tables 42 industries and 20 categories of final demand are distinguished (see annex for a complete list). For this study we additionally separated the refinery sector from the chemical industry, arriving at a total of 43 industries. Such a high level of aggregation has certain disadvantages for the analysis of environmental issues, since several environmentally relevant sectors are aggregated. This may lead to aggregation errors in the results. Currently the IOT for 2005 is being further disaggregated in the energy and transport sector in a project for the Swiss Federal Office for the Environment (FOEN). Due to time constraints it was not possible to use this IOT in the present project. To improve

10 By contrast, energy and environmental statistics often relate to the territorial principle and thus include energy consumption and emissions within the territorial boundaries of a country. The residence principle is explained in more detail in chapter 2.

the accuracy of results it would be valuable to integrate the disaggregated IOT at a later stage.

Sectoral disaggregation

For our analysis it is necessary to separate the use of domestic and imported goods. The Swiss IO table does not make such a separation and other comprehensive information on the use of imported goods is not available. We therefore assume that imported goods are used proportionally to total use, with the exception of exports. The share of imported goods that are re-exported without further treatment is unknown. We restrict the possibility of re-exports to goods where the volume of exports exceeds domestic supply and roughly estimate the volume of re-exports for the respective product groups. Based on these assumptions the intermediate input matrix and the final demand matrix respectively are split into a matrix showing use of domestic goods and a matrix containing the use of imported goods. Thus the import matrices do not contain actual imports of industries and private households, but rather hypothetical imports.

3.3 Categories of final demand

Final demand expenditures

Final demand consists of consumption of private households and non-profit institutions, government consumption, capital investment and exports. The original IO table distinguishes 12 categories of private consumption according to the COICOP[11] classification. For the present analysis expenditures for food and for beverages were merged into one category. Furthermore certain expenditures by government or non-profit institutions for goods that ultimately serve the needs of private households (e.g. health, educational and cultural services) were also allocated to the respective private consumption categories since households benefit from these expenditures. The remaining consumption of non-profit institutions was added to miscellaneous consumption of private households. Remaining government consumption and social security expenditures were merged into the category residual public final demand.

In the standard IOT, capital investment is part of final demand. It includes investment in residential buildings, offices or manufacturing plants as well as capital equipment (machinery, vehicles etc.). In our analysis we aim at allocating investment to the respective driving factors as far as possible. Investment in residential buildings is allocated to the private households' category "housing". Investment by industries is allocated to these industries and linked to their production activities. Public investment, which serves a general purpose and thus is difficult to allocate (e.g. investment in roads or military equipment) remains with residual public final demand. Especially allocation of investment to industries is highly uncertain since the capital stock of the specific industries is unknown. As a rough estimate we distributed investment according to the industries' depreciation, distinguishing between buildings and capital equipment. Since depreciation of the Swiss industries is also unknown, we roughly estimated industry-specific depreciation with data from the German national accounts (Destatis 2009).

[11] Classification of Individual Consumption by Purpose, see e.g. http://ec.europa.eu/eurostat/ramon/nomenclatures for further details

Tab. 5 > Original and new final demand categories[12] of the IOT 2005

The table gives an overview of the final demand categories used in this study after reallocations as explained in the text.

	Value 2005 [MM CHF]		Value 2005 [MM CHF]
Original categories of final demand		New categories of final demand	
Food and non-alcoholic beverages	28 732	Nutrition and tobacco	38 191
Alcoholic beverages, tobacco	9 460	Clothing and footwear	10 696
Clothing and footwear	10 696	Housing, water, electricity, gas and other fuels	63 364
Housing, water, energy	63 364	Furnishings, household equipment etc.	12 223
Furnishings, household equipment etc.	12 223	Health	48 707
Health	40 046	Transport, incl. fuels	24 071
Transport	24 071	Communication	7 339
Communication	7 339	Recreation and culture	24 712
Recreation and culture	22 638	Education	24 351
Education	1 402	Restaurants and hotels	18 853
Restaurants and hotels	18 853	Miscellaneous goods and services	35 311
Miscellaneous goods and services	30 539	Government consumption	25 020
Consumption of Non-profit institutions	9 276	Residential investment	23 042
Government consumption	49 237	Government investment	3 843
Social security expenditures	4 961	Change of inventories and NAV	1 927
Capital investment in equipment	52 392	Export	226 250
Capital investment in buildings	45 805		
Inventory change	-510	Removed from final demand	
Net acquisition of valuables (NAV)	2 436	Other capital investment in buildings	18 920
Exports	226 250	Capital investment in equipment	52 392
Total	659 213	Total	659 213

Source: Nathani et al. 2008, calculations Rütter + Partner

3.4 Linking foreign trade data with IOT

Linking SITC and CPA

The estimation of environmental impacts related to the Swiss imports and exports makes use of data from the foreign trade statistics published by the Swiss Federal Customs Administration (Tab. 6). In these the traded goods are recorded with their quantities and their values. The goods are classified according to the SITC classification. For the IO analysis we reclassified them according to the CPA classification that is compatible with the IO table. In some cases the transfer from the SITC to the CPA classification is not unambiguous. Therefore we had to make simplifying assumptions.

It has to be noted that the total balance cannot be simply calculated by subtracting total mass of exports from imports in one sector due to the different types of goods imported and exported within one sector. This is explained in detail in sub-chapter 3.5 and such differences found between goods imported and exported have been considered.

12 Final demand categories follow the COICOP classification internationally used in national accounting, see http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5

In the IOT, commodity imports and exports from the customs statistics are supplemented with other items, which are not recorded in the customs statistics, to deliver total imports and exports. Imports are supplemented with the expenditures of Swiss residents as tourists in foreign countries and with data from the balance of payments on service imports. Likewise exports in the IOT additionally contain expenditures by non-residents such as tourists in Switzerland and other items from the balance of payments. These differences are taken into account in the calculation of environmental impacts related to imports by correction factors.

Correction factor for goods import according to residence principle

Tab. 6 > Trade of goods and electricity (kg and kWh, respectively) in the year 2005

The table shows the total trade balance of Switzerland for goods (kg) and electricity (kWh) according to trade statistics (not including the correction factor for the residence principle).

	Import	Export
Total	47 090 967 655	15 034 984 024
00. Live animals other than animals of division 03	4 388 414	3 154 907
01. Meat and meat preparations	103 822 322	7 657 503
02. Dairy products and birds' eggs	108 116 407	118 376 908
03. Fish (not marine mammals), crustaceans, molluscs and aquatic invertebrates, and preparations thereof	57 389 619	202 337
04. Cereals and cereal preparations	630 833 172	69 588 702
05. Vegetables and fruit	918 224 377	359 370 414
06. Sugars, sugar preparations and honey	398 990 638	19 824 176
07. Coffee, tea, cocoa, spices, and manufactures thereof	195 217 252	172 162 529
08. Feeding stuff for animals (not including unmilled cereals)	667 514 856	83 141 373
09. Miscellaneous edible products and preparations	110 323 814	138 728 872
11. Beverages	708 498 696	279 599 915
12. Tobacco and tobacco manufactures	42 680 705	40 632 978
21. Hides, skins and furskins, raw	330 863	15 394 142
22. Oil-seeds and oleaginous fruits	79 153 624	694 289
23. Crude rubber (including synthetic and reclaimed)	40 046 205	8 285 307
24. Cork and wood	956 386 280	1 923 675 465
25. Pulp and waste paper	643 790 852	558 794 740
26. Textile fibres (other than wool tops and other combed wool) and their wastes (not manufactured into yarn or fabric)	39 460 411	56 023 105
27. Crude fertilizers, other than those of division 56, and crude minerals (excluding coal, petroleum and precious stones)	7 938 351 960	993 453 059
28. Metalliferous ores and metal scrap	544 987 165	785 778 147
29. Crude animal and vegetable materials, n.e.s.	173 423 706	43 562 721
32. Coal, coke and briquettes	284 236 935	367 217
33. Petroleum, petroleum products and related materials	12 867 784 019	1 002 910 514
34. Gas, natural and manufactured	2 591 251 718	54 182 041
41. Animal oils and fats	10 469 792	2 834 546
42. Fixed vegetable fats and oils, crude, refined or fractionated	111 083 513	2 923 475
43. Animal or vegetable fats and oils, processed; waxes of animal or vegetable origin; inedible mixtures or preparations of animal or vegetable fats or oils, n.e.s.	13 200 707	3 847 649
51. Organic chemicals	1 119 311 922	247 235 363

	Import	Export
52. Inorganic chemicals	635 877 217	120 487 647
53. Dyeing, tanning and colouring materials	323 259 626	198 353 553
54. Medicinal and pharmaceutical products	57 337 606	78 943 440
55. Essential oils and resinoids and perfume materials; toilet, polishing and cleansing preparations	229 717 337	176 446 368
56. Fertilizers (other than those of group 272)	263 332 149	4 321 205
57. Plastics in primary forms	1 070 469 035	371 606 264
58. Plastics in non-primary forms	303 445 847	254 742 121
59. Chemical materials and products, n.e.s.	1 403 161 484	371 227 475
61. Leather, leather manufactures, n.e.s., and dressed furskins	3 385 838	1 178 305
62. Rubber manufactures, n.e.s.	131 736 526	61 848 012
63. Cork and wood manufactures (excluding furniture)	712 998 334	529 559 167
64. Paper, paperboard and articles of paper pulp, of paper or of paperboard	1 399 523 881	1 542 608 483
65. Textile yarn, fabrics, made-up articles, n.e.s., and related products	154 802 531	114 168 936
66. Non-metallic mineral manufactures, n.e.s.	2 631 665 614	556 072 032
67. Iron and steel	2 277 288 371	1 132 855 756
68. Non-ferrous metals	475 334 812	230 151 078
69. Manufactures of metals, n.e.s.	596 879 134	336 708 173
71. Power-generating machinery and equipment	60 172 141	66 313 296
72. Machinery specialized for particular industries	210 445 869	259 524 390
73. Metalworking machinery	53 747 253	99 558 402
74. General industrial machinery and equipment, n.e.s., and machine parts, n.e.s.	299 705 592	202 554 401
75. Office machines and automatic data-processing machines	53 718 960	9 149 955
76. Telecommunications and sound-recording and reproducing apparatus and equipment	43 111 377	7 209 990
77. Electrical machinery, apparatus and appliances, n.e.s., and electrical parts thereof (including non-electrical counterparts, n.e.s., of electrical household-type equipment)	242 424 352	199 446 040
78. Road vehicles (including air-cushion vehicles)	611 191 552	308 694 503
79. Other transport equipment	51 879 872	26 678 152
81. Prefabricated buildings; sanitary, plumbing, heating and lighting fixtures and fittings, n.e.s.	122 543 972	30 369 717
82. Furniture, and parts thereof; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings	470 413 333	149 783 235
83. Travel goods, handbags and similar containers	22 624 015	4 725 478
84. Articles of apparel and clothing accessories	98 075 573	8 163 109
85. Footwear	29 658 988	2 008 449
87. Professional, scientific and controlling instruments and apparatus, n.e.s.	25 364 549	26 288 708
88. Photographic apparatus, equipment and supplies and optical goods, n.e.s.; watches and clocks	15 914 514	8 707 175
89. Miscellaneous manufactured articles, n.e.s.	592 199 608	326 615 017
93. Specific trade incidents	58 188 390	225 427 548
97. Gold, non-monetary (excluding gold ores and concentrates)	102 459	86 050
35. Electric current	33 542 000 000	30 099 000 000

Source: Eidg. Oberzolldirektion 2005

3.5 Calculation of environmental impacts due to imports of commodities

In general the same methodology as in a former study for calculating the embodied greenhouse gas emissions of Switzerland is used (Jungbluth et al. 2007). Since then the background data have been updated (ecoinvent Centre 2010). Also the internal database of ESU-services has been revised (Jungbluth et al. 2011a). Thus, it was possible to better investigate the environmental impacts of imports in certain sectors such as textiles and electronics.

Environmental impacts of goods

Here we only describe the basic principles, the detailed description can be found in the former study (Jungbluth et al. 2007). Environmental impacts are calculated per kilogram of imported goods in a specific sector according to the nomenclature used in the foreign trade statistic. Therefore the environmental impacts of the most important products in one sector are linked to similar life cycle inventories for such products. In most cases life cycle inventories of 5 to ten products are considered for calculating an average environmental impact per kg of one sector of the trade statistic. These inventories are then linked to the amount of traded goods according to Tab. 6.

Transport to Switzerland

Transports are generally assessed with standard distances concerning different modes of transportation (Jungbluth et al. 2007). There is no statistical data about transport chains used for importation of goods to Switzerland.

Exported waste

Exports of waste are a specific issue. Within the framework of the used trade balance, exports of wastes are shown within several categories. It is not easy to evaluate if these wastes are sold or if they are exported against payment for final treatment. Furthermore it is not possible to summarize the wastes easily. So far we could not estimate the environmental impacts due to export of wastes, which are finally treated outside of Switzerland.

Tab. 7 > Combination of foreign trade data with unit process raw data from the ecoinvent database

The foreign trade data are linked to ecoinvent datasets and confidential datasets of the ESU-database where ecoinvent data are not available. All datasets are available publicly as a system process.

Name	Location	InfrastructurePro	Unit	SITC-01, meat and meat preparations, import	SITC-01, meat and meat preparations, export	Unit	Faktor	meat and meat preparations	import	export
Location				CH	CH				103'102'216	9'521'410
InfrastructureProcess				0	0				103'102'216	9'521'410
Unit				kg	kg				103'102'216	9'521'410
transport, freight, rail	CH	0	tkm	0	8.36E-2	km	200	transport statistics	-	41.8%
transport, lorry >28t, fleet average	CH	0	tkm	0	1.14E-1	km	200	transport statistics	-	57.1%
transport, barge	RER	0	tkm	1.40E-1	8.15E-3	km	800	transport statistics	-	1.0%
transport, freight, rail	RER	0	tkm	8.25E-2	0	km	600	transport statistics	13.8%	-
transport, lorry >16t, fleet average	RER	0	tkm	4.09E-1	0	km	600	transport statistics	68.1%	-
transport, aircraft, freight	RER	0	tkm	3.46E-2	2.55E-3	km	5000	transport statistics	0.7%	0.1%
transport, transoceanic freight ship	OCE	0	tkm	1.74E+0	0	km	10000	transport statistics	17.4%	-
beef, IP, at slaughterhouse	CH	0	kg	9.31E-2	4.43E-4	011.00	1	Fleisch von Rindern, frisch, gekühlt oder gefroren	9'600'728	4'218
meat mixed, IP, at slaughterhouse	CH	0	kg	8.05E-1	8.64E-1	012.00	1	Fleisch (ohne solches von Rindern) und geniessbare Schlachtnebenerzeugnisse, frisch, gekühlt oder gefroren, für die menschliche	83'006'935	8'223'790
meat mixed, organic, at slaughterhouse	CH	0	kg	1.84E-2	1.24E-1	016.00	1	Fleisch und geniessbare Schlachtnebenerzeugnisse, gesalzen, in Salzlake, getrocknet oder geräuchert; geniessbares Mehl von Fleisch oder von	1'897'149	1'178'393
meat mixed, IP, at slaughterhouse	CH	0	kg	8.34E-2	1.21E-2	017.00	1	Fleisch und geniessbare Schlachtnebenerzeugnisse, zubereitet oder haltbar gemacht, a.n.g.	8'597'404	115'009
storage, fresh meat, in cold store	RER	0	kg	8.98E-1	8.64E-1			storage of chilled meat		
processing and distribution, meat, conserved	CH	0	kg	1.02E-1	1.36E-1			processing of meat		

Source: Eidg. Oberzolldirektion 2004; Jungbluth et al. 2007 and own assumptions

3.6 Calculation of environmental impacts due to service imports

The environmental impacts of services provided abroad are roughly estimated. Some activities behind a service can be quantified by the amount of working hours in an office or transport services carried out on behalf of the business services. However, the actual quantification of environmental impact caused by services is a challenge.

For the majority of services, the environmental impact has therefore been set equal to the environmental impact caused by the services derived in Switzerland.

On the other hand, for some economic sectors, the ecoinvent database (ecoinvent Centre 2010) or the internal ESU database provides LCI data, which allow for an approximation of the environmental impact.

> The environmental impact caused by hotels and restaurants is approximated using LCI data for an overnight stay in an average European hotel (Hamele & Eckardt 2006). We assume that a global average price of 60 CHF is paid for an overnight stay.
> The LCI data of transport services refers to transport by lorry. The transport costs are set to 0.25 CHF/tkm (Universität St. Gallen 2007).
> Health and social work services abroad often include stays in recovery centres or therapy in a clinic. These services are roughly approximated by an overnight stay in a five star European hotel (500 CHF) and a session in an indoor swimming pool (100 CHF), in order to represent the stay and therapy in a clinic (Sesartic & Stucki 2007).

For all other service imports we assume that the imported service has the same environmental impacts as the service provided in Switzerland. More detailed LCI data were not available for these types of services.

3.7 Data quality

For assessing the data quality of the economic and LCA data used in the analysis several issues need to be considered. They are described in some detail in this chapter.

Breakdown of IOT production sectors

The first issue concerning data quality is the availability of breakdown data to distinguish different economic sectors in the IOT. We could distinguish 43 sectors. But, for some sectors economic activities with large variations in emission intensity are aggregated which can lead to considerable uncertainties.

G01b05 Primary sector

The primary sector covers agriculture as well as forestry and fisheries. Many environmental problems are related to the use of pesticides and fertilizers in agriculture, while they do not play a role in forestry. Thus, environmental intensities of agriculture are underestimated while those of forestry products are overestimated due to this aggregation.

G24 Chemicals

The chemicals sector is quite important for the calculation of exports. Large differences can be expected in the environmental impacts caused by basic chemicals or fine chemicals like pesticides and pharmaceutical products. Thus a further disaggregation would also be necessary for this sector.

G40b41 Electricity and water

Also the sector energy and water supply (NOGA 40-41) aggregates several activities, which show quite different environmental impacts (supply of electricity, gas, distance heat and water). Environmental impacts due to the delivery of electricity are underestimated while those of gas and water supply are overestimated due to this aggregation. Trade with electricity is known to be a major issue for exports as well. Due to the low level of detail available in the IOT these exports cannot be calculated very well.

G60b62, transport

Different means of transport (air, water, road and train) as well as passenger and goods transports are concluded in one economic sector. They also show quite different emission patterns and are quite important for the total environmental impacts.

There is an ongoing project of the FOEN to better disaggregate data for energy and transport services, but results were not yet available.

Use of imported goods and services

In the published IOT the use of imported goods is not distinguished from the use of domestic goods. In this study we separate the use of imported and of domestic goods, but largely assume identical use patterns due to lack of information. The only exception concerns the use of crude oil that is allocated to the refinery sector. The assumption of identical use patterns also causes a bias that may be large with regard to selected sectors. We assume the bias to be smaller with regard to the allocation of indirect environmental impacts to final consumption categories, since the production chains linked to final consumption usually include a large variety of economic sectors thus leading to a levelling of the bias.

Mining sector

The most prominent example is the mining sector. In Switzerland mainly production of gravel, sand and stones belongs to this sector. For imports the provision of crude oil or metal resources is assigned to this sector. The environmental impacts as well as the use patterns in the Swiss economy can be assumed to be quite different. Thus e.g. important crude oil will be used by refineries only and not by the building sector. In the case of crude oil it was possible to allocate the imports solely to the refinery sector. For other imports this was not possible due to lack of information.

Definition of consumption categories

Consumption categories can be interpreted quite differently. The definition in this report follows standard assumption. But, it has to be noticed that on a first view one might interpret the activities differently. Thus, e.g. energy uses for cooking or for transporting foodstuffs in the car are not covered under the category nourishing, but under mobility or energy consumption by households. Thus, for the interpretation of these data the definition has to be kept in mind.

Trade statistics

Trade statistics are the only major data source used in this project that is updated on an annual basis. Different classifications of traded goods are possible. Unfortunately we had to use a classification that does not match well with the classification used in the IOT, because we had to rely on data of a former project. The data quality could be improved by using a classification better fitting with the IOT, but the workload would be considerable. Nevertheless the quantity and type of traded goods is recorded well in the used data.

LCA data for goods

The linkage of trade statistics with LCA data shows quite diverse data quality. For some sectors e.g. crude oil and refinery products the LCA data quality is excellent and matches well with the information provided in the trade statistics. For other sectors e.g. electronics there are also very few LCA data available that cannot cover the diversity of imported products well enough. Also differences in the regional origin of products could not be investigated in detail. Nevertheless we assume that the most important imports are covered well with the approach used.

LCA data for services

Most service imports could only be estimated by using Swiss data from the EE-IOA. For some sectors rough assumptions based on LCA data could be used. The overall environmental importance of service imports is low and thus these uncertainties do not influence much the results of this project.

Double counting

In some cases the combination of the two methods can lead to double counting. Transport of imported goods is calculated with LCA data assuming transport means and distances up to the Swiss border. As far as the transport services are performed by domestic companies, the environmental impact of transport is also included in the results of IO modelling.

4 > Domestic emissions and resource uses and allocation to economic sectors and final demand

The total emissions caused and resources used in Switzerland have to be investigated and allocated to production sectors and the final demand categories. This chapter and Appendix 1 describe the data sources for the domestic emissions and resource uses and their allocation (assignment to a specific sector that emits or uses the resource). This chapter builds on the inventory of emissions and resource uses developed in a former report for the ecological scarcity method. Emissions and resource uses within the boundaries of the Swiss economy are allocated to the economic sectors or final demand, where they are emitted or used, respectively (see Annex "Allocation of domestic emissions and resource uses to economic sectors and final demand"). Readers who are only interested in the final results of this study can skip this chapter.

4.1 General allocation rules

This chapter builds up on the inventory of emissions and resource uses described in a former report on the ecological scarcity method (Frischknecht et al. 2009). These emissions and resource uses are allocated to economic sectors and the private households as depicted in the input-output table. As mentioned before the input-output table follows the residence principle to define the boundaries of the economic system of a country. The residence principle deviates from the territorial principle mainly used in environmental statistics. To be compatible with the underlying IO table it would be the ideal approach to transfer the environmental data from the territorial to the residence principle. Due to lack of data this is only possible for greenhouse gas emissions, where the necessary data are available from the Swiss NAMEA Air (BFS 2009; 2011). For all emissions except greenhouse gases we use the territorial principle. The error due to this approximation is considered to be negligible compared to other uncertainties.

SwissPRTR

Some information about different emissions is retrieved from the Swiss database of pollutant release and transfer register (SwissPRTR, BAFU 2010a). However, for most pollutants the allocation to the different economic sectors and the final demand cannot be based on the SwissPRTR, since this database includes only companies with extensive emissions as described in PRTR-V (2007). Emissions from agriculture and the transport sector are excluded or only included in the total of diffuse emissions, which are not broken down any further. For many substances the specified figures are only available for a minor share of emissions and the major share of emissions remain unspecified. For example 99% of the ammonia emissions are called unspecified and the sources are given only for 1%.

Energy consumption

Emissions that are related to the combustion and use of fuel oil, petrol coke, petrol, diesel, kerosene, coal, natural gas, or wood, are allocated in accordance with the sectoral consumption of these energy carriers. Also e.g. land occupation related to fuel consumption is directly allocated to the sectors using the fuel. Thus it is not possible to evaluate the overall relevance e.g. of transport or heating related environmental impacts in the production sectors.

In general the following information and assumption were used for the allocation of total emissions to single production sectors or consumption categories:

> Split-up of greenhouse gases and direct energy carriers as backbone were available from the Swiss Federal Office of Statistics
> The FOEN provided detailed emission split up of air-emission statistics
> Different literature sources were evaluated
> Total LCA of exports and imports helps to see major contributions of single exchanges
> Some exchanges are mainly from one sector (e.g. agricultural land occupation)
> IOT data can also be used as backbone e.g. for infrastructure related exchanges

4.2 Overview on total domestic emissions and resource uses in Switzerland

Tab. 8 shows a summary of all direct emissions and resource uses that are accounted for in the calculation of direct environmental impacts. A description on how this table can be read is presented in Tab. 1 on page 37.

The allocation of the emissions and resource uses to the different sectors of consumption and production are described in the appendix for this chapter. Even more detailed information on the allocation and data are available electronically.

Tab. 8 > Raw data for total emissions in Switzerland according to the residence principle

This table provides an overview on total emissions and resource uses of Switzerland in the year 2005. Within the previous chapters we investigated the allocation of these figures to the different sectors of consumption and production. Some more information can be found in the GeneralComment field. Detailed data will be electronically available.

	Name	Unit	Total emissions, residence principle	Standard Deviation 95%	General comment
	Location InfrastructureProcess Unit		CH 0 a		
resource, in air	Carbon dioxide, in air	kg	6.12E+9	1.22	(4,2,1,1,1,3); BFS (2009); calculated with emissions from primary sector,
emission air, unspecified	Carbon dioxide, fossil	kg	4.94E+10	1.07	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005), carbon monoxide and carbon dioxide in stratosphere subtracted
emission air, lower stratosphere + upper troposphere	Carbon dioxide, fossil	kg	6.92E+7	1.09	(2,1,1,1,1,3); calculated from 30% of kerosene consumption, aviation

	Name	Unit	Total emissions, residence principle	Standard Deviation 95%	General comment
	Location InfrastructureProcess Unit		CH 0 a		
emission air, unspecified	Carbon dioxide, biogenic	kg	6.12E+9	1.07	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
	Dinitrogen monoxide	kg	1.10E+7	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
	Methane, biogenic	kg	1.34E+8	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
	Methane, fossil	kg	3.05E+7	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
	Sulfur hexafluoride	kg	1.10E+4	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
	Methane, tetrafluoro-, R-14	kg	9.01E+3	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	kg	5.18E+5	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
	Carbon monoxide, fossil	kg	3.43E+8	5.02	(3,1,1,1,1,3); Frischknecht et al. (2009), BAFU (2010b) and split according to the consumption of energy carriers
	Methane, trichlorofluoro-, CFC-11	kg		1.56	(4,1,1,1,1,3); statistics for 2005, cooling devices
	Methane, trichlorofluoro-, CFC-11	kg	1.67E+5	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Methane, dichlorodifluoro-, CFC-12	kg	1.00E+5	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Ethane, chloropentafluoro-, CFC-115	kg	3.70E+3	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Methane, chlorodifluoro-, HCFC-22	kg	2.29E+5	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	kg	5.30E+3	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Ethane, 1,1-dichloro-1-fluoro-, HCFC-141b	kg	7.40E+4	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Methane, bromochlorodifluoro-, Halon 1211	kg	6.70E+3	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Methane, bromotrifluoro-, Halon 1301	kg	6.30E+3	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Methane, bromo-, Halon 1001	kg	1.90E+4	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Ethane, 1,1,1-trichloro-, HCFC-140	kg	3.90E+4	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	Methane, tetrachloro-, R-10	kg	2.20E+3	1.56	(4,1,1,1,1,3); Reimann et al. (2009); allocation: own estimation based on application fields (BAFU 2010a)
	NMVOC, non-methane volatile organic compounds, unspecified origin	kg	1.01E+8	1.52	(3,1,1,1,1,3); BAFU (2010b)
	Nitrogen oxides	kg	8.36E+7	1.52	(3,1,1,1,1,3); BAFU (2010b)
	Ammonia	kg	6.26E+7	1.24	(3,1,1,1,1,3); BAFU (2010a, 2010b); agriculture
	Sulfur dioxide	kg	1.65E+7	1.12	(3,1,1,1,1,3); BAFU (2010b)
	Hydrogen chloride	kg	5.60E+5	1.56	(4,1,1,1,1,3); BUWAL (1995), split up like SO2 emissions
	Hydrogen fluoride	kg	4.10E+4	1.56	(4,1,1,1,1,3); BUWAL (1995), split up like SO2 emissions
	Benzo(a)pyrene	kg	1.85E+2	3.02	(3,1,1,1,1,3); BAFU (2010b) and split according to the consumption of energy carriers
	PAH, polycyclic aromatic hydrocarbons	kg	9.15E+2	3.02	(3,1,1,1,1,3); BAFU (2009b, 2010b); without benzo(a)pyrene
	Particulates, > 10 um	kg	4.40E+6	1.52	(3,1,1,1,1,3); BAFU (2010b) and split according to the consumption of energy carriers
	Particulates, > 2.5 um, and < 10um	kg	1.13E+7	2.02	(3,1,1,1,1,3); BAFU (2010b) and split according to the consumption of energy carriers
	Particulates, < 2.5 um	kg	1.04E+7	3.02	(3,1,1,1,1,3); BAFU (2010b) and split according to the consumption of energy carriers
	Particulates, diesel soot	kg		3.02	(3,1,1,1,1,3); excluded from analysis
	Benzene	kg	1.06E+6	3.05	(4,1,1,1,1,3); BUWAL (2003d), about 75% from traffic, rest from oil and wood heating
	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	kg	1.86E-2	3.02	(3,1,1,1,1,3); BAFU (2010b)
	Lead	kg	2.65E+4	5.02	(3,1,1,1,1,3); BAFU (2010b)
	Cadmium	kg	1.29E+3	5.02	(3,1,1,1,1,3); BAFU (2010b)
	Zinc	kg	5.60E+5	5.06	(4,1,1,1,1,3); BUWAL (1995), split according to the fuel consumption
	Mercury	kg	1.14E+3	5.02	(3,1,1,1,1,3); BAFU (2010b), split according to the consumption of energy carriers
emission water, river	Nitrogen	kg	3.14E+7	1.51	(2,1,2,3,1,3); Prashun et al. (2005); allocation based on GSA & GBL (2003), agriculture and effluent treatment
	Phosphorus	kg	1.69E+6	1.51	(2,1,1,1,1,3); Prashun et al. (2005); allocation based on Binder (2009), agriculture and sewage treatment
	COD, Chemical Oxygen Demand	kg	4.77E+7	1.78	(5,3,1,3,1,3); Dinkel & Stettler (2004); agriculture and effluent treatment
	TOC, Total Organic Carbon	kg	1.59E+7	1.78	(5,3,1,3,1,3); Dinkel & Stettler (2004); allocation based on own estimation, agriculture and sewage treatment
	DOC, Dissolved Organic Carbon	kg	1.59E+7	1.78	(5,3,1,3,1,3); Dinkel & Stettler (2004); allocation based on own estimation, agriculture and sewage treatment
	BOD5, Biological Oxygen Demand	kg	4.77E+7	1.78	(5,3,1,3,1,3); Dinkel & Stettler (2004); allocation based on own estimation, agriculture and sewage treatment
	Arsenic, ion	kg	8.60E+3	5.33	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000), allocation based on rough estimation
	Lead	kg	3.20E+4	5.33	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000), allocation based on average of soil and air emissions

	Name	Unit	Total emissions, residence principle	Standard Deviation 95%	General comment
	Location InfrastructureProcess Unit		CH 0 a		
	Cadmium, ion	kg	6.10E+2	3.29	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000); fertilizer and pesticides
	Chromium, ion	kg	2.50E+4	3.29	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000); industry, corrosion of chromium steel products and fertilizers
	Copper, ion	kg	7.40E+4	3.29	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000); roof run off, water supply and use as fungicide (50% estimation)
	Nickel, ion	kg	8.40E+4	5.33	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000); allocation based on own estimation, agriculture and sewage treatment
	Mercury	kg	2.00E+2	5.33	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000); chemical industry, disposal sector, energy sector
	Zinc, ion	kg	1.67E+5	5.33	(5,1,1,5,3,3); IKSR (2004); BUWAL et al. (2000); roof run off, tyre wear and water supply
	Carbon-14	kBq		3.01	(2,1,1,1,1,3); SITC categories LCI, weighted
	AOX, Adsorbable Organic Halogen as Cl	kg	2.90E+5	1.50	(1,1,1,1,1,3); BAFU 2010a, effluent treatment, manufacturing of pulp and paper, chemical industry
	Chloroform	kg	1.90E+3	3.05	(4,1,1,1,1,3); AUE (2005), effluent treatment
	PAH, polycyclic aromatic hydrocarbons	kg	1.40E+2	3.01	(2,3,1,2,1,3); AUE (2005); from road runoff, allocation depending on fuel consumption
	Benzo(a)pyrene	kg	4.80E+1	3.01	(2,3,1,2,1,3); IKSR (2004), from road runoff, allocation depending on fuel consumption, from wood preservatives (railways, households), from cigarette consumption
	Estradiol	kg	5.00E+0	3.01	(2,2,1,3,1,3); Aerni et al. (2004), use of pharmaceuticals
emission water, ground	Nitrate	kg	1.51E+8	1.51	(2,3,1,3,1,3); BUWAL (1996)
emission soil, agricultural	Lead	kg	8.00E+4	1.12	(2,1,1,1,1,3); Keller et al. (2005)
	Cadmium	kg	3.00E+3	1.12	(2,1,1,1,1,3); Keller et al. (2005)
	Copper	kg	1.20E+5	1.12	(2,1,1,1,1,3); Keller et al. (2005); Arx (2006); emissions from fertiliser and pesticide application in agriculture and gardens, from wood preservatives for railways, and from ballots
	Zinc	kg	8.70E+5	1.12	(2,1,1,1,1,3); Keller et al. (2005)
emission soil, unspecified	Chromium VI	kg	2.52E+4	1.58	(4,3,3,1,1,3); Frischknecht et al. (2007); wash out from power poles
	Copper	kg	1.33E+4	1.58	(4,3,3,1,1,3); Frischknecht et al. (2007); wash out from power poles
	Boron	kg	8.02E+3	1.58	(4,3,3,1,1,3); Frischknecht et al. (2007); wash out from power poles
	Fluoride	kg	2.59E+4	1.58	(4,3,3,1,1,3); Frischknecht et al. (2007); wash out from power poles
technosphere	application mix, pesticides	kg	1.52E+6	1.09	(2,2,1,1,1,3); Jungbluth et al. (2010a); application mix, application in agriculture, railways and private gardens
resource, in water	Energy, potential (in hydropower reservoir), converted	MJ	1.18E+11	1.09	(2,1,1,1,1,3); BFS (2009), BFE (2004)
resource, biotic	Energy, gross calorific value, in biomass	MJ	3.44E+10	1.09	(2,1,1,1,1,3); BFS (2009), BFE (2004); allocation to primary sector
resource, unspecified	Energy, waste	MJ	1.60E+10	1.09	(2,1,1,1,1,3); BFS (2009), BFE (2004); proxy for energy from biomass waste
resource, in air	Energy, solar, converted	MJ	1.09E+9	1.09	(2,1,1,1,1,3); BFS (2009), BFE (2004)
	Energy, kinetic (in wind), converted	MJ	3.01E+7	1.09	(2,1,1,1,1,3); BFS (2009), BFE (2004)
resource, in ground	Energy, geothermal, converted	MJ	6.09E+9	1.09	(2,1,1,1,1,3); BFS (2009)
	Oil, crude, in ground	kg		1.09	(2,1,1,1,1,3); BFE (2004)
	Gas, natural, in ground	Nm3		1.09	(2,1,1,1,1,3); BFE (2004)
	Coal, hard, unspecified, in ground	kg		1.09	(2,1,1,1,1,3); BFE (2004)
	Uranium, in ground	kg		1.09	(2,1,1,1,1,3); BFE (2004)
resource, unspecified	Energy, waste	MJ	1.97E+10	1.09	(2,1,1,1,1,3); BFS (2009), BFE (2004); proxy for non-renewable energy from waste
emission air, unspecified	Heat, waste	MJ	4.56E+11	1.22	(4,1,1,1,1,3); BFE (2004); Assumption that all energy carriers are used in Switzerland
resource, land	Occupation, urban, continuously built	m2a	1.38E+9	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, industrial area, vegetation	m2a	1.59E+8	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, mineral extraction site	m2a	8.06E+7	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, dump site	m2a	8.06E+7	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, traffic area, road network	m2a	8.09E+8	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, traffic area, rail network	m2a	8.45E+7	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, industrial area, built up	m2a	7.29E+7	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001); investments in building sector
	Occupation, industrial area, vegetation	m2a	1.29E+8	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001); investments in building sector
	Occupation, arable	m2a	2.78E+9	1.12	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, permanent crop, vine	m2a	1.54E+8	1.12	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, permanent crop, fruit	m2a	4.55E+8	1.12	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, pasture and meadow	m2a	1.19E+10	1.12	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, forest	m2a	1.03E+10	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
	Occupation, shrub land, sclerophyllous	m2a	2.46E+9	1.51	(2,1,1,1,1,3); area statistics for 1992/97 (BfS 2001)
resource, in water	Water, unspecified natural origin	m3	2.57E+9	1.22	(4,1,1,1,1,3); FAO (2010), Weber & Schild (2007) and BWG (2003); incl. cooling water of thermal power plants
resource, in ground	Gravel, in ground	kg	3.40E+10	1.09	(2,1,1,1,1,3); Rubli et al. (2005), only mining and quarrying sector
emission water, ground-, long-term	TOC, Total Organic Carbon	kg	2.33E+7	1.51	(2,1,1,1,1,3); BUWAL (2003c)
resource, in ground	Volume occupied, underground deposit	m3		1.09	(2,1,1,1,1,3); BUWAL (2003c)

	Name	Unit	Total emissions, residence principle	Standard Deviation 95%	General comment
	Location InfrastructureProcess Unit		CH 0 a		
technosphere	disposal, hazardous waste, 0% water, to underground deposit	kg	3.69E+7	1.09	(2,1,1,1,1,3); BUWAL (2003c)
resource, in ground	Volume occupied, final repository for radioactive waste	m3	2.18E+2	1.09	(2,1,1,1,1,3); Dones (2003); wastes from nuclear power
	Volume occupied, final repository for low-active radioactive waste	m3	1.23E+3	1.22	(4,1,1,1,1,3); Dones (2003); Nagra (2008; 2009); wastes from nuclear power, industry, research and medicine
emission air, unspecified	Heat, waste	MJ	2.13E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Crude oil
	Heat, waste	MJ	2.14E+11	1.07	(1,1,1,1,1,3); BFS (2009), burning of light fuel oil
	Heat, waste	MJ	5.81E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Heavy fuel oil
	Heat, waste	MJ	1.42E+11	1.07	(1,1,1,1,1,3); BFS (2009), burning of Gasoline
	Heat, waste	MJ	7.23E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Diesel oil
	Heat, waste	MJ	6.22E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Kerosene
	Heat, waste	MJ	3.15E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Petrol coke
	Heat, waste	MJ	1.63E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Other oil products
	Heat, waste	MJ	2.18E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Non energy use oil products
	Heat, waste	MJ	6.26E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Coal
	Heat, waste	MJ	1.11E+11	1.07	(1,1,1,1,1,3); BFS (2009), burning of Gas
	Heat, waste	MJ	7.86E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Industrial waste (non biomass)
	Heat, waste	MJ	1.19E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Municipal solid waste (non biomass)
	Heat, waste	MJ	4.19E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Industrial waste (biomass)
	Heat, waste	MJ	1.19E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Municipal solid waste (biomass)
	Heat, waste	MJ	3.13E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Wood
	Heat, waste	MJ	2.44E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Biogas
	Heat, waste	MJ	2.45E+8	1.07	(1,1,1,1,1,3); BFS (2009), burning of Biofuels
	Heat, waste	MJ		1.07	(1,1,1,1,1,3); BFS (2009), burning of Hydro power
	Heat, waste	MJ	1.06E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Solar energy
	Heat, waste	MJ	4.04E+6	1.07	(1,1,1,1,1,3); BFS (2009), burning of Wind power
	Heat, waste	MJ	6.09E+9	1.07	(1,1,1,1,1,3); BFS (2009), burning of Other renewable energy (esp. heat from the environment)
	Heat, waste	MJ	1.59E+11	1.07	(1,1,1,1,1,3); BFS (2009), burning of Nuclear fuels
	Heat, waste	MJ	2.27E+11	1.07	(1,1,1,1,1,3); BFS (2009), use of Electricity
	Heat, waste	MJ	1.73E+10	1.07	(1,1,1,1,1,3); BFS (2009), burning of Distance heat

Source: Own estimation based on several literature sources cited in the table

4.3 Data documentation in EcoSpold format

In order to allow other persons to use the data established for this project all data are transformed for further calculations into the EcoSpold format v1.0 (see annexe). This format was developed for the exchange of LCI data between LCA software and databases. It includes quantitative information about inputs and outputs to a unit process as well as the documentation of the data. Data in this format can be imported to an LCA software. This is necessary in order to link them to other LCA data and to do the final calculation of results.

4.4 Data quality

For the estimation of data quality and uncertainties the Pedigree-Matrix developed for the ecoinvent database has been used. This allows a rough calculation of lognormal data quality indicators. We can distinguish the following issues concerning the overall data quality of emission data investigated for Swiss consumption and production in the framework of the input-output-table. These are the coverage, the total amount and the allocation to single production sectors and consumption categories.

Coverage

The investigation has been focused on emissions and resource uses as assessed with the ecological scarcity method (Frischknecht et al. 2009). There are several other possible emissions which are not covered by this method e.g. due to lack of data or because political targets for their reduction have not been set. A known gap is the inventory on land transformation in Switzerland (that is not assessed in the ecological scarcity method, but in other LCIA methods such as Eco-indicator 99 (H,A)). Thus, e.g. there might be further emissions of NMVOC not distinguished or there might be other types of metal emissions. The coverage is fully appropriate for an LCIA with the ecological scarcity method, but there might be gaps or bias concerning the coverage if other LCIA methods are used which cover additional types of emissions or resource uses.

Residence or territorial principle

The economic activities are defined according to the residence principle while most emission data are only available for the territorial boundaries of Switzerland. Thus, only greenhouse gas emissions could be investigated correctly according to the residence principle and this led to an increase of about 7%. The deviation between the two principles is considered to be low for the calculation of the total flow and thus we assume this uncertainty to be low compared to other sources of uncertainty. Nevertheless this leads presumably to an underestimation of environmental impacts.

Total flow in 2005

The total flow in 2005 could be investigated in most cases based on reliable statistical data or publications by the FOEN. In some cases rough assumptions had to be made based on the observation of pollutant concentrations in the environment. Especially diffuse emissions e.g. from tyre abrasion or washouts are difficult to quantify. Nevertheless the general quality of the inventory of the total flow is assumed to be sufficient for the purpose of this study.

Allocation

The third step in the analysis was the allocation of the total flow to single economic sectors or consumption categories. For the split-up of greenhouse gases and a range of other emissions into air, detailed statistics about the sources of emissions were available from the Swiss Federal Office of Statistics and the Swiss Federal Office of Energy. Hence, the allocation of these substances is of sufficient data quality. Furthermore, a low uncertainty is given for those exchanges that are related to mainly one sector (e.g. agricultural land occupation). In several cases detailed information was not available and estimations had to be made based on knowledge e.g. about the fuel use in different sectors. There might also be some room for interpretation to which activities such emissions should be assigned. Thus, e.g. emissions of refrigerants during the use of refrigerators might be allocated to the activity of nutrition (a refrigerator is mainly used for this purpose), the purchase of household goods (the refrigerant is bought together with the refrigerator), the energy use in refrigerators (it is emitted mainly if the refrigerator is operated) or the disposal activity. Thus, quite a lot of uncertainties can be expected in the allocation of those emissions.

It is not possible to fully quantify the exact range of uncertainty that results from the different steps of investigation.

5 > Environmental impacts of Swiss consumption and production in 2005

In this chapter the impact assessment for emissions and resource uses is shown. With this the total (potential) environmental impacts of Swiss consumption and production are analysed. The main life cycle impact assessment (LCIA) method used for this is the Swiss ecological scarcity method 2006. Other LCIA methods are applied as examples. Results are detailed for the two perspectives investigated in this report: the production perspective (environmental impacts caused within the boundaries of Switzerland), and the consumption perspective (environmental impacts caused by Swiss consumption).

This analysis shows the importance of environmental impacts due to imports and exports. It also shows that it is not sufficient to analyse the carbon footprint or energy consumption to obtain a true and fair view of the environmental impacts due to consumption and production. The uncertainty analysis and a digression on the critical burden of the environmental impact of Switzerland finalize the chapter.

5.1 Global warming potential

5.1.1 Introduction

As data availability was best for greenhouse gases the first step of the analysis contained an in depth analysis of the global warming potential (GWP) due to Swiss production and consumption. As a first step we performed an in depth analysis of the global warming potential (GWP). In other countries similar studies have primarily been done for greenhouse gas emissions, using different methodological approaches, thus allowing for comparisons with this study. The results for emissions related to imported goods can also be compared with the results from a former Swiss study using a different approach. Furthermore data availability is better and data uncertainty is lower for greenhouse gas emissions compared to other environmental indicators. The reader interested in the overall picture taking into account all environmental impacts may skip this chapter and continue reading with chapter 5.2.

In this chapter Swiss greenhouse gas emissions and the associated global warming potential are presented from the production and the consumption perspective. Additional figures with more detailed results can be found at the end of this sub-chapter.

The results were calculated according to the procedure mentioned in chapter 2.1. For emissions related to the import of services we assume partly domestic production (IOT) and emission intensities and partly use our own estimation based on LCA studies (sub-chapter 3.6).

5.1.2 Characterisation factors for global warming potential

Characterisation of global warming potential with IPCC 2001

For this study the characterisation factors published by the IPCC 2001 (Albritton & Meira-Filho 2001) are used. This achieves consistency with former studies and official documents on greenhouse gas accounting. In addition to the former study on embodied greenhouse gas emissions, now emissions due to land transformation for imported goods are also included.

IPCC 2007 not used

It has to be noted that these factors have been revised in the meantime (Solomon et al. 2007). Some characterisation factors have changed (e.g. for methane and dinitrogen monoxide). For several substances characterisation factors have been published for the first time.

Comparison and differences to national UNFCCC inventories of GHG emissions

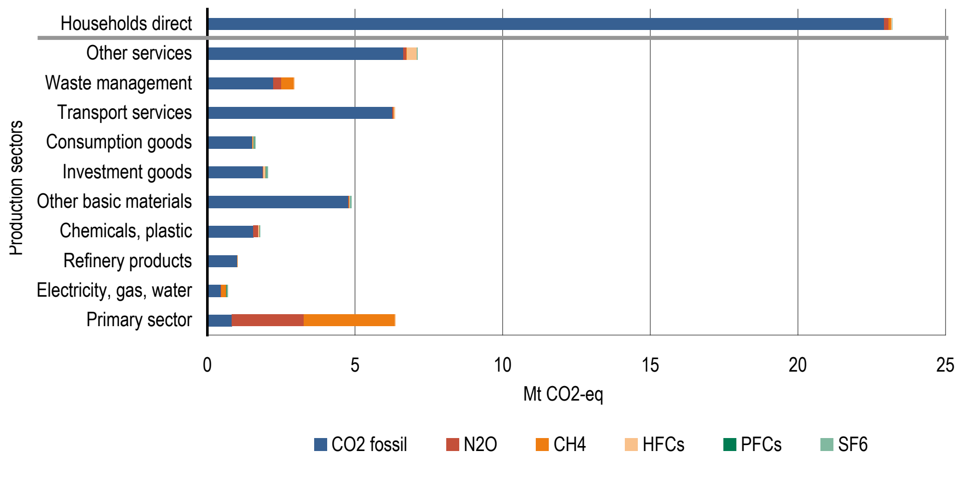
There are two main differences between the UNFCCC GHG inventories and the data used in this study. Whereas the residence principle is used in this study in accordance with national accounting system boundaries, the Swiss UNFCCC inventory refers to the territorial principle. The differences mainly emerge for traffic related emissions. The second difference is the consideration of greenhouse gas emissions from air traffic that is not fully accounted for in the national GHG statistics.

5.1.3 Production perspective

The following figure displays an overview of the direct emitters of greenhouse gases in Switzerland (production perspective). In total 58 Mt CO_2-eq. are emitted in Switzerland. Furthermore approximately 6 Mt biogenic CO_2-emissions are emitted that are not included in the global warming potential of Switzerland. Out of the total global warming potential, CO_2 accounts for 87%, while CH_4 and N_2O each account for 6%. The other gases together contribute 1.7%.

Fig. 18 > Production perspective: Swiss greenhouse gas emissions 2005 by economic actor

Direct greenhouse gas emissions are displayed by attributing greenhouse gas emissions in CO_2-equivalents to the emitting economic actors (households and production sectors). The sectoral aggregates used in this figure are described in the annex.



Source: BFS 2009; 2011, calculations Rütter + Partner

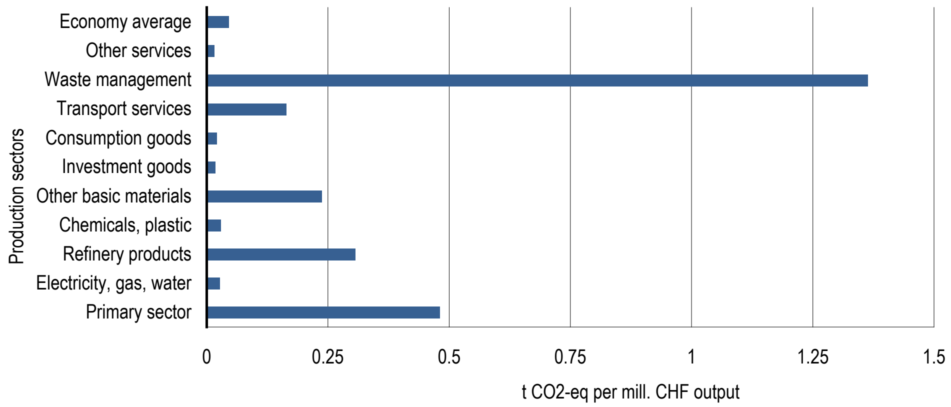
- With 39% of total direct greenhouse gas emissions, households are the most important source in Switzerland. These emissions mainly stem from the use of energy for heating and mobility.
- Electricity is almost completely generated without CO_2 emissions. Therefore this industry is much less relevant than in most other industrialised countries. Its emission share is less than 1%.
- The industry sector accounts for almost 19% of total emissions, with the basic materials industry, the chemicals industry and refineries contributing strongly.
- The service sector accounts for over 30% of total emissions, with the transport sector and waste management being relatively large contributors.
- The primary sector accounts for approx. 10% of total global warming potential.
- Non-CO_2 greenhouse gases, especially methane and N_2O are mainly emitted in the primary sector and by waste management.

Impacts per unit of gross output

Beside the absolute values the sectoral differences in specific emissions per unit of output are also of interest. The following figure shows the greenhouse gas emissions per unit of gross output[13]. The variation is quite large. The most emission-intensive sectors are waste management and refineries. The values for waste management mainly are related to waste incineration. It has to be noted that in this calculation no benefit for co-generation of electricity and distance heat is allocated to waste incineration as would be done in a life cycle assessment. The primary sector, basic industry and transport services also have emission intensity well above the total economy average also displayed in the figure. For the other sectoral aggregates significant variations can be assumed. The sectoral emission intensities are documented for each sector in the accompanying Excel file (allocation-emissions-sectors-direct.xlsx).

Fig. 19 > Production perspective: Specific greenhouse gas emissions 2005 by production sector

Specific direct greenhouse gas emissions per unit of gross output are displayed for the production sectors and for the total economy average.



Source: BFS 2009, 2011, calculations Rütter + Partner

[13] For most industries gross output is largely equal to turnover. Important exceptions are industries like trade, financial services or intermediary transport services, where different definitions of gross output apply according to the principles of national accounting.

5.1.4 Consumption perspective

5.1.4.1 Calculation with EE-IOA

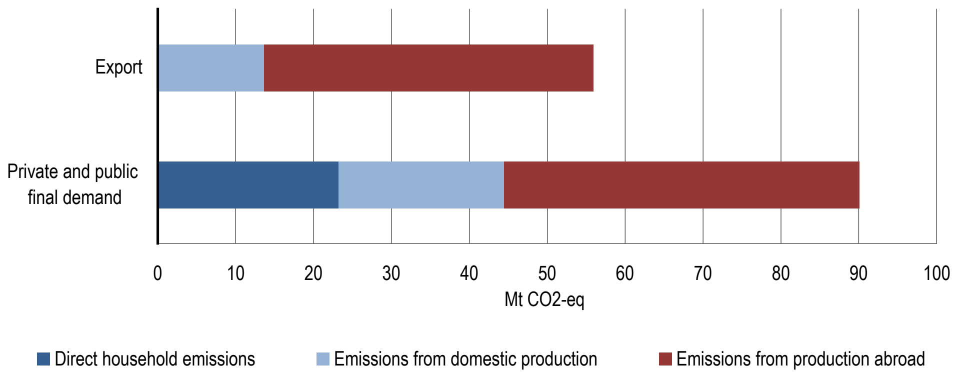
Turning to the consumption perspective, we allocate direct and indirect emissions to final demand in Switzerland. Thus the emissions allocated to a final demand category include direct household emissions if existing, indirect emissions from domestic production of goods and indirect emissions from production of goods abroad that are imported to Switzerland. The indirect emissions generally include the complete supply chains of goods. Indirect emissions thus also include emissions from production activities outside Switzerland. Fig. 20 shows an overview of these total greenhouse gas emissions caused by final demand. It also includes exports as part of final demand, which are then subtracted in the consumption perspective.

Allocation of emissions to domestic final demand and exports

If we take indirect emissions outside Switzerland into account, the total greenhouse gas emissions increase from 58 to 147 Mt CO_2-eq. A significant share of these emissions (56 Mt CO_2-equiv.) can be attributed to the manufacturing of exports, i. e. for goods that are destined for foreign countries. Thus the remaining 91 Mt CO_2-eq are induced by domestic final demand in Switzerland.

Fig. 20 > Total greenhouse gas emissions caused by final demand

Total GHG emissions in Switzerland are allocated to final demand, showing the contribution of private and public final demand and exports. Emissions are subdivided into direct emissions by households, indirect emissions from the production of domestic goods and indirect emissions from the production of imported goods abroad.



Source: calculation ESU-services Ltd. and Rütter+Partner

The main results are the following:

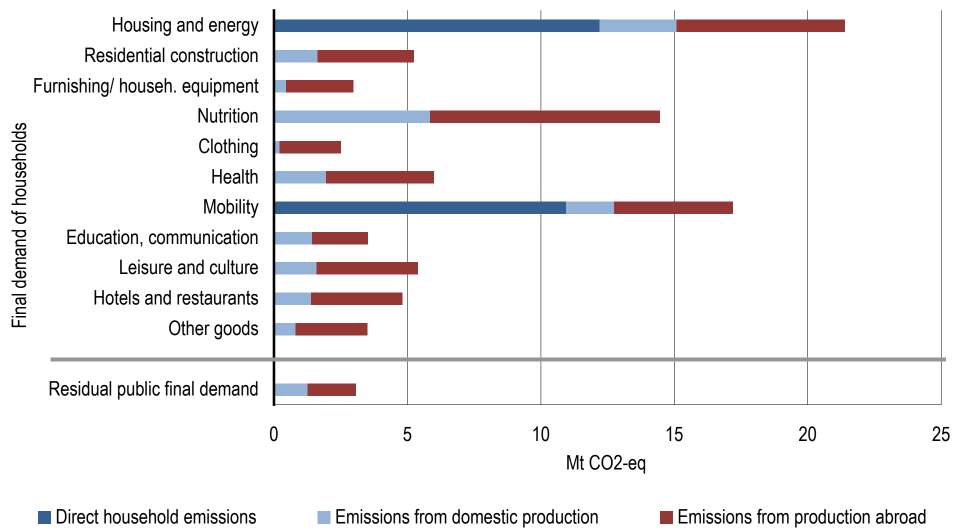
- Private and public final demand is the most important category of final demand with regard to global warming potential. It induces 90 Mt CO_2-eq, equalling 62% of total emissions. 26% of these emissions are directly emitted by households. 74% are related to the manufacturing of goods. Here the share of imported goods is more than twice the share of domestic goods.
- The production of exports also has a large relevance (38% of total emissions) and especially a large share of "imported" emissions. This result shows that energy-intensive goods (e.g. metals or chemical products) are imported and processed in Switzerland. The resulting products are then exported.
- Inventory change and net addition of valuables form a further component of final demand that is not shown in this and the following figures, since its relevance is negligible.

Private and public final demand categories

The following figure shows the greenhouse gas emissions caused by private and public final demand in more detail. It displays the contribution of the consumption categories of private households and of residual public final demand and the breakdown of emissions into direct emissions, indirect emissions from domestic production and indirect emissions from production of imported goods.

Fig. 21 > Consumption perspective:
Swiss greenhouse gas emissions caused by private and public final demand

GHG emissions induced by private and public final demand are displayed in more detail, highlighting the relevance of the various consumption categories. Again emissions are subdivided into direct emissions, emissions from the production of domestic products and of imported products.



Source: calculation ESU-services Ltd. and Rütter+Partner

> Housing (incl. residential construction) and mobility are the main sources of direct greenhouse gas emissions but also contribute most to total emissions. Nutrition is the third single important category. Together these three categories are responsible for 67% of total emissions induced by private consumption.
> Most of the consumption categories induce significant emissions outside Switzerland. Apart from direct emissions, these "imported emissions" dominate domestic emissions for most categories.
> The category 'housing and energy' includes general housing expenditures, including e.g. rents, energy, water and waste management services, maintenance and housing services. Direct emissions are related to fuels mainly used for heating and warm water. Other domestic emissions mainly stem from waste management and other services. A large share of emissions induced abroad takes place in the life cycles of imported energy carriers. Housing and energy induces a quarter of total emissions related to private consumption.
> Two other consumption categories belong to the housing domain. The category 'residential construction' includes all emissions related to the construction of residential buildings in 2005. Emissions for construction are much lower than for housing and energy. Here construction and manufacturing of investment goods (e.g. heating equipment) are responsible for the emissions. Furnishing and household equipment is less relevant, but has a large share of imported emissions.
> The second most important category 'mobility' is responsible for 20% of household-induced emissions. It includes expenditures for fuels, vehicles, repair and maintenance and transport services. Direct emissions are related to fuel use by households. The transport services sector mainly is responsible for domestic emissions, whereas emissions in foreign countries are mainly induced in the fuel life cycles and by production of vehicles.
> Emissions for nutrition with a share of 17% are related to agricultural products and products from the food industry in and outside of Switzerland. Nutrition related emissions are also included in the category "hotels and restaurants".
> The remaining emissions caused by private consumption are shared among the other consumption categories, with health and leisure being more important than others.

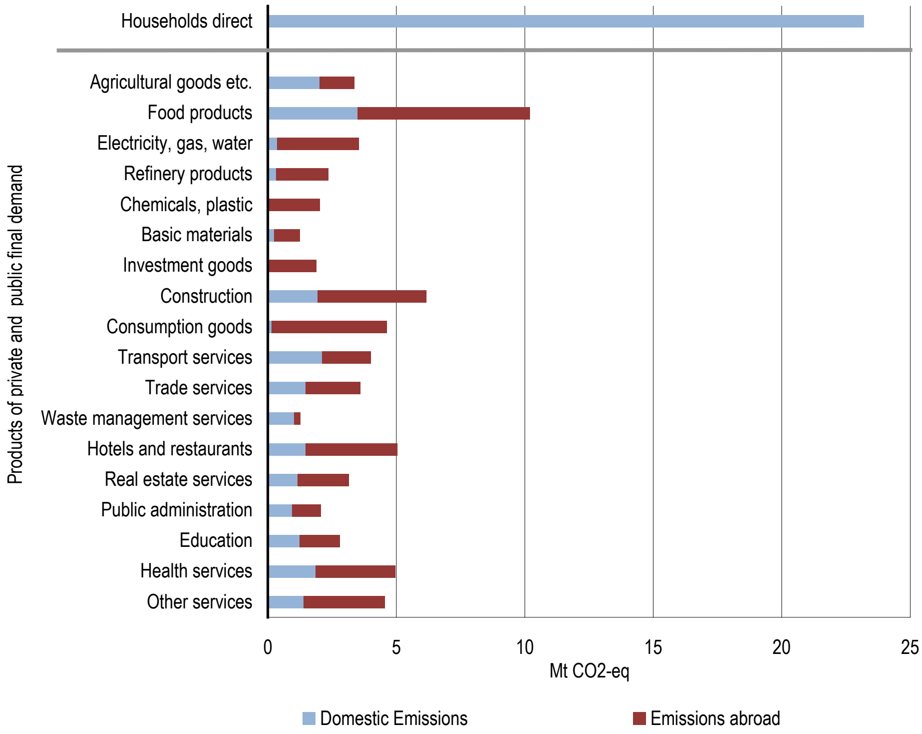
Emissions induced by domestic final demand can also be analysed from a different perspective. We can allocate total emissions to the products used by final demand instead of the final demand categories. Fig. 22 shows the relevance of various product groups, also in relation to direct household emissions. As far as commodities are concerned, agricultural and food products are important product groups with regard to global warming, followed by construction and consumption goods. Generally a large share of emissions is caused in foreign countries. This points to the fact that most energy-intensive materials needed for the production of these goods are manufactured abroad. Surprisingly services account for a large share of emissions, which mainly is due to the significant share of these services in household expenditures. Emissions stem from several different product groups, with hotel and restaurant services, health services, transport and trade services being among the more relevant.

Emissions induced by goods of private and public final demand

Emissions caused by demand for services are specifically increased by the allocation of capital investment. While the share of emissions related to the production of investment goods in total emissions is 10% for final demand on average, the respective share reaches 15% for transport services and even 22% for 'other services'.

Fig. 22 > Consumption perspective: Greenhouse gas emissions caused by consumption of goods

This figure displays the product groups of private and public final demand and their associated GHG emissions. The values show the total emissions caused in the supply chains of these products up to their supply to final demand. Domestic emissions and emissions caused outside Switzerland are distinguished. For comparison household direct emissions are also displayed. The displayed product groups are similar to the sectoral aggregates described in Tab. 25.



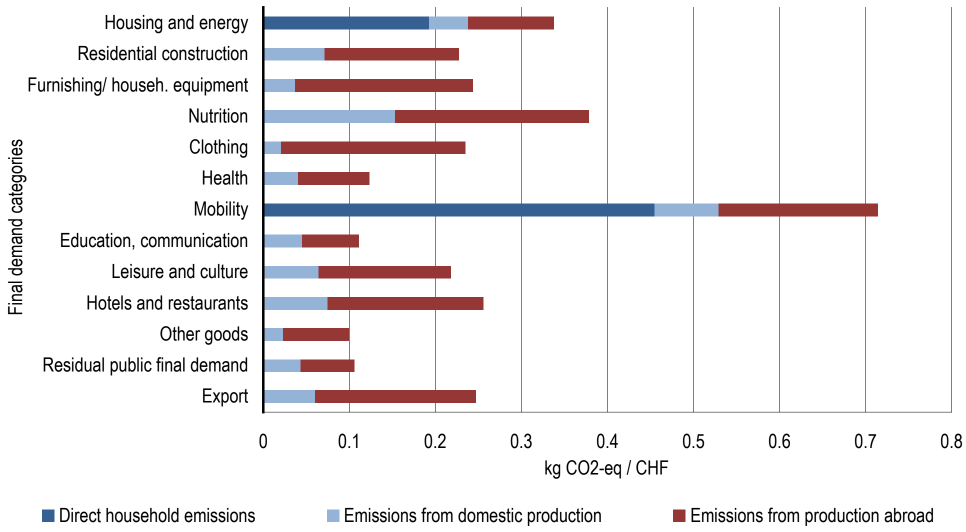
Source: calculation ESU-services Ltd. and Rütter+Partner

Emission intensities of final demand categories

Beside absolute GHG emission levels, which are also influenced by absolute consumption levels, it is interesting to look at specific emissions per expenditure unit of final demand (Fig. 23). Mobility is by far the most emission-intensive category. Housing and energy and nutrition are the next most emission-intensive categories, though not as much above the intensity average of final demand as mobility. With regard to housing this can be explained with the large share of expenditures for imputed and actual rents that have low emission intensity. Other consumption categories with high emission intensities are furnishing and household equipment, residential construction and clothing. Exported goods also tend to be rather emission-intensive. Interestingly no consumption category is far below the average intensity.

Fig. 23 > Emission intensities of different final demand categories

This figure displays emission intensities of the final demand categories. Total greenhouse gas emissions per expenditure unit of final demand is shown and the contribution of direct household emissions, domestic emissions for producing goods and emissions caused by the production of imported goods.



Source: calculation ESU-services Ltd. and Rütter+Partner

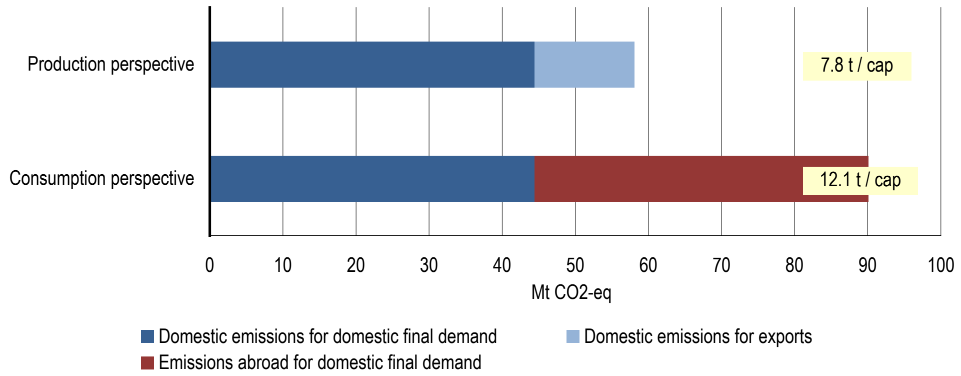
Looking at Swiss greenhouse gas emissions from a bird's-eye view, we can state the following. In the production perspective about 58 Mt CO_2-eq were emitted by the Swiss economy in 2005, equalling 7.8 t per capita. 14 Mt or approx. 25% can be allocated to the production of exported goods, while three quarters were induced by domestic final demand.

In the consumption perspective, excluding domestic emissions due to exported goods and including foreign emissions related to imported goods, total emissions amount to 90 Mt CO_2-equiv., which is equal to 12.1 t per capita. Approximately half of these emissions (or 46 Mt) are due to imported goods and are thus caused outside Switzerland.

Comparison of emissions from consumption and production perspective

Fig. 24 > Total Swiss greenhouse gas emissions from a production and a consumption perspective

This figure compares the Swiss greenhouse gas emissions from the production and the consumption perspective. The emissions from the production perspective include domestic emissions for producing exported goods. These are not included in the consumption perspective. Instead emissions abroad for the production of imported goods are considered. The balance refers to emissions that are related to net imports.



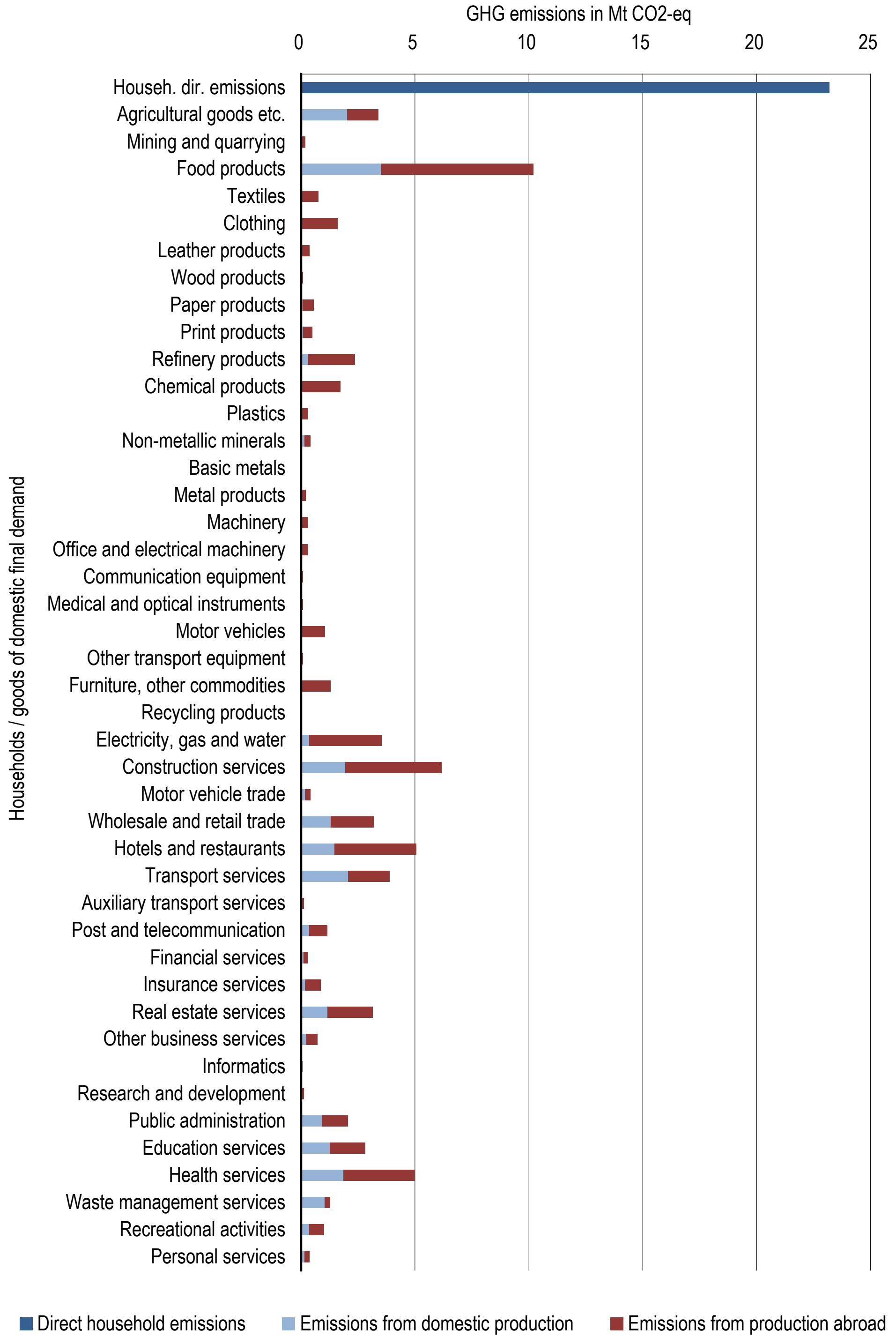
Source: calculation ESU-services Ltd. and Rütter+Partner

5.1.4.2 Selected results in detail

In this section selected results from the consumption and production perspective are shown in more sectoral detail.

Fig. 25 > Consumption perspective: Cumulative emissions due to domestic final demand – detailed results by product group of domestic final demand

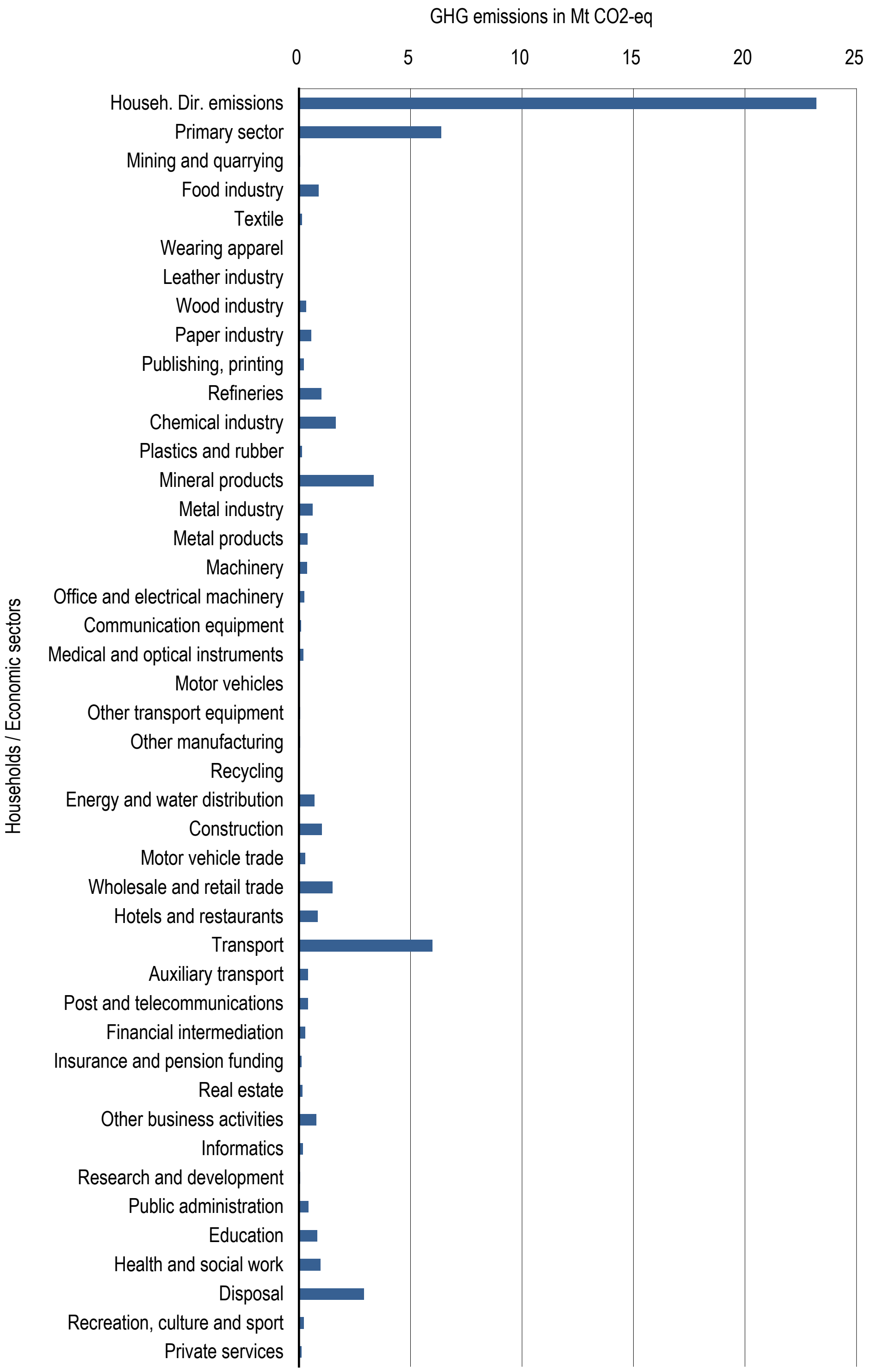
This figure displays the total greenhouse gas emissions induced by the goods delivered to domestic final demand, distinguishing between domestic emissions and emissions abroad. Household direct emissions are displayed for purpose of comparison.



Source: calculation ESU-services Ltd. and Rütter+Partner

Fig. 26 > Production perspective: Direct emissions by economic actor – detailed results

This figure displays the direct greenhouse gas emissions of households and economic sectors



Source: calculation ESU-services Ltd. and Rütter+Partner

5.1.4.3 Calculation based on territorial emissions, trade balance for goods and LCA data

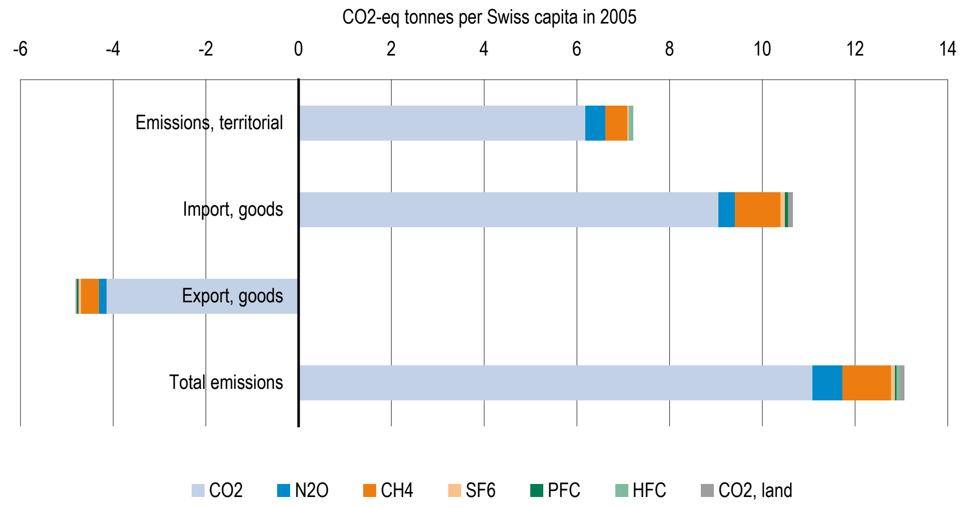
LCA&trade: territorial emissions and trade of goods

In this chapter we calculate total results according to the methodology developed in a former project (Jungbluth et al. 2007). For Swiss emissions only the emissions according to the national greenhouse gas inventory are taken into account (BAFU 2010b). Thus we use the territorial principle in contrast to the residence principle used in the previous chapter. Imports and exports of services are not included in the calculation. Exports of goods are calculated from foreign trade data instead of calculating them with the input output table. This approach is termed here in short "LCA&trade".

Fig. 27 shows the results of this calculation. Data have been slightly changed accounting for updated information concerning the direct emissions as well as revised LCA data for imports and exports of goods.

Fig. 27 > Greenhouse gas emissions per Swiss capita. LCA&trade approach

This figure investigates the greenhouse gas emissions per capita according to the calculation with the trade balance and territorial (instead of residence) emissions. According to this calculation per capita emissions amount to 13 t CO_2 -eq.

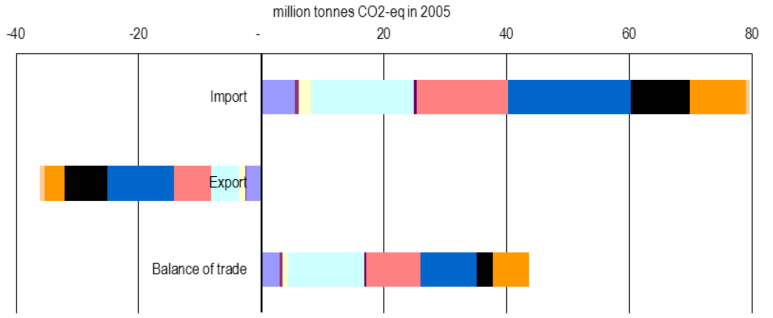


Source : Calculation ESU-services Ltd.

Fig. 28 evaluates the importance of different types of goods in the balance of imported and exported emissions.

Fig. 28 > Greenhouse gas emissions of different industry sectors in the trade balance

The figure evaluates the contributions of different industry sectors to the total trade balance of greenhouse gas emissions. The total imports amount to 79 million tonnes of CO_2-eq. Exports according to the trade balance are as high as 35 million tonnes CO_2-eq. Energy, chemicals and the manufacturing of goods are the most important sectors for the total balance.



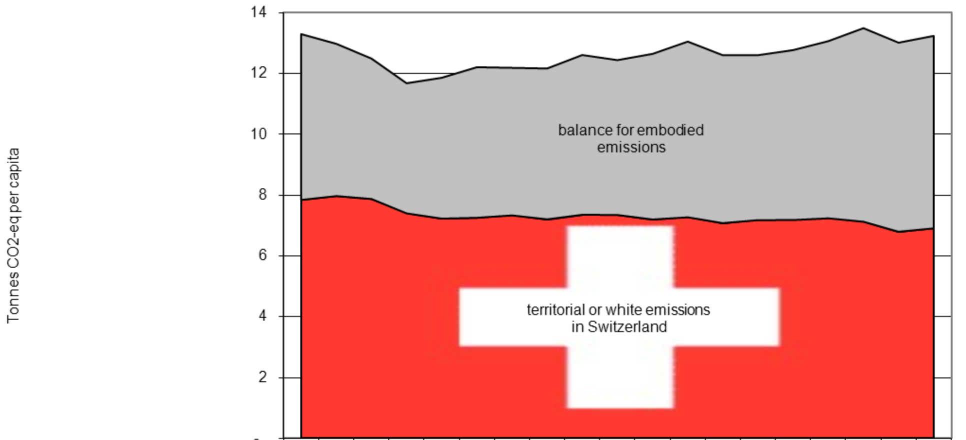
	Balance of trade	Export	Import
Food and animals	3.0	-2.4	5.5
Beverages and tobacco	0.4	-0.2	0.5
Other raw materials	1.0	-1.0	2.1
Energy carriers and electricity	12.3	-4.5	16.8
Fat and oils from biomass	0.4	-0.1	0.5
Chemicals	8.8	-6.1	14.9
Manufactured goods	9.2	-10.8	20.0
Machinery and vehicles	2.5	-7.1	9.6
Other finished goods	5.9	-3.1	9.1
Goods	-0.2	-0.8	0.6
Total	43.5	-36.1	79.5

Source : Calculation ESU-services Ltd.

Fig. 29 shows a calculation for the development of total greenhouse gas emissions per capita during recent years. It has to be noted that for imports and exports LCA data have not been adapted according to the development of production processes, but reflect the presently best available data. Thus, the figure mainly represents the change of territorial emissions, the increase of population and the change in the amount and type of traded goods. It has to be noted that total emissions due to trade rose since 1993 and are levelled out partly by the increase in the Swiss population.

Fig. 29 > Development of territorial and embodied greenhouse gas emissions of Switzerland (tonnes CO_2-eq per capita and year).

The direct per capita emissions decreased during the last decade due to constant absolute emissions and a rise of the number of people living in Switzerland. Including the embodied emissions a slight increasing trend of the per capita emissions is visible since 1993. Only embodied emissions of goods and electricity trade are included. One reason for the increase of embodied emissions in 2005 is the reduced export of electricity. Data for direct emissions used for this time series are not consistent with the data used in this study because they only account for territorial emissions from a geographical but not from the economic perspective.



	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
total of territorial and embodied emissions	13.3	13.0	12.5	11.7	11.9	12.2	12.2	12.2	12.6	12.4	12.6	13.1	12.6	12.6	12.8	13.1	13.5	13.0	13.2
balance for goods and electricity	5.5	5.0	4.6	4.3	4.6	5.0	4.9	5.0	5.3	5.1	5.4	5.8	5.5	5.4	5.6	5.8	6.4	6.2	6.3
territorial emissions of Switzerland	7.8	8.0	7.9	7.4	7.2	7.3	7.3	7.2	7.4	7.3	7.2	7.3	7.1	7.2	7.2	7.2	7.1	6.8	6.9

Updated calculation ESU-services Ltd. following Jungbluth et al. 2007 and territorial emissions excluding LULUCF (BAFU 2010b).

5.1.4.4 Comparison of results and explanation of differences

Finally we compare this balance of Swiss emissions calculated with an environmentally extended IO analysis with a calculation using LCA data for imported and exported goods. Total domestic emissions are not identical because the LCA calculation covers emissions within national boundaries (territorial) while the EE-IOA analysis covers emissions according to the residence principle of national accounts. Import-related emissions are more or less identical, since also in the IOA approach they are calculated using LCA data. The main difference between the two approaches can be found for exported goods. While the IO approach estimates the export-related emissions to reach 7.1 t CO_2-eq. per capita, the LCA approach calculates only 4.5 t CO_2-eq.

Tab. 9 > Comparison of the total results of the EE-IOA and the LCA&trade approach for the year 2005

The comparison of the two approaches reveals some differences. Domestic emissions are about 6% higher according to the residence principle. Also the import of goods is increased and the import of services considered additionally. But, on the other hand exports according to the EE-IOA calculation are considerably higher, which leads to lower per capita emissions due to Swiss consumption.

	EE-IOA [t CO_2-eq. / cap]	LCA&trade [t CO_2-eq. / cap]	Difference [t CO_2-eq. / cap]
Residence / territorial emissions	7.8	7.2	-0.6
Imports, goods	11.2	10.6	-0.6
Imports, services	0.7	n.d.	-0.7
Exports, total	7.5	4.7	2.8
Consumption-related emissions	12.1	13.1	1.0

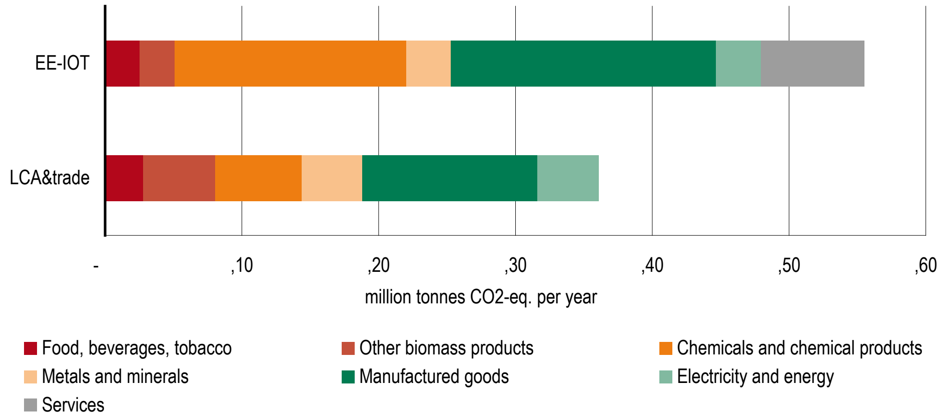
Source: calculation ESU-services Ltd. and Rütter+Partner

The significant difference regarding exports can be analysed in more detail by looking at the results of specific product groups. This comparison is only partly possible since the product classification used in the trade statistics is not completely compatible with the classification for production sectors used in the IOT (see sub-chapter 3.4). But for some important product groups a comparison is feasible.

This comparison shows that large differences occur for services, chemical and manufactured products, whereas food, beverages and tobacco are fairly similar (Fig. 30). Also the result for exports of electricity and energy is quite different, but these are not as important in the total view. The GHG emissions allocated to chemical products are much higher in the IO approach, while they are lower for energy carriers.

Fig. 30 > Comparison of export-related GHG emissions calculated with two approaches

The comparison of the calculation with two approaches shows considerable differences for the resulting exported emissions. Most important differences are found for the export of services, chemicals and manufactured goods.



Source: calculation ESU-services Ltd. and Rütter+Partner

In principle the differences are due to differences in the system boundary, the aggregation level, the methodological approach, and data sources. The contribution of each of these factors is difficult to evaluate (Tab. 10). In the IO analysis domestic production is allocated to the categories of final demand and thus partly to exports. The results of this allocation may differ from the allocation on the basis of LCA data. The rather high aggregation level of the Swiss IO table probably leads to aggregation errors in the calculation procedure, which would be lower with a more disaggregated IO table. On the other hand the LCA data basis may not be detailed enough to cover the enormous variety of products imported and exported in an adequate way. To pinpoint the specific reasons for differences, a more detailed analysis of the results would be necessary.

Tab. 10 > Comparison of the detailed results of the EE-IOA and the LCA&trade approach for the year 2005

The different results for different types of goods exported from Switzerland have been analysed in more detail. Main differences are found for the export of chemicals and neglecting of service exports in the LCA&trade approach.

	Difference EE-IOA vs. LCA&trade [million t CO_2-eq]	Possible explanations
Food, beverages, tobacco	0.4	Difference is small and might also be due to different classifications of goods.
Other biomass products	-2.7	Some textiles seem to be more important according to trade statistics.
Chemicals and chemical products	10.7	High price products exported are not covered well in LCA because no sufficiently detailed data
Metals and minerals	-1.1	
Manufactured goods	6.6	Production processes might be underestimated with LCA data
Electricity and energy	-1.1	Exports seem to be better covered in LCA. The IOT cannot differentiate enough between different types of energy and especially electricity trades. Re-exports underestimated. Disaggregation in IOT would be necessary.
Services	7.4	Services are not included in the calculation with LCA data and trade balance
Total	20.1	Main differences for chemicals and services

Source: calculation ESU-services Ltd. and Rütter+Partner

5.2 Environmental impact assessment

5.2.1 Overview on total environmental impacts of Swiss consumption and production

Cumulative environmental emissions and resource uses are calculated in this study, by using two approaches. Here we provide a first overview of the results.

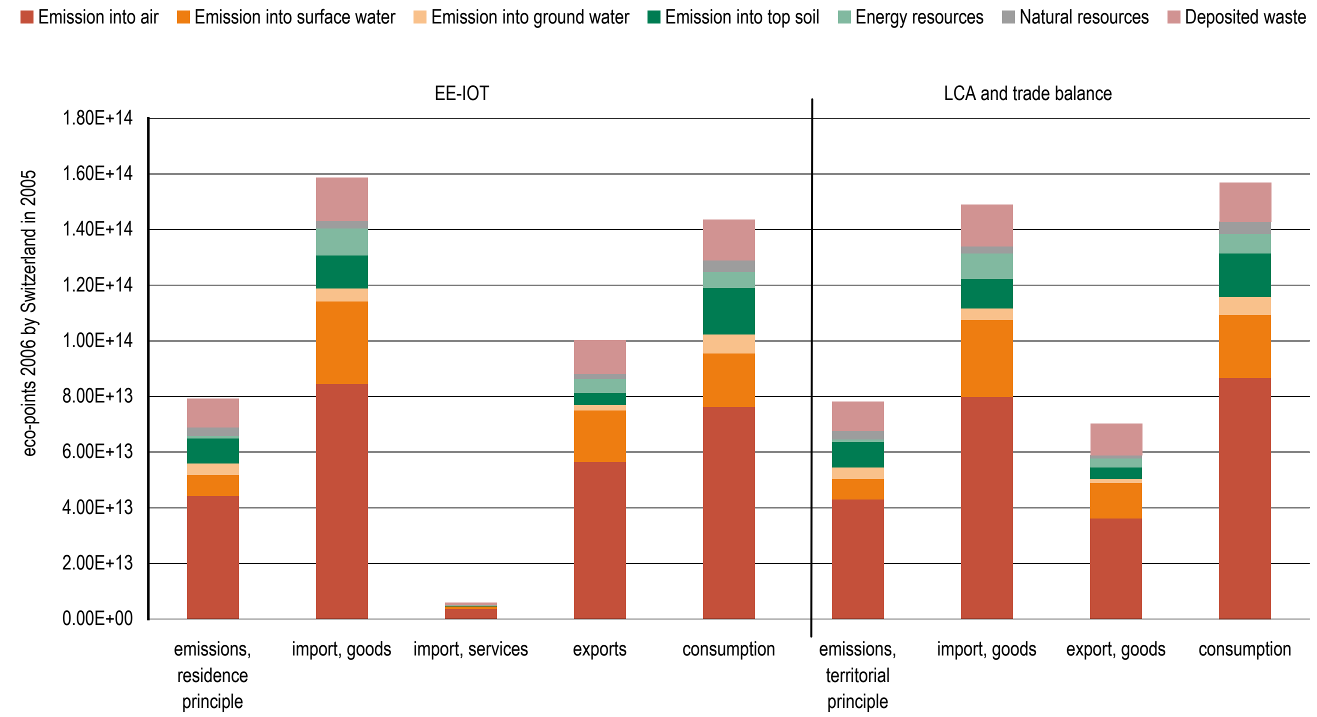
The first approach is the environmentally extended IO analysis developed in this research project. The Swiss domestic emissions and emissions related to the production of imported goods and services abroad are allocated to the categories of final demand (private and public consumption as well as exports). EE-IOA

The second approach follows the methodology developed in a former project on the accounting of embodied greenhouse gas emissions (Jungbluth et al. 2007). Starting point are the emissions within the territory of Switzerland. Emissions due to imports of goods are added to the foreign trade balance and emissions due to Swiss exports are subtracted. Emissions are calculated in both directions with data from trade statistics and LCA data. The emissions due to Swiss consumption are calculated as the balance. LCA&trade

The results of both approaches show some differences. As discussed for greenhouse gases already, the second approach results in significantly lower exported emissions and thus higher values for the emissions that have to be attributed to Swiss consumption.

Fig. 31 > Total environmental impacts caused by consumption and production of Switzerland, investigated by two different approaches and the ecological scarcity method 2006

This figure shows the calculation of the environmental impacts of the final demand in Switzerland according to two different approaches. One is mainly based on the residence principle and uses the EE-IOA for calculating exports. The other is based on the territorial principle and uses trade statistics and LCA data in order to calculate the environmental impact of exports. For this calculation emissions cannot be subdivided into direct emissions by households, emissions from the production of domestic goods and from the production of imported goods. In each case direct emissions plus imports equal the exports plus consumption.



Economic data	none	Foreign trade: Eidg. Oberzoll-direktion 2005; Nathani et al. 2008	IOT: Nathani et al. 2008			none	Eidg. Oberzolldirektion 2005		Calculated
Environmental data	Statistics: BFS 2011; Frischknecht et al. 2009	LCA: ecoinvent Centre 2010; Jungbluth et al. 2011a		Calculated		Statistics: Frischknecht et al. 2009	LCA: ecoinvent Centre 2010; Jungbluth et al. 2011a		Calculated

Source: calculation ESU-services Ltd. and Rütter+Partner with the above mentioned principal main data sources

5.2.2 Production perspective

The production perspective on direct impacts is a national perspective, as it only considers impacts occurring within the country. This perspective can inform national environmental policy as it shows the situation and impact in the country. It does not identify indirect environmental impacts. Therefore the identification of the drivers of the environmental impact should not be carried with this perspective on direct environmental impacts only.

First we show the allocation of environmental impacts to economic sectors and household activities. Then we evaluate the importance of single emissions and resource uses for the final results. In a third step differences in results according to different accounting principles are discussed.

5.2.2.1 Results for economic sectors and household activities

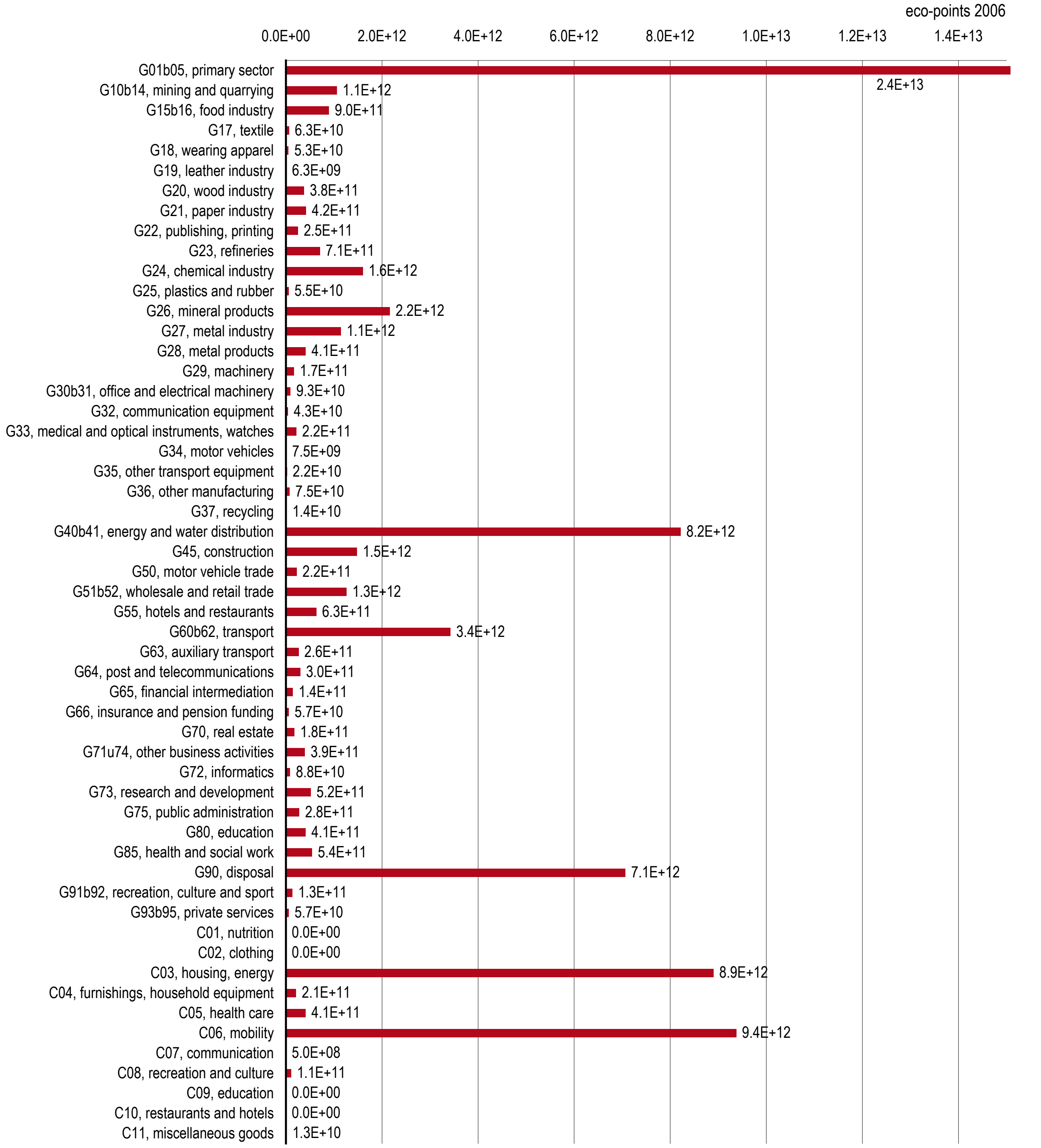
The allocation of domestic emissions and resource uses to different economic sectors and consumption categories is used in order to calculate the domestic environmental impact with the ecological scarcity method. In total an environmental impact of about 80 trillion eco-points are caused by the direct emissions in Switzerland.

There are some considerable differences if the distribution of total impacts in Fig. 32 is compared with the GHG emissions shown in Fig. 18. Thus, e.g. the importance of the primary sector is considerably higher. Also the energy, gas and water sector is more important if one considers all types of environmental impacts caused in this sector. Within the primary sector several import environmental impacts such as air emissions (NH_3, N_2O or methane), water emissions (nitrate, phosphate), emissions of heavy metals and pesticides to soil as well as resource uses of water and land are taken into account. Direct impacts of households are mainly caused by the combustion of fuels for cars and heating.

Primary sector most important

Fig. 32 > Production perspective: ecological scarcity (eco-points 2006) from direct Swiss residence emissions and resource uses in 2005 by economic agent

Residence emissions and resource uses are assessed with the ecological scarcity method 2006. They are displayed by emitting economic agent (households and industries). Households (C01-C11) contribute about 24% to the total direct emissions. The most important agent is the primary sector (G01b05) contributing about 31% of potential environmental impacts due to the domestic emissions.



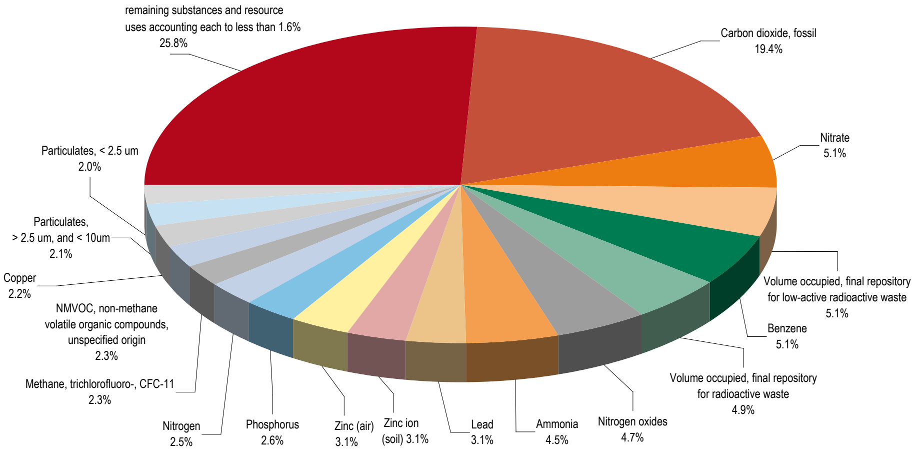
Source: calculation: ESUservices

5.2.2.2 Importance of single emissions and resource uses

Here the importance of different types of residence emissions and resource uses is evaluated. The LCIA method of ecological scarcity is applied.

Fig. 33 > Share of individual emissions and resources on the environmental impact caused by residence emissions in Switzerland, ecological scarcity method 2006

Carbon dioxide is the most important emission. This is followed by other air (e.g. benzene) and water (e.g. nitrate) emissions. In general the result is not influenced by a single emission alone and a lot of emissions contribute partly to the result. Remaining substances include for example also energy and water resources where each one has a share below 1.9%.



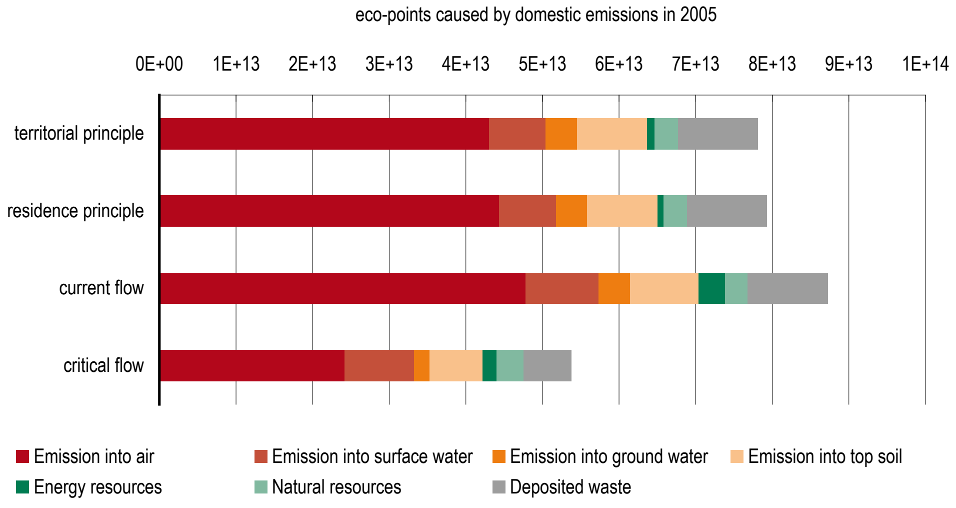
Calculation ESU-services Ltd.

5.2.2.3 Total environmental impact due to domestic emissions and resource uses

Fig. 34 shows the environmental impacts caused by direct emissions in Switzerland, investigated by different principles. Only the greenhouse gas emissions in Switzerland were investigated according to the territorial and the residence principle. Thus, differences between the results for these two columns are rather small.

Fig. 34 > Total environmental impacts caused by direct emissions in Switzerland, investigated by different principles, ecological scarcity method 2006

Here we compare the total emissions recorded with different principles. The residence principle takes an economic perspective and records emissions of Swiss companies and households. The territorial principle takes the Swiss borders as system boundary. For the current flow of the ecological scarcity method also the use of energy resources in Switzerland, that are extracted elsewhere (e.g. crude oil), is taken into account (but not all other emissions and resource uses linked to trade). Finally it is possible to calculate the critical flow of emissions and resource uses according to the political targets that are investigated in the ecological scarcity method. This defines the reduction of burdens as shown under ecological scarcity to a level aimed at by the Swiss policy-makers (Frischknecht et al. 2009).



Calculation ESU-services Ltd.

5.2.3 Consumption perspective

The consumption perspective is a more comprehensive perspective. It considers all environmental impacts in one country as well as environmental impacts caused abroad due to final consumption. In this chapter the calculation of the total environmental impacts of final demand in Switzerland is shown and analysed.

First, different LCIA methods are used to analyse the importance of emissions and resource uses. Then the share of production sectors for total results is discussed. Different categories of household consumption are analysed in another sub-chapter. Furthermore the share of domestic and embodied emissions is investigated.

5.2.3.1 Analysis of emissions and resource uses with different LCIA methods

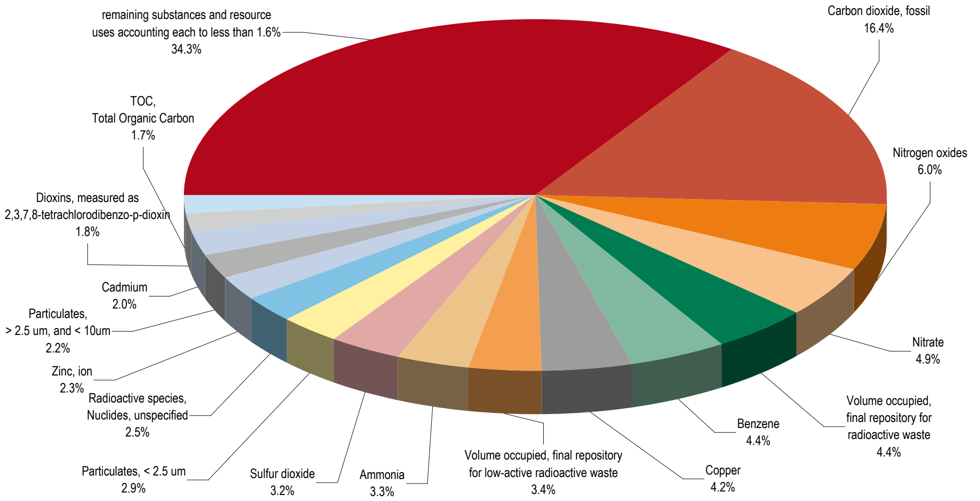
In this chapter the environmental impacts of Swiss consumption are analysed in more detail. The calculation follows the EE-IOA approach developed in this project. We evaluate in this chapter the contribution of different types of emissions and resource uses for the final impact assessment results. Different LCIA methods are applied.

Ecological scarcity

Fig. 35 is based on an evaluation with the LCIA method ecological scarcity. It shows the most important emissions and resource uses contributing to the total impact of Swiss consumption. Within this evaluation copper emissions to soil are more important than in the assessment of domestic emissions. This is due to the import of products such as coffee and cocoa.

Fig. 35 > Share of individual emissions and resource uses on the total environmental impact caused by private consumption in Switzerland, ecological scarcity method 2006

The total environmental impact is the sum of many different emissions and resource uses. The most important emission – carbon dioxide – has a share of only 16% of total burden. Carbon dioxide is followed by other emissions to air and water. In general the result is not influenced by a single emission alone and a lot of emissions contribute partly to the result.



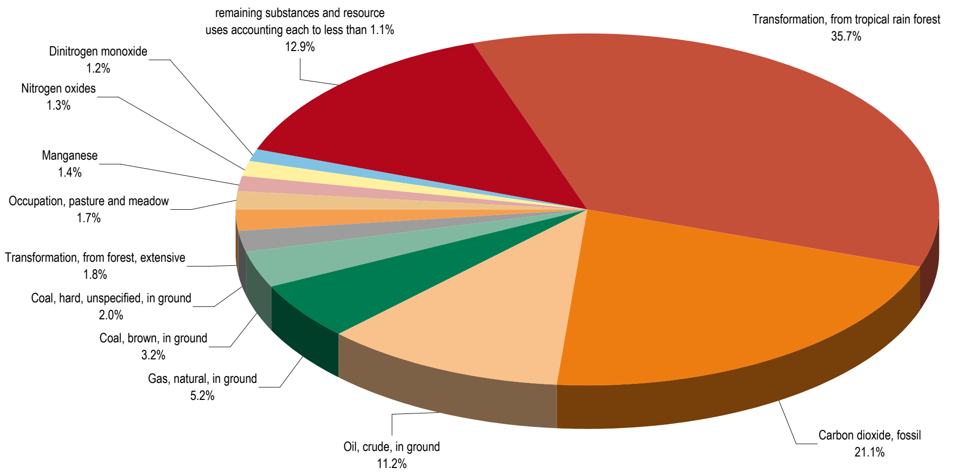
Calculation ESU-services Ltd.

Fig. 36 shows an evaluation of the most important emissions and resource uses for the total impacts of Swiss consumption when using the LCIA method ReCiPe, (normalisation based on emissions in Europe, Hierarchist weighting).

ReCiPe, Europe

Fig. 36 > Share of individual emissions and resources on the total environmental impact caused by private consumption in Switzerland, ReCiPe, Europe, endpoint (H,A)

The most important aspect according to this method is the clear-cutting of rain forest for plantation of e.g. palm fruits, coffee or soy beans. With the inventory flow concerning transformation of forests, the loss of biodiversity is assessed in this LCIA method. The loss of biodiversity due to land transformation is not shown within the evaluation with ecological scarcity 2006. Carbon dioxide and energy resources also contribute high shares to total environmental impacts when using this LCIA method.



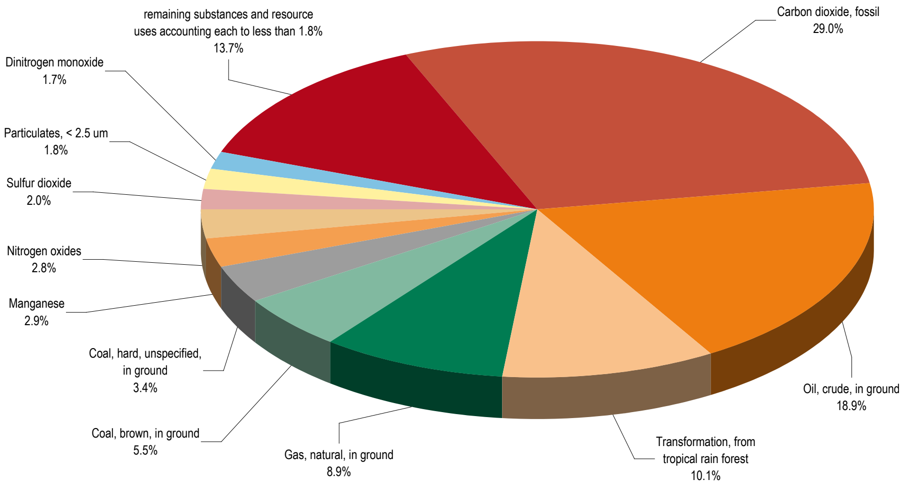
Calculation ESU-services Ltd.

ReCiPe, World

Fig. 37 shows an evaluation of the most important pollutants when assessing the total impacts of Swiss consumption with the LCIA method ReCiPe, Hierarchist weighting. Now we use the normalisation based on worldwide emissions and resource uses. The evaluation shows that this is more appropriate in the case of an LCA that includes also production processes from all over the world. This better reflects the importance of deforestation that does not take place in Europe but is considered for imported products.

Fig. 37 > Share of individual emissions and resources on the total environmental impact caused by private consumption in Switzerland, ReCiPe, World, endpoint (H,A)

Land transformation gets a considerably lower share if the world wide emissions are considered in the normalisation step. Carbon dioxide and fossil energy resources are the most important issue. Two thirds of the total environmental impact is due to energy use and fossil carbon dioxide.



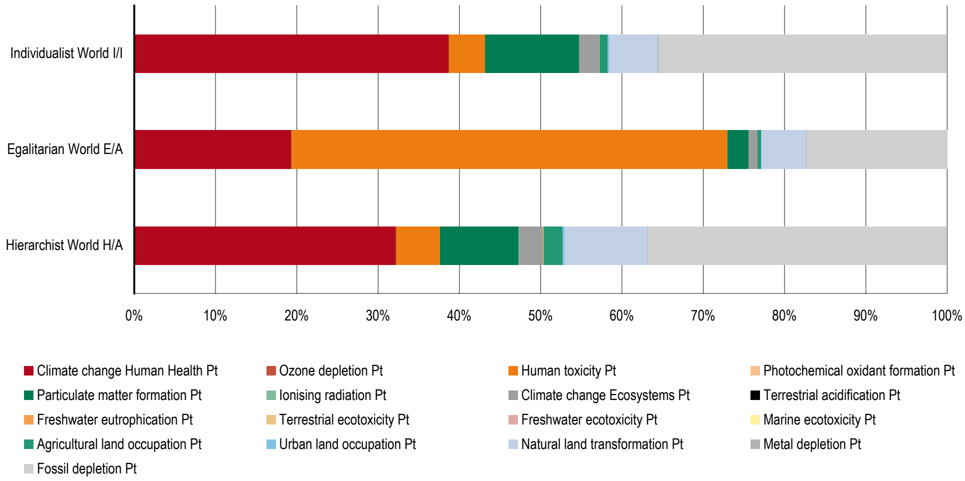
Calculation ESU-services Ltd.

The LCIA method ReCiPe offers the evaluation of environmental impacts with three individual perspectives on methodological choices (Hofstetter 1998).

Three perspectives in ReCiPe

Fig. 38 > Share of damage categories on the total environmental impact caused by private consumption in Switzerland, ReCiPe, World, endpoint with three different perspectives used in the weighting

The three perspectives on methodological choices in the ReCiPe methodology show mainly differences in the assessment of human toxicity and particulate matter formation. In the Egalitarian worldview human toxicity is considered more serious while the two others put a higher importance on aspects of particulate matter formation. In all three perspectives results are dominated by the use of fossil fuels and resulting impacts due to climate change (> 60%). The legend for the colours can be read from left to right.



Calculation ESU-services Ltd.

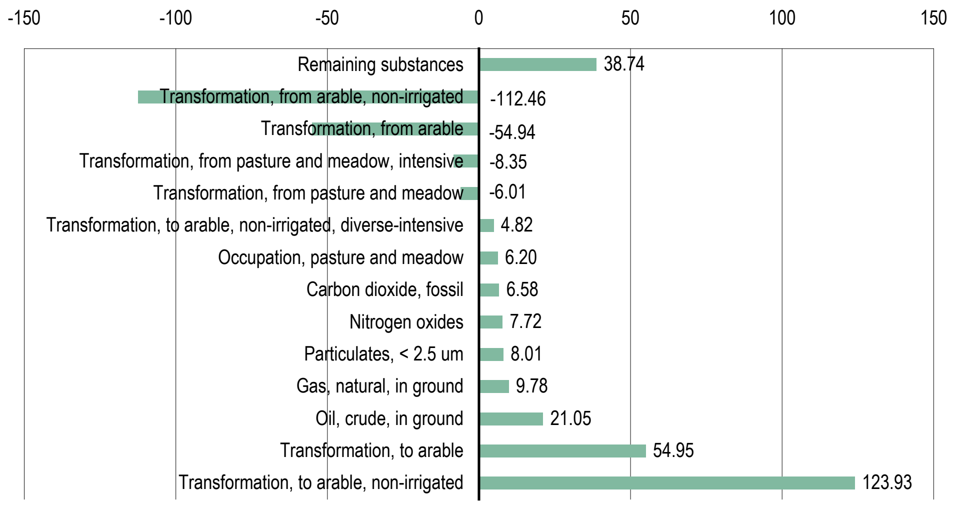
Fig. 39 shows an evaluation of the most important pollutants while assessing the total impacts of Swiss consumption with the LCIA method Eco-indicator 99 (H,A). The method considers land transformation issues as quite important. However, it has to be considered partly as an artefact as transformation from and to all types of land uses is inventoried in the same dataset according to the ecoinvent methodology. Thus, each dataset contains information for transformation "from" and "to" separately, but quite often both types are similar and thus add up to zero in the total balance. Recipe, in contrast, only considers transformation of forestland.

Eco-indicator 99 (H,A)

Most important in an assessment with the Eco-indicator 99 (H,A) are thus energy resources and land occupation. Carbon dioxide emissions are less important than in other LCIA methods evaluated before. This may reflect the fact that the issue of global warming got more attention in the recent past and thus weighting in e.g. ReCiPe or ecological scarcity has been adapted.

Fig. 39 > Share of individual emissions and resources in percent of the total environmental impact caused by private consumption in Switzerland, Eco-indicator 99, endpoint (H,A)

Importance of single elementary flows for the total assessment with Eco-indicator 99 (H,A). It has to be noted that transformation is recorded twice and often the negative results for transformation from a land occupation type balance with the positive for transformation, to a land occupation type.



Calculation ESU-services Ltd.

Differences between LCIA methods

For understanding the differences between LCIA methods, an assessment with each LCIA method of the overall annual environmental impacts of Switzerland is helpful. All methods show global warming, energy depletion and land occupation as important issues. In some methods these categories fully dominate the results while the ecological scarcity method shows a more balanced picture of several emissions and resource uses. These differences do not allow conclusions about one method being superior to another. Therefore, the point of view of the decision maker has to be taken into account. It would be possible to attribute individual and customized weights to the damage categories of ReCiPe for instance.

Monitoring single emissions is not sufficient

The analysis shows that it is not sufficient to only consider single indicators such as carbon footprint, ecological footprint or water footprint as these do not reflect the full diversity of different types of environmental problems.

The ecological scarcity method reflects best the positions of the FOEN and Swiss policy because it has been developed by this organization.

5.2.3.2 Analysis of goods delivered to final demand

Food products with high share of environmental impacts

The environmental impacts from the consumption perspective can also be analysed with regard to the goods delivered to final demand instead of consumption categories. Fig. 40 displays these environmental impacts per capita and per unit of product value[14]. In absolute terms agricultural goods, food products and hotel and restaurant services account for a significant part of environment impacts which can be attributed to food. Other important goods are energy carriers and construction services. Services also have a large share of total environmental impacts. They are distributed among a large variety of services, with health services being among the more important ones.

Waste management, energy and food with high specific impacts

Looking at the specific environmental impacts per unit of product value delivers a different picture. Here waste management services have the highest environmental intensity, followed by agricultural products, energy carriers and food products. Not surprisingly material goods have a much higher intensity than services (except for waste management and transport). Yet due to the large economic relevance of services in domestic final demand these are significant in absolute terms. Yet an important part of indirect environmental impacts in the supply chains of services are probably related to production of material goods. These are not directly visible in an analysis that focuses on products of final demand.

High significance of environmental impacts caused abroad

For most of the products delivered to final demand the environmental impacts caused in other countries are significantly larger than the impacts caused in Switzerland. Apart from food products the share of emissions abroad is larger for material goods than for services. Waste management and agricultural goods are important product groups with a high share of domestic impacts.

[14] For methodological reasons product value is measured in producer prices. These are lower than purchaser prices paid by consumers, since trade and transport margins and net commodity taxes (e.g. VAT, mineral oil tax) are excluded.

Fig. 40 > Total environmental impact and environmental intensities of domestic final demand by product group 2005

These two figures show the total environmental impact of domestic final demand with regard to the products delivered to final demand. Domestic impacts and impacts in other countries are distinguished. Direct household emissions are displayed for reasons of comparison. The left figure shows the environmental impact per capita. The right figure displays the environmental intensity per unit of product value (in producer prices, i.e. without trade and transport margins and net commodity taxes).

Source: calculation ESU-services Ltd. and Rütter+Partner

5.2.3.3 Analysing household consumption with different impact assessment methods

Final consumption of households has been divided into several sub-categories. The contribution of these categories is analysed in the following figure.

Nutrition most important

Nutrition is the most important household consumption category if the LCIA method considers a range of environmental impacts. The share of nutrition for total results is in the range of 25% to 35%. However, it is only a little bit more than 10% or 15% if only the non-renewable energy demand or global warming potential are considered, respectively. Mobility and housing are other important consumption categories with regard to the total environmental impacts caused.

LCIA method important for conclusions

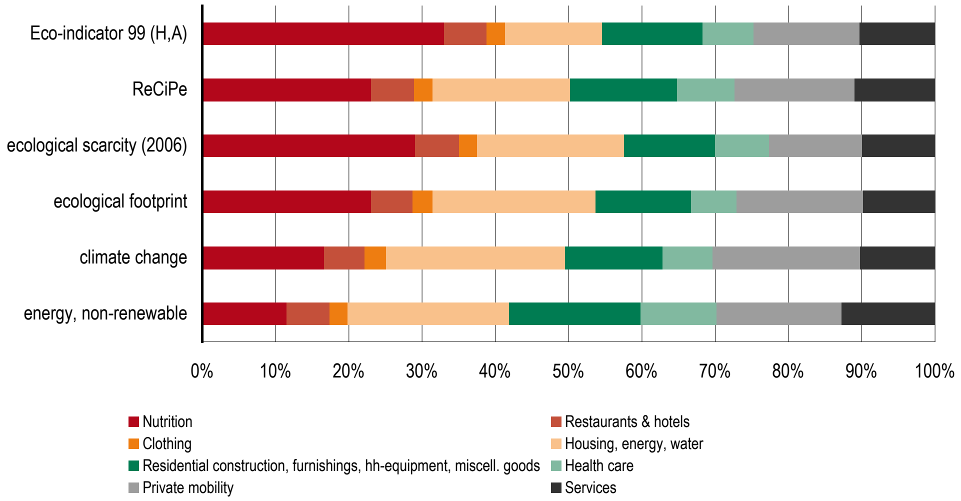
Thus, the LCIA method has important implications for such an analysis. The food sector is more important if several types of environmental impacts are considered. Energy demand or global warming potential are thus not sufficient indicators for a further evaluation of this consumption sector.

Comparison with other studies

The results found for the contribution to climate change can be compared with a former IOA for Switzerland (Hertwich & Peters 2009). This analysis did not only find a considerably higher carbon footprint (see comparison in Tab. 11), but also a different share of some consumption categories. According to Hertwich (2009) food contributes only 11% for the total and mobility accounts for 26%.

Fig. 41 > The proportion of environmental impact for each category of final consumption

The importance of single consumption categories depends also on the LCIA method used. An evaluation of the impacts with the energy demand or climate change attributes much lower environmental impacts to nutrition than an evaluation with other methods. This shows that the primary sector causes directly a range of environmental impacts that cannot be covered with simplified methods like energy demand or carbon footprint.



Calculation ESU-services Ltd.

5.2.3.4 Importance of domestic and embodied environmental impacts for final demand

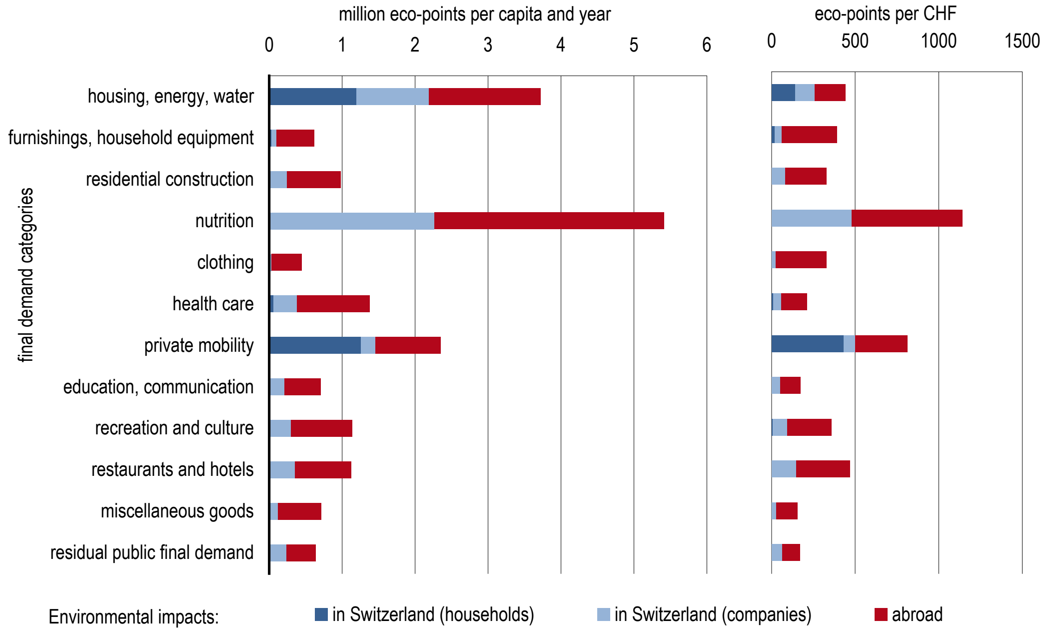
The following figure shows an evaluation concerning the share of emissions and resource uses abroad compared to the emission by domestic production of the Swiss industry and direct emissions of households. The emissions are shown for the final demand categories of households.

Fig. 42 > Total emissions per final demand category (million eco-points per year and capita)

This figure displays environmental impacts of the final demand categories evaluated with the ecological scarcity method. Direct emissions of households are relevant in the housing and mobility sector. The share of imports is high within the category clothing and low e.g. for nutrition. But for all categories emissions abroad are more important than the emissions by Swiss companies.

Fig. 43 > Emission intensities of final demand categories (eco-points per CHF expenditure)

Different final demand categories differ also considerably concerning the environmental impacts per expenditure unit of final demand. The highest impacts are caused per CHF spent on nutrition. Mobility is another activity with high specific environmental impacts. Spending more money on education or communication can reduce environmental impacts.



Source: calculation ESU-services Ltd. and Rütter+Partner

5.2.4 Environmental profile of Swiss production sectors

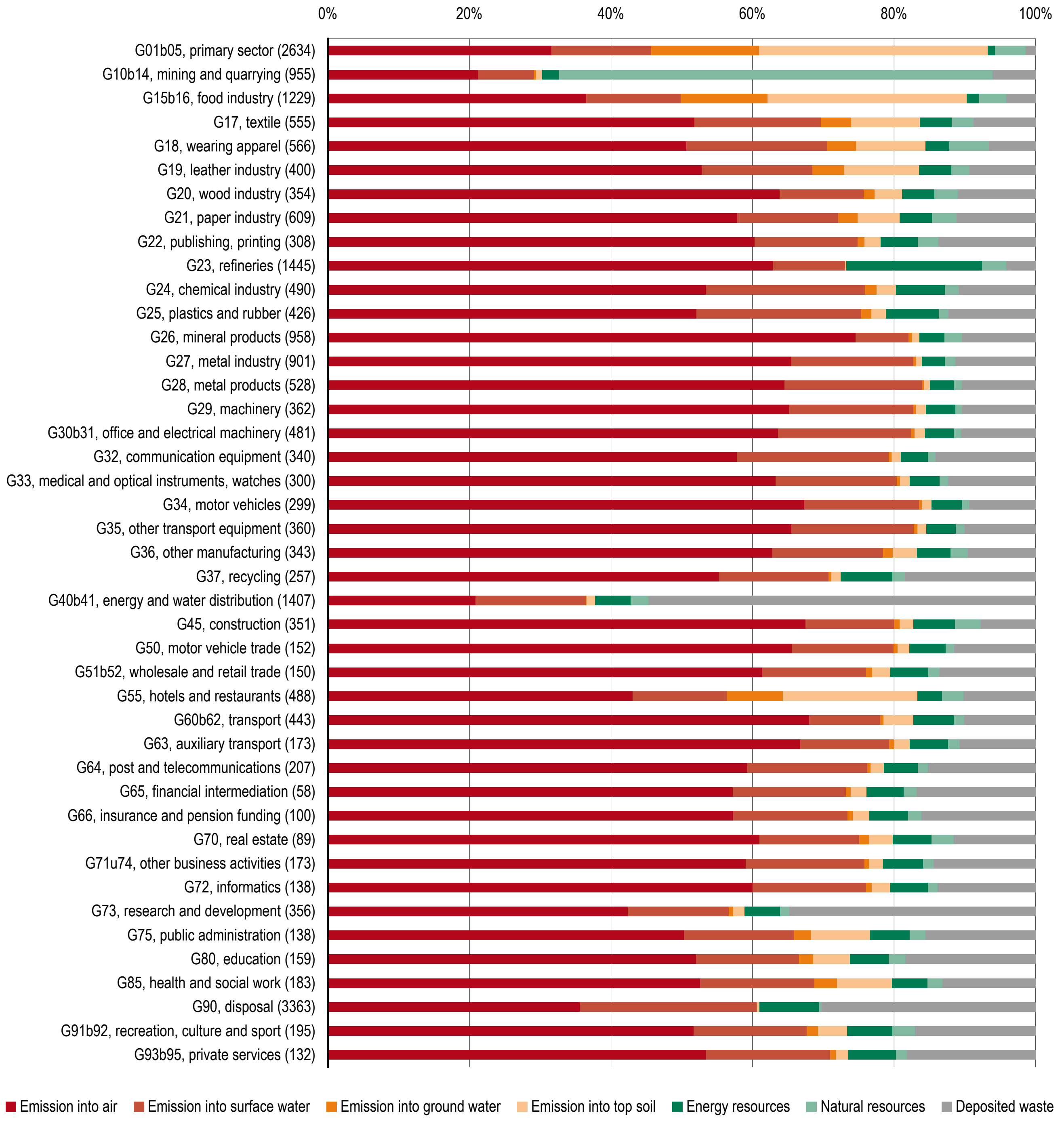
Environmental intensity per gross output

Different production sectors show quite differing environmental impacts in relation to their gross economic output. The gross output is the sum of added value, Swiss and imported deliveries and taxes on goods. These differences are analysed in Fig. 44 for all economic sectors.

There are important differences concerning the type of emissions or resource uses. Thus, e.g. the extraction of gravel is shown as a use of natural resources in the mining sector. Nuclear wastes are allocated to the energy sector. Agriculture contributes to emissions of pesticides and heavy metals in soils.

Fig. 44 > Environmental profile of Swiss production sectors
(Share of emission categories in the total results. Total ecopoints per CHF output in brackets)

Share of different types of environmental impacts per economic output of the Swiss production sectors are evaluated (UBP). Three sectors show a distinctive different emission and resource use profile. The energy sector causes high environmental impacts in the category of deposited waste. The mining sector makes use of natural resources like gravel. The primary sector has a high share of emission to soil and groundwater.



Source: calculation ESU-services Ltd. and Rütter+Partner

5.2.5 Analysis of exports

Exports of environmental impacts

Exports have a considerable importance for the total balance. Here we analyse in more detail the share of economic activities for total exports. Two points are interesting.

Fine chemicals should be investigated in more detail

Exports of chemicals lower the total environmental balance considerably. This is due to the high value of chemicals exported from Switzerland. The calculation with the trade balance and LCA data results in much lower exported impacts. Thus, it might be necessary to investigate this sector in more detail e.g. for fine chemicals, pharmaceuticals or plant protection agents in future analysis.

Electricity trade cannot be analysed with the IOT

The export of environmental impacts from the energy sector is quite low, even knowing that the trade with electricity is an important issue in environmental accounting for Switzerland. We assume that these impacts are underestimated since in the IOT electricity is aggregated with gas and water supply. This may not account for the importance of the electricity trade correctly.[15]

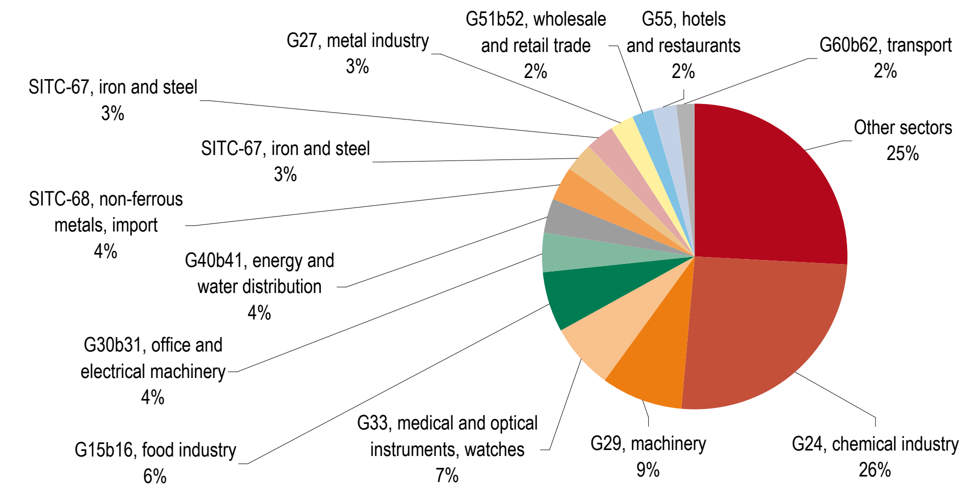
An approach based on LCA data seems to be more appropriate in this case.

Jewellery and watches

A sector of exports often mentioned in the case of Switzerland is the production of high priced watches and jewellery. This does not show up very prominent in the analysis (G33, G36) as it is also part of a larger sector and not regarded separately. Also there might be some underestimation as imports of e.g. of gold and silver are not fully related to the export of such products. Furthermore so far no LCA data for diamonds are available which will have most likely high emission intensities per kg.

Fig. 45 > Share of sectors for exports of environmental impact

Exports of chemical products are the most important contribution to total exports of environmental impacts. Machinery is second most important. The energy and water distribution has only a share of 2% in the total export of environmental impacts.



Calculation ESU-services Ltd.

[15] According to the FOEN, a disaggregation of the Swiss IOT has been made in the meantime, but it was not possible to consider it for this report.

5.2.6 Further discussion of results

5.2.6.1 Comparison of results of Top-Down and– Bottom-Up approaches

In this chapter the results of the top-down analysis presented in this report are compared to the results calculated directly with a bottom-up approach. For the bottom-up approach we use LCA data on products and services and link them to statistical data available for the most important consumption activities (Fig. 46).

Food consumption

Environmental impacts of food consumption are calculated with statistical data for food availability (Schweizerischer Bauernverband 2007) and LCA data of food production (Jungbluth et al. 2011a). Rough assumptions have been made for transports, distribution and packaging. The results calculated in the bottom-up approach are lower than results calculated by the top-down approach used in this study. It can be assumed that within the bottom-up analysis several food processing stages and preparation in restaurants are not covered fully and thus underestimated. It also seems as if yields might be overestimated in the LCA database. The EE-IOA (top-down approach) probably underestimates the environmental impacts because a part of agricultural emissions is assigned to forestry products in the primary sector and consumption in restaurants is shown separately. To further analyse environmental impacts of nutrition more detailed LCA data for food should be analysed and it would be necessary to distinguish forestry and agriculture in the IOA.

Food consumption analysis with LCA

The analysis with LCA and EE-IOA reveals meat products, but also beverages like coffee and wine to be most important for the environmental impacts caused. While the importance of meat is well known, possible environmental impacts of coffee, cocoa and wine have so far not been discussed in detail.

Energy use in households

The estimation for energy use by private households is based on the national statistics (BFE 2006). Consumption data for goods covered in the IOT category of housing were not available. Thus, this calculation underestimates the impacts in the classification according to the IOT. Therefore we made a second estimation only including provision of fuels and electricity and direct emissions of this activity. Still the results calculated with the EE-IOA are higher than the bottom-up approach. The higher results are also due e.g. to the inclusion of emissions related to accidental fires or refrigerants in the EE-IOA which are not included in the bottom-up approach and the possible underestimation of electricity exports. Thus, the results are more or less comparable between the different approaches and the available explanation of differences.

Energy use analysis with LCA

The calculation with LCA data allows further conclusions to be drawn. Electricity use accounts for about 50% and heating oil for 40% of the environmental impacts of the housing sector. Thus, these are the two most important potentials for improvements, e.g. by saving energy or by using renewable energy sources.

Mobility

The statistical data for traffic provide detailed information for the kilometre driven with different means of transportation (BFS/ARE 2007). They seem to consider only persons over 6 years of age. Business trips have been excluded in the calculation. In a second approach we use data investigated in a household survey (Girod & de Haan

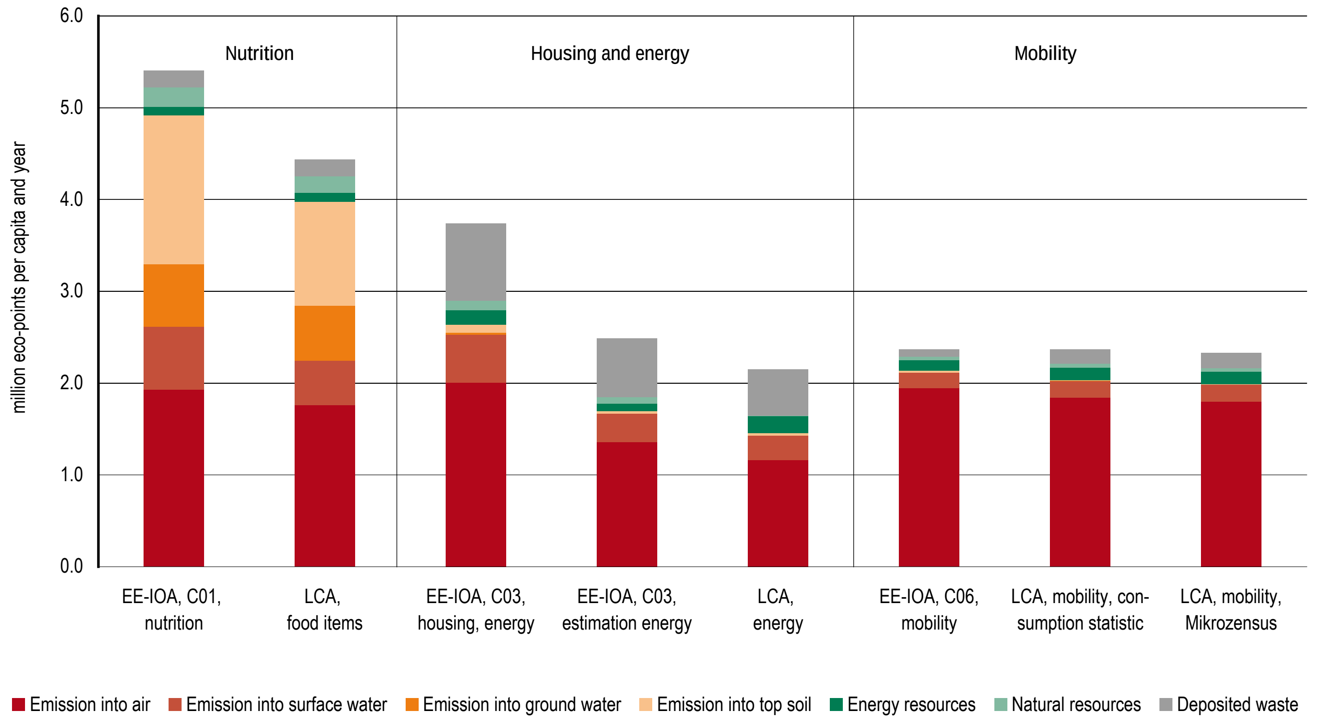
2010, based on BFS 2007). In this case all three approaches show about the same results. But, they show some differences concerning the emission patterns. Within the EE-IOA approach the use of energy resources and deposited waste seems to be underestimated while it overestimates the air emissions. This is due to the aggregated sector providing electricity.

Mobility analysis with LCA

The calculation with LCA data allows further conclusions to be drawn. Use of passenger cars accounts for more than 80% of the environmental impacts, followed by flights with about 9%. Thus, reducing the specific fuel use and kilometres driven of private cars is the most important issue.

Fig. 46 > Comparison of environmental impacts calculated top-down and bottom-up per capita

The results of three household activities can be compared with results of a bottom-up calculation with LCA data. Some differences are found and explained. Results for mobility are about the same. The impacts for nutrition and energy are higher if calculated with the EE-IOA than in the LCA analysis.



Calculation ESU-services Ltd.

5.2.6.2 Uncertainty analysis

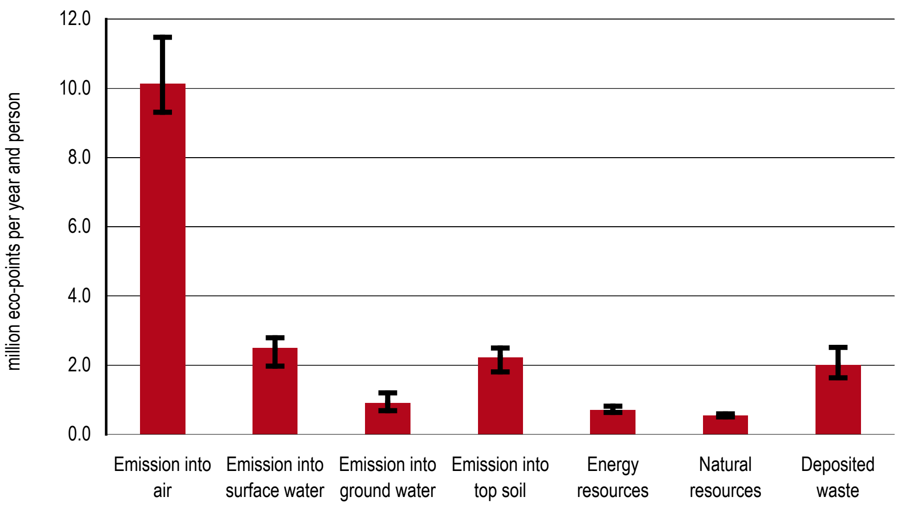
Life cycle inventory data in the EcoSpold format includes also information about the lognormal uncertainty of each single input and output in the life cycle inventories. Most information on uncertainties is based on generic assumptions and the estimation of the data quality with a pedigree matrix. This allows roughly estimating the uncertainty of results in a Monte-Carlo simulation (Dones et al. 2005; Frischknecht et al.

2007b; PRé Consultants 2009). It has to be noted that the uncertainty of the LCIA method is not included in such a calculation.

In Fig. 47 the uncertainties for the ecological scarcity results on total final consumption in Switzerland are estimated.

Fig. 47 > Monte-Carlo uncertainty simulation for the results calcualted for the total consumption in Switzerland

The Monte Carlo simulation shows a different range of uncertainties for different types of environmental impacts. Emissions to ground water are recorded with the highest uncertainties while LCI data on natural resources show the lowest uncertainty. The overall uncertainty of the results due to the uncertainty of LCI data is estimated to be in the range of ± 10%.



Calculation ESU-services Ltd.

5.2.6.3 Comparison with other studies

With regard to greenhouse gas emissions and the ecological footprint we can compare our results to other studies for Switzerland. A comparison for the full range of environmental impacts is not possible, since to our knowledge other comparable studies only exist for single household activities, but not for the whole consumption and production.

High variation in published results

Tab. 11 contains the estimates of several studies on the greenhouse gas emissions that can be attributed to Swiss consumption. Whereas most of the studies investigate values between 8.6 and 13 t CO_2-eq per capita, Hertwich & Peters (2009) come up with an estimate of over 18 t CO_2-eq per capita. Iha et al. (2010) calculated about 15 tonnes for CO_2 only. Thus, multi-regional IOA models seem to estimate the emissions to be higher than the models based on a bottom-up approach for imports.

Multi-regional IOA with tendency for higher results than bottom-up

Since the various studies use very diverse methodologies, it is difficult to identify the reasons for these differences. It would be necessary to analyse the results in detail and to compare the contributions of consumption categories and different imports. It seems reasonable that each of the approaches has specific strengths and shortcomings. An in-depth analysis would also provide hints on how to improve the results by combining the strengths of the approaches.

Tab. 11 > Comparison of the results for greenhouse gas emissions and ecological footprint per capita in different studies

Several studies have already been conducted in order to calculate the GHG emissions and the ecological footprint due to Swiss consumption. Here we compare the results of the latest studies. It seems that multi-regional IOA models tend to estimate higher environmental impacts than models based on bottom-up calculation for imported goods.

Tonnes CO_2-eq per capita	Ecological footprint (incl./excl. nuclear) [ha per capita]	Source	Method
11	4.5 / 3.6	The present study for 2005	EE-IOA & LCA data for imports
13	5.0 / 3.8	The present study trade statistics and LCA for 2005	Trade statistics and LCA data
(only CO_2) 14.9	- / 5.6	Iha et al. 2010 for 2001/02	Multi-regional IO-modelling with the purpose to calculate the environmental footprint. Swiss IOT based on OECD-IOT (Nathani et al. 2006; Yamano & Ahmad 2006).
8.6		Girod & de Haan 2010	LCA data for single products and consumption statistics
12.5		Jungbluth et al. 2007, trade statistics and LCA in 2004	Trade statistics and LCA data
(only CO_2) 9.5		Jungbluth et al. 2007, IOT according to OECD methodology (Ahmad & Wyckoff 2003) for 1995	Multiregional IO-modelling with simple IOT distinguishing only about 12 sectors.
(only CO_2) 8.8	4.7 / 3.9	von Stokar et al. 2006 for 2002	Direct emission and land use in Switzerland. Database for traded goods
11.8		Känzig & Jolliet 2006	Estimation based on different studies (own calculations for heating and mobility).
9.0		Bébié et al. 2009, 2000W Society	This calculation only takes into account the provision and combustion of energy carriers and electricity. Emissions of methane and nitrogen dioxide not related to energy use, and all grey emissions due to the trade with other goods and services are not included.
18.4		Hertwich & Peters 2009 in 2001	Multiregional IO-modelling

Source: depiction ESU-services Ltd. and Rütter+Partner with mentioned literature

5.2.6.4 Estimating threshold limits for environmental impacts caused by Swiss consumption

Limit value for environmental impacts

An important question is how the environmental impacts caused by Switzerland compare to the targets for a sustainable world or the political targets in Switzerland. Targets for the (worldwide) environmental impacts caused per person in a sustainable world are so far not available despite proposals for a set of so-called Global Environmental Goals (see Perrez & Ziegerer 2008). However, we can estimate the level of environmental impacts that should be achieved according to the goals of Swiss policies and that are reflected in the method of ecological scarcity. Such a threshold level is also important for the simplification of ecological scarcity results that could be used for environmental product information (see Jungbluth et al. 2011b).

Present total burden of consumption

Starting point is the environmental impact of current final consumption in Switzerland. In total 20 million eco-points were caused per capita in Switzerland in 2005. This result has been calculated with the total impacts of consumption (Fig. 48) divided by the Swiss population.

Current flow

In Fig. 34 the actual and critical flow are introduced. The calculation of the current flow in Switzerland includes domestic emissions and resource uses accounted for with the ecological scarcity method. A part of e.g. the energy resource extraction takes place outside Switzerland.

Critical flow

The critical flow defines the target according to the Swiss policies for domestic emissions and resource uses of Switzerland (including energy resources extracted abroad). The difference between the two columns 'current flow' and 'critical flow' defines the total reduction target for direct emissions and resource uses in Switzerland of about 40%. The critical flow amounts to about 7 million eco-points per capita. But, reduction targets for single emissions and resource uses are not identical. For instance, the reduction targets concerning air emissions are set at about 50% while for natural resources the reduction targets would even allow a slight increase (Frischknecht et al. 2009).

Critical burden

The goal is to define a critical burden of total environmental impacts (a kind of environmental budget) that a person in Switzerland is allowed to cause. Ideally this target would be the same for all the people in the world. This includes also the emissions and resource uses due to trade with goods and services. Such a target figure is necessary if one wants to relate the environmental impacts of a specific product or activity to a threshold level of sustainable consumption.

At least 38% reduction for achieving political targets

For calculating the critical burden in Fig. 34 the same reduction targets as found for the critical flow have been applied to the seven categories of emissions and resource uses. This results in a target environmental impact to be caused per capita and year and amounts to about 12 million eco-points. However this approach is defendable only for countries with a similar environmental quality to the world average. For countries with a relatively high environmental quality and a relatively high level of environmental impacts caused abroad through imported products, this approach leads to an underestimation of the reduction needed.

More than 62% reduction for a neutral balance and achieving political targets

In an even stricter point of view one could also argue that Switzerland should aim at a neutral trade balance with respect to environmental impacts. To be more precise: assuming that the total environmental impact caused by Swiss consumption and production should not exceed the total environmental impact per capita acceptable in Switzerland, environmental impacts caused through net imports must be compensated by even further emission reductions domestically. Or in other words Swiss consumers should (in balance) not burden foreign people with environmental impacts caused by their consumption. With this point of view total environmental impacts would be limited to the critical flow defined by Swiss policies. Thus, a reduction by more than 60% would be necessary.

World average is 47% lower

In a global perspective it is also interesting to compare environmental impacts caused by Swiss consumption with the world average. Such an average has been roughly assessed with normalisation data provided by the ReCiPe methodology (Goedkoop et al. 2009). As this methodology does not account for waste deposits and groundwater emissions, these had to be estimated roughly with Swiss data. With this a reduction of 47% of total environmental impacts should be aimed at in order to adapt to the world average. This would not yet decrease the environmental impact today but would ensure equal opportunities for all people.

Rising population

However the world average impacts per capita should not be confused with a sustainable level of impacts per capita: our planet's capacity to absorb environmental impacts does not (automatically) grow with rising impacts per capita and with a growing population. As total environmental impacts need to be reduced, the reduction per capita also needs to be corrected by the population growth. Thus, if the worldwide population grows by 10% over the next ten years, an additional reduction of 1% per year needs to be considered for the per capita target.

Time frame for reductions

A critical point is the time frame of achieving the critical burden. We consider 20 years to be a reasonable time frame within which the critical burden should be achieved. This is in the range covered by political decisions, which build the underlying framework for the development of this LCIA method. Thus, one might develop an annual reduction target. A linear calculation would set the target each year 400 000 eco-points lower. Thus in 2010 it is 19.6 MM eco-points, in 2011 it is 19.2 MM eco-points and so on.

Targets need to be defined independently of growth

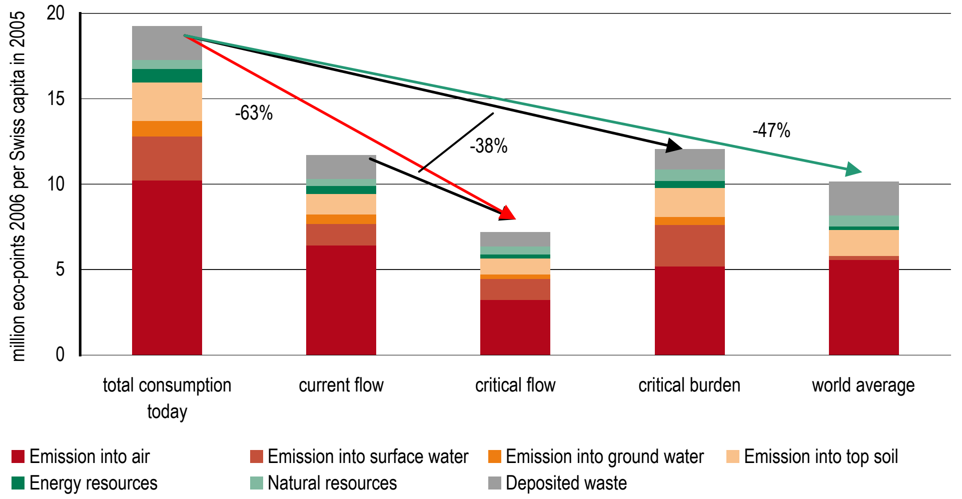
This discussion also shows that it is not sufficient to define environmental targets as a reduction of environmental impacts per gross domestic product. It is necessary to define targets on the level of environmental impacts per earth available for living because the stock of natural resources will not rise with population or welfare growth.

Further discussion necessary

A considerable reduction of emissions and resource uses is necessary independently of the reasoning chosen. The choice of the most appropriate reduction target is a political one. The present analysis can provide the necessary background data for such a discussion. Nevertheless we would propose to aim at least for a 40% reduction of the environmental impacts caused by present-day Swiss consumption.

Fig. 48 > Estimation for the target value or critical burden of total environmental impacts caused by Swiss consumption

The reduction targets are calculated using the environmental impacts of the year 2005 according to the ecological scarcity method for each environmental compartment (e.g. emissions to water or air). The reduction factors are then applied on the environmental impacts of consumption. According to this the critical burden would at least be 38% lower compared to the present environmental impact caused by Swiss consumption. Two other approaches considering no net imports or world average would result in reduction targets of 63% and 47%, respectively.



Calculation ESU-services Ltd.

6 > Conclusions

In this chapter the main conclusions are drawn from the pilot study investigating the environmental impacts of consumption and production in Switzerland. It also provides a comparison to the results of other studies concerning the total environmental impacts and its split up to different household activities. The most important consumption areas are nutrition, the use of energy in households and private travelling by different means of transportation.

6.1 Analysis of the environmental impacts of Switzerland

Within this pilot study we evaluated and analysed the total environmental impacts of Swiss consumption and production.

Production perspective

The allocation of total domestic emissions and resource uses to different economic sectors and consumption categories is used to calculate the domestic environmental impact with the ecological scarcity method. In total an environmental impact of about 80 trillion eco-points are caused due to the direct emissions in Switzerland. The most important agent is the primary sector contributing about 29% of potential environmental impacts due to the domestic emissions. So far emissions from agriculture, forestry and fishery are not disaggregated, which would be an important prerequisite for more detailed analysis. Direct emissions from households contribute about 25% to the total direct emissions. Carbon dioxide is the most important emission. This is followed by other air (e.g. nitrogen oxide) and water (e.g. nitrate) emissions.

Consumption perspective

The main evaluations in this study investigated the environmental impacts of Swiss consumption. The following paragraphs all refer to the consumption perspective.

Imports and exports are important

For a true and fair view on the environmental impacts caused due to Swiss consumption patterns it is necessary to consider the importance of imports and exports. Imports to Switzerland cause higher environmental impacts than the direct emissions and resource uses by Swiss households and companies. On the other hand exports of goods and services lower this balance. Nevertheless the total balance is nearly twice as high as when accounting only for the direct emissions and resource uses in Switzerland.

Confirmation of results

Two different methods have been applied for calculating the total balance. The main difference concerns the calculation applied for exports:

> In the first approach the environmental impact of exports were calculated using the economic data of the IOT.
> The second approach estimated the exports of goods with the trade statistics and LCA data for the environmental impacts.

The two methods show significant differences concerning the environmental impacts that can be attributed to Swiss exports. In both cases there are considerable uncertainties, which make it difficult to decide which result is more accurate. The further comparison with other publications in Tab. 11 highlights that there is still some uncertainty concerning the correct result of such a calculation. Nevertheless, both methods show that the trade with goods and services is an important issue that needs to be considered.

Top-down or bottom-up

Furthermore it was possible to compare the results for the three most important consumption categories with a bottom-up calculation based on national statistics and LCA data (sub-chapter 5.2). This calculation confirms the general tendency, but highlights also some weak points for both approaches. For an LCA calculation of environmental impacts due to nutrition it is also necessary to better investigate the processing stages of food products. Furthermore it is necessary to distinguish between animal products and plant based food products, which was not possible with the EE-IOA available for this study. The EE-IOA for energy use does sometimes wrongly address certain emissions and resource uses due to the aggregation of different economic sectors in the IOT. Results calculated for mobility are quite close between the two approaches.

Impact assessment

Different LCIA methods have been used in order to aggregate emissions and resource uses and to assess the environmental impacts. These show some differences concerning the importance of single emissions or resource uses. However, they do not put into question the main result that environmental impacts of imports and exports have to be considered for a true and fair view on Swiss consumption.

11–13 tonnes CO_2-eq per capita

The total greenhouse gas emissions per capita are estimated to be in the range of 11–13 tonnes CO_2-eq per capita in the year 2005. This is considerably more than the direct emissions of about 8 tonnes CO_2-eq per capita.

Agriculture more relevant in environmental evaluation

Compared to the analysis of greenhouse gas emissions the consideration of a wider range of environmental impacts clearly shows a more complete picture. From the production perspective both approaches, the pure EE-IOA approach as well as the approach combining EE-IOA with trade statistics and LCA, indicate a large relevance of direct emissions from households. The primary sector (especially agriculture) becomes much more relevant if environmental impacts other than greenhouse gases are considered. Waste management (due to emissions) and electricity, gas and water supply (due to resource use) also gain in importance. On the other hand transport services become less relevant.

Relevance of energy consumption difficult to evaluate

It is known that many environmental impacts are related to the use and combustion of energy carriers. The EE-IOA approach assigns these emissions directly to the economic sector where the fuel is used (e.g. chemical production without specifying if it is used for transport or for combustion). Thus, it is not possible with the Swiss IOT for the year 2005 to directly evaluate e.g. the relevance of transport- and heating-related emissions for single economic sectors or for the whole production sector. Therefore it would be necessary to assign such emissions to a specific type of economic activity.

Shift of priorities with impact assessment

In the consumption perspective it is striking that the environmental impacts attributed to exports are larger than those induced by domestic final demand. Only taking greenhouse gas emissions into account, domestic final demand is much more relevant than exports. Focusing on household consumption we can see that the consumption category nutrition is more important, when the total environmental impact is considered.

In the consumption perspective as well as in the production perspective the relevance of transport decreases when all environmental impacts are taken into account instead of focusing on greenhouse gases only. These results point to the fact that for priority setting in environmental policy it is necessary to consider a wide range of environmental impacts.

At least 40% reduction necessary for compliance with Swiss environmental policy goals

The total environmental impacts of Switzerland are calculated to be in the range of 20 million eco-points per capita. This amount needs to be reduced by about 40% to 63%, depending on the point of view on Switzerland's responsibility for global environmental impacts.[16]

6.2 Priority areas for sustainable consumption and production

With this study we confirm other existing research work on the importance of different areas of consumption (Hertwich & Peters 2009; Hofstetter 1992; Jungbluth et al. 2003; Känzig & Jolliet 2006; Knoepfel 1995). The most important areas are nutrition, housing (including the direct energy use of households for heating) and mobility.

Nutrition

Within consumption categories, nutrition is most important and causes about 30–40% of total environmental impacts. Also environmental impacts per CHF spent on this activity are higher than for other activities. People's nutrition is important with regard to many environmental impacts not directly linked to the combustion of energy carriers, such as emissions of ammonia, dinitrogen monoxide, methane, nitrate and phosphate. Heavy metals and pesticides from fertilizers and plant protection agents are another issue of concern. Also impacts due to water use and land occupation must be considered. There are no easy solutions for the reduction of these environmental impacts. Improving agriculture always has to balance out different goals such as increase of the yield and reduction of the inputs. While consumers always eat more or less the same amount of food, they can choose diets with e.g. fewer animal products in order to reduce the environmental impacts.

Energy use and housing

Energy use by households and residential buildings are another important area. There is a large variety of options to reduce the environmental impacts. The most important are the reduction of energy uses by good thermal insulation and energy-efficient appliances, the reduction of the area used for living or the reduction of the purchase of goods.

[16] 40% when applying domestic reduction targets also to imports, 63% when assuming that the Swiss population should be allowed to cause as much environmental impacts as it is willing to accept on its own territory

Also for mobility large differences can be expected between different households and thus important improvement potentials. Important choices are e.g. on having a car or not, the distance between home and working place, the fuel efficiency or the decisions made about the distance travelled during holidays.

Mobility

This study and the data investigated in this study can be used to carry out scenario analysis on a macro or country level. They do not help to identify the improvement options in detail. Therefore more detailed investigation of different choices in LCA case studies for the identified areas is necessary.

LCA for detailed analysis in priority areas

6.3 Influence of life cycle impact assessment method

For understanding the differences between life cycle impact assessment (LCIA) methods, an assessment with each LCIA method of the overall annual environmental impacts of Switzerland is helpful. All methods show global warming, energy depletion and land occupation as important issues. In some methods these categories fully dominate the results while the ecological scarcity method shows a more balanced picture of several environmental impacts. These differences do not allow conclusions about one method being superior to another. Therefore, the point of view of the decision maker has to be taken into account.

The ecological scarcity method reflects best Swiss policy because it is based on Swiss environmental regulation and it has been developed by the FOEN. It is based on political goals.

Ecological scarcity reflect political goals for reduction of emissions and resource uses, and cannot set political goals for the same issue

Thus, it would be a self-fulfilling prophecy (or positive feedback loop) if one tries to derive new political goals for the importance of specific emissions and resource uses by applying the ecological scarcity method (while it is important to discuss the overall critical flow). It is not possible to identify from a scientific point of view priority emissions or resource uses with the methodology because this priority has already been identified while establishing this impact assessment method. It would be wrong to conclude from such an evaluation that the most important emissions or resource uses should get more attention or vice versa, that those with low importance should get less attention.

6.4 Usefulness of combining LCA and EE-IOA

Within this study we developed a novel approach for combining the environmentally extended input output model with LCA data for imported goods and services.

The inclusion of imports is important in the case of Switzerland. Many single country EE-IO models assume in such a case that imported products are manufactured with the same environmental impacts as domestic products. This is not feasible in the case of Switzerland as several imported products are not produced in Switzerland and thus Swiss data cannot be representative for these imports.

The good availability of LCA data for a variety of products allows the relevance of imports to be estimated by using trade statistics. Another option would be to estimate the environmental impacts of imports with EE-IO models from other countries that have a comprehensive database of sectorial environmental impacts. This latter option (with EE-IO models from other countries) has not been carried out within this study due to budget restrictions.

The study shows that both methods have certain weaknesses and that it is difficult to verify which approach is more reliable for such a total assessment.

The study proves that it is possible to investigate the total environmental impacts caused by the consumption in a country. It also shows that there might be large uncertainties e.g. in the calculation of exported goods. Therefore, some key issues for further improvement are identified in the following chapter.

In the case of Switzerland it seems to be necessary to disaggregate the IOT in the areas of primary production, chemicals, electricity and water supply and the transport sector. The analysis would benefit from a better availability of LCA data for products such as electronics or textiles.

6.5 Uncertainties in the accounting method

Data quality considerations

The main data uncertainties have been described in the previous sub-chapters 3.7 and 4.4. We already identified a range of issues, which have an important influence on the results:

- Different accounting principles with territorial (IOT 2005) and residence principle (National inventories on environmental issues).
- The Swiss IOT is too aggregated with regard to environmentally relevant sectors.
- The Swiss IOT does not distinguish between the use of domestic and imported products. In this study highly simplifying assumptions had to be made concerning this matter.
- For some direct emissions the total amount released in Switzerland is only known roughly (e.g. heavy metal emissions to water).
- For some emissions it is difficult to make an allocation to production sectors (e.g. emissions of refrigerants)
- LCA data for certain categories of imported goods are not sufficiently detailed.
- Existing LCA data do not reflect differences in production patterns between different countries (except for electricity).
- Product categories used in foreign trade statistics and IOT do not match perfectly.

At least 20% to 30% uncertainty

All these issues have an influence on the final results of this analysis. The overall uncertainty of results has also been estimated by means of a Monte Carlo simulation and by comparing results calculated with different approaches. We estimate the overall uncertainty of all results calculated with this type of analysis to be at least in the range of 20% to 30%. This has important implications if one wants to monitor the development over time as changes being lower than the uncertainties might be difficult to verify.

The major results and conclusions of the analyses have been verified by comparison with literature data and alternative approaches. Furthermore, uncertainties for partial results are not independent of each other. Thus, even with the high uncertainty mentioned before, we consider the main findings to be valid. The uncertainties have especially to be considered if the data are used for analysis going beyond what has been done here, e.g. into more detail of comparing single products or branches. In this case the results need then to be critically evaluated and reassured by different means of analysis.

LCA does not underestimate impacts

The analysis also shows that there is no general trend of LCA results to be lower than results calculated with EE-IOA. For some categories of exports (e.g. electricity) or final demand (transports) results calculated by LCA are higher or in the same order of magnitude. LCA results do more accurately reflect the environmental profile of certain products and production processes.

7 > Outlook

The environmental impacts of Swiss consumption and production have been investigated for the first time in this pilot study. In this chapter some conclusions concerning the further development of this research field and potential update and improvement possibilities are drawn.

7.1 Further development of the approach

Options for improvement

In sub-chapter 6.5 several issues of uncertainties and data quality have been discussed. Thus, several improvement options exist for the EE-IOA developed in this project or for a future update of this approach.

There are different possible strategies for further improvements:

> Improve the approach developed here for the year 2005 by e.g. better differentiating the Swiss IOT[17]. Thus, the shortcomings could be better addressed in order to achieve more reliable results.
> Use alternative procedures in order to confirm the results of this study, e.g. use a multiregional IO model to calculate the environmental impacts of imported goods or use data from other countries with EE-IO tables. Or carry out a sensitivity analysis with data from 2001 in order to identify most critical and sensitive modules of the approach. This might help to clarify whether a partial update (e.g. only economic data or only environmental data) makes sense.
> Update the full calculation for a new reference year (e.g. 2010) while in parallel improving the shortcomings or trying new approaches. This would be the most time-consuming procedure, but would better ensure that the reference year is also be up-to-date.

Improvement options

Several improvement options for the present approach are mentioned in Tab. 12. It is not easy to decide which ones are the most important. One next step could be to integrate the results of an ongoing project for disaggregating data in the energy and transport sector. Given the importance of nutrition for the total results, it would be good also to use a better disaggregation of the primary sector and distinguish in a first step plant production, animal production, forestry and fishery as separate sectors.

Verification of data

There are still quite a lot of deviations between different approaches for calculating the total environmental impacts due to Swiss consumption. In order to better verify the results we would propose calculating the results additionally with a multi-regional IO model and/or by using foreign EE-IOA data in order to estimate the imports of goods and services.

[17] A more differentiated IOT for energy, water and transport use as well as NAMEA for energy will be available in 2011

Full update

The results in this study are calculated as a combination of several parts of information. Many of these parts were available from previous research projects with the reference year 2005, which made it relatively easy to execute this study. For a future update each of the basic sets of data has to be investigated again. To investigate the situation in a new reference year it is necessary to update each part of the puzzle and combine it again in one study. The amount of work necessary for this study and for a future update for one reference year (e.g. 2010) is summarized in the following table. The workload for an update is considered to be higher than for the present study because some pieces of information would not be readily available.

Regular update

For a regular update it is necessary to update each piece of information as outlined in the last paragraph. The analysis shows that all these issues have an influence on the final results. Thus, a partial update may not be sufficient for monitoring trends. Furthermore it has to be considered that the range of uncertainty is about 20%-30%. Thus, for monitoring changes going below this range of uncertainty all influencing factors have to be interpreted and ascertained.

Simplified approach

The total emissions due to Swiss consumption can also be calculated in a simplified approach as used in the study on embodied greenhouse gas emissions (Jungbluth et al. 2007) and termed here LCA&trade. To carry out an LCA&trade analysis for Switzerland only the information marked with an asterisk “*” needs to be updated. But such a simplified approach would not enable the importance of single economic sectors or of specific consumption categories to be analysed.

Tab. 12 > Pieces of information used in this study and workload for improving or updating of the EE-IOA

The investigation in this study combines different data sources. For an update the workload might be considerably higher because many parts of information are so far not updated regularly. Updating only one piece of the puzzle will not be sufficient for drawing any conclusion on the development and change of environmental impacts caused by Swiss consumption. In the simplified approach LCA&trade only data sources marked with an asterisk would be necessary.

Piece of information	Data source for 2005 in this study	Improvement options for the reference year 2005	Future update, e.g. to be planned for 2010, (improvement options should be considered as well)
Input-output table	Available from Nathani et al. 2008	Use the results of an ongoing FOEN project for disaggregation of transport and energy sector. Further disaggregation of the sectors on agriculture and forestry, and different types of chemicals. Improve allocation of imported goods to use in industries and final demand.	New IOTs will probably be available in the future; though the level of disaggregation is uncertain. For environmental analysis a low level of aggregation with regard to environmentally sensitive industries would be important.
Trade balance *	Available from Eidg. Oberzolldirektion 2005	Use CPA classification	Will be updated regularly by the Directorate General of Customs.
LCA database *	Available from ecoinvent Centre 2010 and ESU-database	ecoinvent data should be updated and extended, but not necessarily for every type of product.	No new investigation necessary
Combination of trade balance with LCA data *	Available from Jungbluth et al. 2007 with simple update	Update if classification is changed from SITC to CPA	Investigation should be harmonized or combined with a possible update of the former FOEN study.
LCA data for service imports *	Investigated for this study	Not important	No new investigation because service imports are of minor importance.
Assigning imports to product classification of Swiss IOT	Investigated for this study	Data would be easier to link with IOT by using CPA classification of goods in the trade balance and redoing the approach.	New investigation necessary
Total domestic emissions *	Available from Frischknecht et al. 2009 with some updates	None	New investigation necessary, only partly regular updates available, e.g. SwissPRTR. An update of the ecological scarcity method is already planned and might be harmonized with an update of the EE-IOT.
Greenhouse gas emissions and energy use by sector	Available from BFS 2011	None	Regularly updated by the Federal Office for Statistics
Allocation of other emissions to economic sectors	Investigated for this study	None in the moment as the best available data have been used, but many rough assumptions were necessary. More detailed data might be provided by Swiss authorities.	New investigation necessary
Multi-regional IO model	Not used here	Use as an additional approach in order to estimate the environmental impact of imported goods. Primarily possible for greenhouse gases.	Ditto
EE-IOA of other countries for imports	Not used here	Use as an additional approach in order to estimate the environmental impact of imported goods.	Ditto
Data provision in EcoSpold v2 format for ecoinvent data v3 or later	Not yet possible	Supply-use data have to be inferred from the IOT. Imports are estimated based on data in the ecoinvent IO repository. Thus, availability of such ecoinvent IO repository is a prerequisite not yet available.	Ditto
Combination and evaluation of all data sources *	Investigated for this study	New analysis according to changes in data.	New analysis necessary

Source: depiction ESU-services Ltd. and Rütter+Partner

The Swiss database of pollutant release and transfer register SwissPRTR (BAFU 2010a) reports emission data on a regular basis. For some substances it includes not only the emissions reported by companies, but also diffuse emissions from agriculture, households and the transport sector, which sum up together with the reported emissions from companies to the total emissions in Switzerland. For the substances where such emission data are available, the total annual emissions could be updated regularly. The allocation to economic sectors and to final demand cannot be based on the SwissPRTR, since the unspecific category "diffuse emissions" represents an important share for most substances.

SwissPRTR

7.2 International application of the methodological approach

The methodological approach used in this pilot study for investigating the environmental impacts of consumption and production has been developed with a specific focus on the Swiss situation. The starting point for this analysis is specific with regard to the high share of imports in total environmental impacts as well as the availability of specific LCA data.

For Switzerland the IOT has only been updated recently, but there is neither a long tradition nor a large research community working with this tool. Thus, the status of development is less advanced than in other countries. This is also reflected by the fact that the Swiss IOT does not distinguish as many sectors as in other economies. Thus, in other countries the concept of EE-IOA might be easier to apply.

Only basic Swiss IOT data

Trade of goods is an important factor for the environmental impacts caused by Swiss consumption. Switzerland imports many basic goods and has an economy specialized in services and high-technology products.

Important impacts of trade

In contrast, Switzerland has a long tradition and excellent availability of life cycle inventory data from LCA databases. This made it possible to estimate the imports with such data.

Good LCI database

Generally the approach used in this study can also be applied for other countries. Since the use of LCI data to assess the environmental impacts of imported goods is rather resource-consuming, the approach might especially be useful for countries with a high environmental relevance of imports and similar data availability.

If imports are not as important or LCI data are not available it might be better to estimate the trade with one or several EE-IOA from other countries. Therefore it is necessary to harmonize the inventory list of emissions and resource uses between the domestic data and the data used for imports investigated in this EE-IOA for other countries.

The analysis could benefit considerably if information about environmental impacts of products or production sectors were available for the main trade partners in publicly available LCI or EE-IOA databases.

> Annexe A: Domestic emissions and resource uses and allocation to economic sectors and final demand

A1 Introduction

This annexe builds up on the inventory of emissions and resource uses described in a former report on the ecological scarcity method (Frischknecht et al. 2009). These emissions and resource uses are allocated to economic sectors and the private households as depicted in the input-output table.

All data investigated here for the actual residential emissions and resource uses in the year 2005 and the allocation to economic sectors and final demand is shown in an EXCEL table (allocation-emissions-sectors-direct.xlsx), which is available with the electronic annex. The data are available in electronic format for download via the following webpage *www.bafu.admin.ch/uw-1111-e*.

A2 Emissions to air

The report on "Human-induced air pollutant emissions in Switzerland from 1900 to 2010" (BUWAL 1995) quantifies the emissions of 17 different pollutants and allocates them to four source groups: transport, industry and commerce, agriculture and forestry, and households. Air pollutants are selected on the basis of their ecological relevance for the whole of Switzerland.

The emissions of SO_2, particulate matter, lead, mercury, cadmium, nitrogen oxides, carbon monoxide, NMVOC, benzo(a)pyrene, and polycyclic aromatic hydrocarbons are allocated to the economic sectors and final demand based on detailed emission data provided by the BAFU (2010c).

A2-1 CO_2, further greenhouse gases and use of energy carriers

Data on greenhouse gas emissions were made available from the Swiss Federal Statistical Office (SFSO). These data were generated through the compilation of the Swiss NAMEA Air for the year 2005 (BFS 2011). The sectoral classification and system boundaries are compatible with the IO table used.

The data also include biogenic CO_2 emissions. These are not considered in the assessment of the global warming potential, since they do not contribute to the greenhouse effect. The biogenic uptake of carbon dioxide is calculated from the biogenic carbon dioxide and the biogenic methane emissions. This carbon dioxide uptake occurs completely in the primary sector. The CO_2 uptake in forestry due to land use changes is also not included in the assessment. It is small compared to the overall emissions (355 tonnes CO_2 in 2005, Liechti 2006). This is consistent with the modelling in ecoinvent, which only takes into account CO_2 from deforestation.

Energy consumption and waste heat emission

The data on energy consumption include the consumption of the relevant energy carriers by economic sector and by households. These data are not directly evaluated as an environmental impact, but they are important inputs for the calculation of greenhouse gas emissions, other energy-related emissions and resource uses. They were also made available by the SFSO. Furthermore the emission of waste heat[18] has been calculated with these data and recorded as an emission to air.

Comparison of NAMEA air and UNFCCC GHG inventory

Due to the residence principle followed in this study the greenhouse gas emission totals used in this study deviate from the emission totals of the Swiss UNFCCC GHG inventory. As the following table shows, the total CO_2-eqivalent according to the NAMEA Air is almost 8% higher than in the GHG inventory. The differences mainly pertain to transport-related emissions. Whereas emissions by Swiss residents abroad largely compensate emissions by non-residents on Swiss territory the main emission increase comes from the inclusion of emissions by national air transport companies in the NAMEA. CO_2 from biomass is larger since not all emissions are included in the GHG inventory.

Tab. 13 > Swiss greenhouse gas emissions 2005 by greenhouse gas (kt CO_2-eq. per year)

Data on greenhouse gas emissions are taken from the NAMEA-air 2005 for Switzerland, supplied by the SFSO. They are compared to the emission totals from the Swiss UNFCCC GHG inventory (without land use change).

Economic actor	CO_2 fossil	N_2O	CH_4	HFCs	PFCs	SF_6	Total CO_2 equivalent	CO_2 from biomass
NAMEA-air	50 056	3 254	3 793	674	51	244	58 072	6 115
Total UNFCCC	46 030	3 219	3 793	674	51	244	54 011	5 869
Deviation	4 026	35	0	0	0	0	4 061	246

BFS 2009; 2011, calculations Rütter+Partner

[18] Waste heat is defined in ecoinvent as the total heat from the combustion of fuels and the energy of used electricity. It is assumed that all these types of energy finally enter the environment in form of heat even if the first energy form might be light or power. The term refers neither to energy losses of a process nor solely to the heat related to the combustion of wastes.

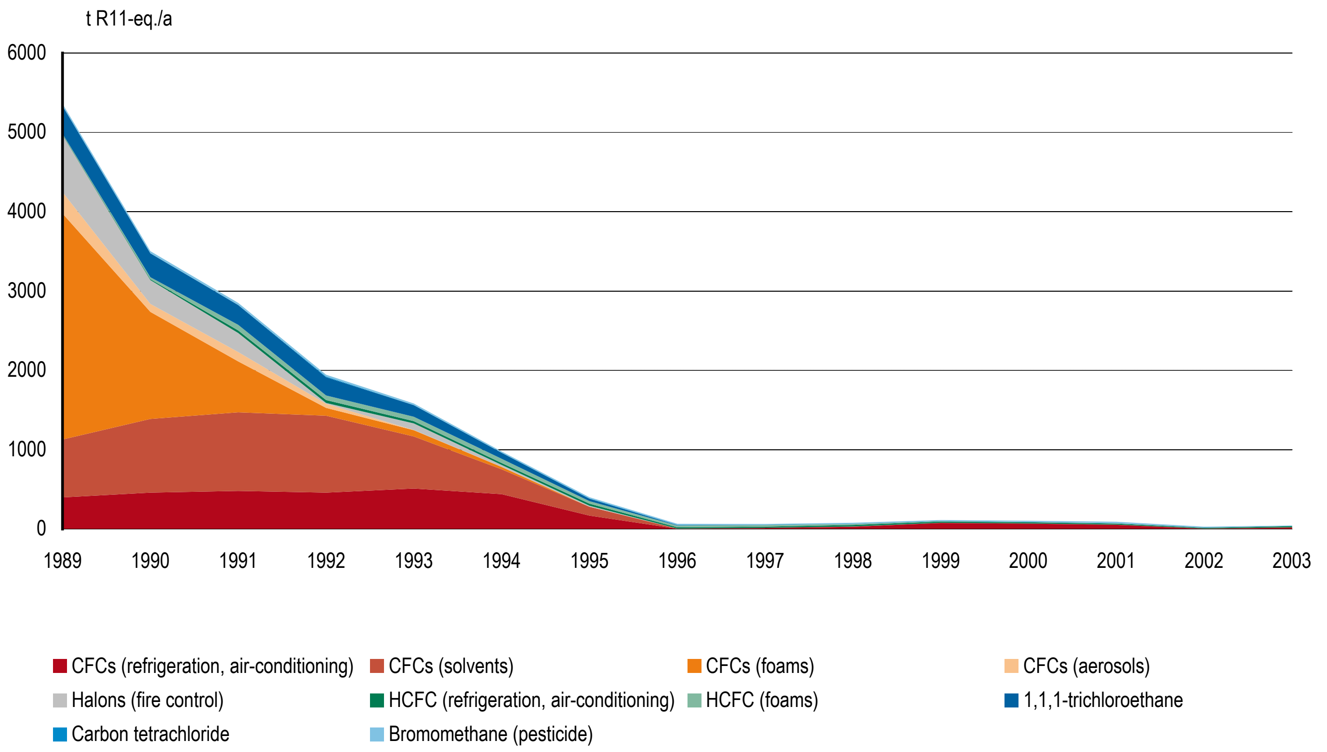
A2-2 Ozone-depleting substances

The most important ozone-depleting substances are CFCs (chlorofluorocarbons), halons and carbon tetrachloride (CCl_4). HCFCs (partially halogenated CFCs) have the same effect, but in a significantly weaker form. Halogenated hydrocarbons that contain no chlorine or bromine atoms, but contain e.g. fluorine (HFCs) have no ozone-depleting effect.

Imports to Switzerland

Swiss imports of ozone-depleting substances have been surveyed by FOEN since 1986 and are well known (cf. Fig. 49 and Tab. 14). No ozone-depleting substances are produced in Switzerland. HCFCs are now only permitted in existing refrigeration systems until 2015. In Switzerland R-22 is the main refrigerant used. Refilling equipment with halons is prohibited in Switzerland since 2003. CFCs are completely prohibited in foams since 1992 and in refrigeration systems since 2004.

Fig. 49 > Development of Swiss imports of ozone-depleting substances from 1989 to 2003, measured in R11-eq.



source: FOEN

Due to the formation of stocks in the past, current emissions of ozone-depleting substances are substantially greater than the present quantities imported. Emissions can be classed in four source groups:

1. Diffuse emissions from foam insulation materials containing CFCs and HCFCs that are already in place in buildings and in refrigeration systems.

2. Losses of CFCs and HCFCs as refrigerants in refrigeration and air-conditioning systems and in heat pumps.
3. Releases from the disposal of insulation material, equipment and systems that contain CFCs, halons or HCFCs (e.g. refrigeration equipment, refrigerators).
4. Halon emissions resulting from the use of fire control equipment and systems.

Tab. 14 > Average imports of ozone-depleting substances in tonnes and in tonnes R11-equivalent over the period from 2001 to 2003

	Imports to Switzerland: average over 2001–2003 period	
	[t/a]	[t R11-eq./a]
CFCs		
Refrigerants	27	27
Solvents	1.3	1.3
Foaming agents (insulation)	0	0
Aerosol propellants	0	0
HCFCs		
Refrigerants (mainly R22)	229	13
Foaming agents (insulation)	32	2.9
Further substances		
Halons (for fire control)	0	0
Trichloroethane (as solvent)	1.0	0.1
Tetrachloromethane (in laboratories)	2.2	2.4
Bromomethane (as pesticide)	17	10
Total	310	57

Source: FOEN

The EMPA has conducted a measurement programme for halogenated gases in the atmosphere since 2000 on the Jungfraujoch mountain. EMPA has found that emissions of the main ozone-depleting substances are dropping (Reimann et al. 2004). The calculation of the flow (Tab. 15) uses the average value of these measurements over the period from 2001 to 2003, and the HCFC-22 and tetrachloromethane import data from the import statistics gathered by FOEN; these figures cover more than 90% of the overall ozone-depleting impact[19, 20].

The national halon register[21] reports a stock of around 200 tonnes in 2005 for the halon 1301 (this is estimated to be 80% of the real stock). Emissions through triggering fire

19 The appraisal is based on the global production volume of halogenated hydrocarbons (AFEAS 2004, AFEAS (2004) Annual Global Fluorocarbon Production (Excel Sheet), retrieved 6.6.2005 from www.afeas.org/., where the contribution of CFC-113 and CFC-114, which are not taken into account in the present report, is around 12%. As these substances have been banned in Switzerland for some time, it can be assumed that their contributions are substantially smaller. The contribution of other CFCs and HCFCs not taken into account is well below 1%.

20 As HCFC-22 can now only be used to refill existing equipment, the imported quantity corresponds roughly to the emitted quantity. Tetrachloromethane is mostly used in small quantities in laboratories, and has little relevance to the emissions balance.

21 Personal communication by B. Horisberger (FOEN) of 15.8.2006

extinguishers are on the scale of 0.2% to 0.6% of the stock, which would amount to a figure of between 500 and 1500 kg emissions to air. The difference to the measurements performed by Empa (see Tab. 15) can probably be explained by unrecorded stocks. The figures provided by the Empa measurements (Reimann et al. 2004) are used here.

Tab. 15 > Swiss emissions of the most important ozone-depleting substances in t/a and as R11-eq./a

		Stock reduction for the year 2005					
		Total		as emissions to air		through disposal	
		[t/a]	[t R11-eq./a]	[t/a]	[t R11-eq./a]	[t/a]	[t R11-eq./a]
CFCs							
CFC -11	CCl_3F	278	278	167	167	111	111
CFC -12	CCl_2F_2	167	167	100	100	67	67
CFC -115	CF_3CClF_2	6.1	3.7	3.7	2.2	2.4	1.5
HCFCs							
HCFC -22	$CHClF_2$	280	15	229	13	51	2.8
HCFC -124	$CHFClCF_3$	6.5	0.1	5.3	0.1	1.2	0.03
HCFC -141b	CH_3CFCl_2	156	17	74	8	82	9.0
Halons							
Halon 1211	$CBrClF_2$	20	61	6.7	20	14	41
Halon 1301	$CBrF_3$	19	192	6.3	63	13	129
Methane, bromo-	CH_3Br	31	19	19	11	12	7.5
Solvents							
Ethane, 1,1,1-trichloro-	CH_3CCl_3	47	5	39	3.9	8.6	0.86
Methane, tetrachloro – *	CCl_4	2.7	2.9	2.2	2.4	0.5	0.53
Total		1015	761	652	391	363	370

* HCFC-22 and tetrachloromethane emissions are not measured. The FOEN import statistics provide approximate values (Tab. 14)

Allocation

The following assumptions are made for the allocation of the emissions based on information from BAFU (2010a):

> CFC-11 is used as insulating material and in refrigeration equipment. It is assumed that 50% is emitted from insulating material, which is allocated to the different sectors according to their occupation of land that is covered with buildings. The other 50% of emissions are allocated for 1/5 to the food industry, 1/5 to the wholesale and retail trade, 1/10 to the chemical industry, 1/10 to the hotels and restaurants, 1/10 to the household equipment category of household needs, 1/5 to the disposal sector (for the dismantling of refrigeration equipment, and 1/10 to air conditioning in cars which are again split up in correspondence to the sectoral fuel consumption.
> CFC-12 is used in refrigeration equipment and as propellant in sprays. We assume that one 3rd of the emissions stem from the use of medical sprays that are allocated

to the health care category of household needs. Two thirds of the emissions are allocated to refrigeration equipment the same way as the CFC-11 emissions.
> CFC-115, HCFC-124 and HCFC-141b are used in refrigeration equipment and the emissions are split up as described for refrigerant emissions of CFC-11.
> HCFC-22 is used in refrigeration equipment and occurs as an intermediate product in the chemical industry. Hence, we allocate two thirds to the refrigeration equipment as described before, and allocate one additional 3rd of the emissions to the chemical industry.
> Halon 1211 is used as an extinguishing agent in fire-fighting installations and extinguishers. One 3rd of the emissions is allocated to each life stage of these systems: production, application, and disposal. Hence, one 3rd is allocated to the chemical industry, one 3rd is split up according to the occupation of land that is covered with buildings (that can catch fire), and one 3rd is allocated to the disposal sector.
> Halon 1301 is used in extinguishers, in refrigeration equipment, and in aviation. One 3rd is allocated for the extinguishers as described for Halon 1211, one 3rd is allocated for the refrigeration equipment as described for CFC-11, and one 3rd is allocated to the transport sector for the emissions from aviation.
> Halon 1001 is used in the chemical industry.
> HCFC-140 is used as a solvent. It is assumed that one 3rd of the emissions arise in the chemical industry, one 3rd in the construction sector and one third in the housing category of household needs.
> Tetrachloromethane is used in extinguishers and as a solvent (BAFU 2010a). It is assumed that the shares of the two applications are 50% each and the further split is in compliance with the descriptions above.

A2-3 NMVOCs and further substances with photochemical ozone creation potential

Environmental relevance

Volatile organic compounds (VOCs) are a group comprising a range of non-toxic to highly toxic and carcinogenic compounds. The Swiss VOC Ordinance (VOC Verordnung, VOCV) defines VOCs as *“organic compounds with a vapour pressure of at least 0.1 mbar at 20 °C or with a boiling point of at most 240 °C at 1013.25 mbar”*. NMVOCs (non-methane volatile organic compounds) are VOCs excluding the gas methane.

Together with nitrogen oxides, NMVOCs are important precursors for photochemical oxidants (giving rise to tropospheric ozone or “summer smog”), which can harm human health and flora. In addition, many VOCs lead to further undesirable impacts upon humans and flora and fauna.

Flow in 2005

Annual NMVOC emissions in Switzerland rose from 70 000 to 324 000 tonnes over the period from 1950 to 1985. Emissions have been dropping since 1985. In 1995 they figured 211 000 tonnes (BUWAL 1991, p. 74). The introduction of the VOC levy in 2000, in combination with increasingly stricter emission rules for vehicles, has contributed to a further halving of emissions to a level of 100 846 t/a (BAFU 2010c; BUWAL 2003b).

Allocation

The NMVOC emissions that are related to the consumption of petrol, diesel, and heating oil are allocated to the economic sectors according to their fuel consumption. The NMVOC emissions from wood firings are allocated according to the sectoral consumption of wood.

NMVOC emissions that stem from the food production, the printing business, refineries, the chemical industry, the metal industry, the primary sector, natural gas pipes (energy distribution), the construction sectors (lacquers and paints), petrol stations (petrol handling), and waste management are identified separately and allocated to the corresponding sectors. Emissions from lacquers and paints that are used in households are allocated to the housing category of household needs, and emissions from the use of equipment in family gardens are allocated to the recreation category of household needs (BAFU 2010c).

A2-4 Nitrogen oxides (NO_x)

Environmental relevance

Nitrogen oxide loads cause many forms of pressure and damage. As a result of their acidifying effect, sensitive ecosystems are severely endangered. Moreover, nitrophilous plants are promoted, which can lead to a reduction of plant diversity and to the loss of ecologically valuable terrestrial and aquatic ecosystems (e.g. oligotrophic grassland and open submerged swards).

Nitrogen dioxide (NO_2) and the secondary particles formed from nitrogen oxides are particularly harmful to human health. Respiratory tract diseases and cardiac disrhythmia are direct effects. Over the longer term, this reduces life expectancy. NO attaches to haemoglobin and thus reduces oxygen transport capacity in blood. Moreover, nitrogen oxides are major precursors in the formation of ground-level ozone, which in turn impairs health.

NO_x appears to at least promote damage to built structures caused by biological processes (dissolution of carbonate materials by nitrifying microflora) (BUWAL 1996; 2005b).

Flow in 2005

Nitrogen oxides are formed above all when fossil energy carriers are burnt. Annual NO_x emissions in Switzerland (measured as NO_2) rose from 31 300 t to 179 000 t over the period from 1950 to 1985. Emissions have been declining since 1985 (BUWAL 1991, p. 72). Thanks to the measures taken, NO_x emissions have dropped substantially. The flow in 2005 was 83 560 t/a (BAFU 2010c). Older publications calculated 91 000 t/a (BUWAL 2005a).

Allocation

Transport is the main source, accounting for 58% of emissions in 2000. Further anthropogenic sources of nitrogen oxides include construction machines and agricultural and silvicultural machines (12%), combustion facilities/furnaces (6%) and certain commercial and industrial processes (24%) (BUWAL 2005b). The nitrogen oxides emissions that are related to the consumption of petrol, diesel, kerosene, natural gas and heating oil are allocated to the economic sectors according to their fuel consumption. The nitrogen oxides emissions from wood firings are allocated according to the sectoral consumption of wood.

Nitrogen oxides emissions from the production of cement and tiles are allocated to the mineral products industry. Those emissions from the combustion of heavy refinery heating oil and liquefied petroleum gas in refineries are related to the corresponding sector. And the specific nitrogen emissions from the primary sector, the construction sector, and the waste management can be identified separately as well and are allocated to the corresponding sectors (BAFU 2010c).

A2-5 Ammonia (NH_3)

Environmental relevance

Ammonia contributes to the acidification and over-fertilization of aquatic and terrestrial ecosystems, leading to longer-term direct and indirect changes to ecosystems. Because of the complexity of the processes, the effects of elevated nitrogen loading are difficult to predict. They include increased sprout growth and greater susceptibility to parasites, and the promotion of nitrophilous plants, thus displacing endemic plant species. Ecosystems recover only very slowly from over-fertilization, if at all (BUWAL 1996; 2005b).

Ammonia also contributes to the formation of secondary particles, which causes human health impacts. Moreover, ammonia in air promotes the formation of sulphuric acid (H_2SO_4) from sulphur dioxide (SO_2) (BUWAL 1996; 2005b).

Flow in 2005

Ammonia emissions rose gradually from the early 20th century onwards, peaking in 1980. Since then, emissions have dropped. In 2005 they totalled 62 596 t NH_3/a (BAFU 2010c). Older publications calculated emissions of 53'400 t NH_3/a (BUWAL 2004b; 2005c).

Allocation

Agriculture is the main source of ammonia, accounting for 93%. Ammonia forms on the one hand in livestock management (animal housing, farmyard manure storage and field application) and, on the other hand, is emitted when mineral nitrogen fertilizers are applied (BUWAL 2005b). According to the BAFU (2010a), other emitters are the chemical industry (1%), the sector of mineral products (5%), and the food industry (1%).

A2-6 SO_2 and further acidifying substances

Environmental relevance

Sulphur dioxide (SO_2) leads to respiratory tract diseases. Through its acidifying effect it also damages plants, sensitive ecosystems and built structures. Moreover, SO_2 is an important precursor of acid precipitation and of aerosols (BUWAL 1995, table 2.1).

Flow in 2005

Annual SO_2 emissions in Switzerland rose from 46 200 to 116 000 tonnes over the period from 1950 to 1980. Emissions have been dropping since 1980 (BUWAL 1991, p. 70). In 2005 they amounted to 16 499 t/a (BAFU 2010c). Older publications calculated emissions of 19 000 t/a (BUWAL 2005c).

Allocation

The SO_2 emissions are split between the economic sector and final demand in accordance with the consumption of different fuels of the sectors. In addition, emissions from the combustion of heavy refinery heating oil and liquefied petroleum gas in refineries are allocated to the corresponding sector. SO_2 emissions from the production of glass, brick and carbide are related to the sector of mineral products. The emissions from aluminium production stem from the metal industry, and the emissions from waste management stem from the disposal sector.

HCl and HF

The emissions of hydrogen chloride and hydrogen fluoride amounted to 560 t and 41 t, respectively, in 2005 (BUWAL 1995). Since these emissions occur in the same combustion processes as the SO_2 emissions, the split up to the different sectors is assumed to be the same.

A2-7 PAHs (polycyclic aromatic hydrocarbons)

Environmental relevance

PAH is an aggregate parameter and stands for polycyclic aromatic hydrocarbons. PAHs have some carcinogenic effects in mammals. They occur exclusively in suspended matter, so the PAH concentration is dependent on the concentration of suspended solids in waters. They arise from combustion processes and runoff from roads.

Flow in 2005

The annual PAH emissions into air amounted to 1.1 t in 2005 (BAFU 2009). Since benzo(a)pyrene which belongs to the PAH group is considered separately, these emissions need to be subtracted from the total PAH emissions. Therefore, the total remaining PAH emissions amounted to 0.91 t in 2005.

Allocation

A major part of the PAH emissions stems from the combustion of fuels and is allocated therefore in compliance with the fuel consumption of the different sectors and the final demand. Other major PAH emissions are identified from the manufacture of basic metals and the primary sector (BAFU 2010c).

A2-8 Benzo(a)pyrene

Environmental relevance

Benzo(a)pyrene (BaP) belongs to the PAH group. BaP is not produced commercially, but is nevertheless widespread, as it is formed in the incomplete combustion of organic material, e.g. in furnaces and engines, but also in cigarettes. The carcenogenicity of BaP has long been proven in experiments on animals, and is probable in humans (IARC Group 2A) (EPA 2006; IARC 1983; UGZ 2003).

Flow in 2005

According to BAFU 2010c, the BaP emissions in 2005 amounted to 199 kg. The same publication also contains detailed information about the sources of the BaP emissions, which is applied for the allocation of the emissions to the economic sectors and the final demand.

Allocation

The BaP emissions from fuel combustion are allocated to the sectors depending on their fuel consumption. Furthermore, major BaP emissions from the manufacture of basics metal and the primary sector are taken into account. BaP emissions from smoking cigarettes are allocated to the recreating category of household demands.

A2-9 Particulate matter (I): PM10, PM2.5 and PM2.5–10

Environmental relevance

Particulate matter (PM) is a mixture that is complex in both physical and chemical terms. It comprises, among other things, soot, geological material, heavy metals, abrasion particles, biological material (e.g. spores) and particles formed in secondary processes in the air (sulphate, nitrate, ammonium, organic carbon) (BUWAL 2001a).

Flow in 2005

For the year 2005, 26 147 tons of **TSP** (total suspended particulates), 21 751 tons of **PM10**, and 10 438 tons of **PM2.5** are reported (BAFU 2010c). The flow for **PM2.5–10** is calculated with the difference of the annual loads for PM2.5 and 10, and figures to 11 314 t. The flow of the dust emissions larger than 10 μm is calculated with the difference of the total dust emissions and the annual loads for PM10 and results to 4396.

Older publications showed 22 000 t/a for **PM10** (BUWAL 2005c) and 12 745 t/a for primary **PM2.5** (Frischknecht et al. 2009).

Allocation

The emissions of particulate matter are allocated to the different sectors and the final demand according to their consumption of different energy carriers. Dust emissions from the manufacture of wood are related to the wood industry. Emissions from the cement industry belong to the sector of mineral products. Agricultural dust resuspension and waste incineration in agriculture and forestry cause particulate emissions that are related to the primary sector. Dust resuspension due to building machines belongs to the construction sector. Abrasion from railway wheels and tracks is allocated to the transport sector. Particulate emissions from illegal waste incineration and fireworks belong to the housing category of household needs.

A2-10 Particulate matter (II): Diesel soot

The sources and impacts of diesel soot are described in the previous section.

Environmental relevance

There is considerable debate on diesel soot at present. This has to do on the one hand with the precise definition (as "elemental carbon" in the present report), and on the other hand with its toxic effects. There are indications that the toxic effect of elemental carbon particles correlates more closely with particle number than with mass. If that is the case, the inventories would need to relate to the particle number. The requisite measurement technology, however, is not yet mature and derivation based on particle number is therefore not (yet) possible.

Flow in 2005

The calculation of the flow in 2005 for **diesel soot** is based primarily on the data given in the BUWAL report UM-136 (BUWAL 2001b), whereby certain updates were performed for road transport, construction machines and aviation. The Swiss Air Pollution Control Ordinance LRV uses the term "diesel soot". In addition to diesel engines, further sources are taken into account in the calculations of which the soot emissions scarcely differ from diesel soot. Following the rules established by SUVA for diesel engines in underground mining, diesel soot is measured as elemental carbon. The emissions of the following processes are taken into account:

- Diesel and internal combustion engines in vehicles (automobiles, buses, utility vehicles, aircraft, ships, locomotives, agricultural vehicles, military vehicles and construction machines)
- Oil and gas firings
- Diesel aggregates
- Gas turbines

Soot emissions from the combustion of wood, coal and wastes are not taken into account. A total current of 3400 t/a results from this calculation.

Soot not included in inventory

So far diesel soot is not inventoried as a separate item in the ecoinvent database or other background data for imports. For consistency reasons we do not include diesel soot in the life cycle inventory developed in this study.

A2-11 Carbon monoxide (CO)

Environmental relevance

CO is a colourless, odourless and tasteless gas. It is toxic when inhaled; low concentrations in the inhaled air already significantly reduce the oxygen transport capacity in the human body (BUWAL 1995).

Flow in 2005

Carbon monoxide is an air pollutant that is formed in incomplete combustion processes. CO emissions can also arise naturally from the chemical transformation processes of micro-organisms (e.g. oxidation of methane). The total emissions in 2005 were 342 864 t/a. Older publications estimated carbon monoxide emissions of 369 000 t/a (Frischknecht et al. 2009).

Allocation

Motor vehicle traffic generates around a half of all anthropogenic emissions (BUWAL 1995, p. 77). Further information is available for the share of industry, primary sector and households. The carbon monoxide emissions that are related to the consumption of petrol and diesel are allocated to the economic sectors according to their fuel consumption. The carbon monoxide emissions from wood firings are allocated according to the sectoral consumption of wood. Carbon monoxide emissions that stem from the primary sector, the construction business and the production of mineral products are identified separately and allocated to the corresponding sectors. Emissions that are emitted by equipment in family gardens are allocated to the recreation category of household needs (BAFU 2010c).

A2-12 Benzene

Environmental relevance

Inhalation is the main exposure route for benzene. Benzene is soluble in fat and is therefore stored in the fatty tissue of the body. As women have a higher body fat ratio than men, the impacts of this pollutant are greater for women. Individuals living or working near to highly frequented roads or petrol stations are also more greatly exposed. Uptake via the skin is only relevant where benzene is handled directly (BUWAL 2003d).

Benzene is toxic to blood formation and chronic exposure can lead to leukaemia. There is unequivocal evidence that benzene is carcinogenic, and strong indications that it is mutagenic. There is no threshold below which exposure to benzene presents no hazard to human health (BUWAL 2003d).

Small quantities of benzene are already present in crude oil. Further quantities are formed when mineral oil is refined and when organic matter is burnt incompletely (e.g. in forest fires). Emissions of benzene to the atmosphere result primarily from combustion processes. In Switzerland, motorized transport is the source of three-quarters of all benzene emissions. The remainder is attributable to wood- and oil-fired heating systems, and to losses in fuel handling and storage (BUWAL 2003d).

Flow in 2005

Emissions in 2000 figured approx. 1370–1430 t/a. A reduction to half this level (680–740 t/a) by 2010 is expected, primarily in the transport sector due to tightened exhaust standards (BUWAL 2003d). The mean value of the years 2000 and 2010 is used here as the flow for 2005, i.e. 1055 t/a.

Allocation

Since three-quarters of all benzene emissions in Switzerland stem from motorized transport, those emissions are distributed to the different sectors depending on their fuel consumption. The remainder that is attributable to wood- and oil-fired heating systems and to losses in fuel handling and storage is distributed depending on the sectors’ consumption of heating oil and wood.

A2-13 Dioxins and furans (PCDD/PCDF)

Environmental relevance

Dioxins and furans (PCDD and PCDF) are chlorinated aromatic hydrocarbons, some of which are highly toxic to humans and animals. There are in total 76 dioxins and 135 furans. They are formed in technological but also in natural combustion processes in the presence of chlorine. These processes always generate a mixture of various individual substances, expressed as a "dioxins and furans" aggregate parameter (PCDD/F) in international toxicity equivalents (I-TEQ).[22] They accumulate in the food chain and are also embryotoxic. Dioxins impair embryonal development in several ways. In particular, they appear to give rise to miscarriage, deformity of (genital) organs, and intellectual deficits (BUWAL 1995; Lippmann 2000).

Dioxins and furans are scarcely volatile; their dispersal is mainly through attachment to particles. The main exposure route is via the ingestion of foods containing fat. In 1990, the WHO set the limit value for the acceptable daily intake (ADI) by humans at 10 pg 2,3,7,8-TCDD-eq per kg body weight. Based on more recent findings, the Dutch health ministry has proposed reducing the ADI limit value to 1 pg I-TEQ/kg body weight. The daily dioxin and furan intake of individuals in Western Europe is between 0.3 and 2 pg I-TEQ per kg body weight. Thanks to the drop in emissions, a reduction of the daily dioxin and furan intake can be expected (BUWAL 1997).

The guideline value for dioxins and furans in soil, which is 5 ng I-TEQ/kg, is not exceeded in Switzerland, except in soils subject to major anthropogenic impact.

Flow in 2005

Before 1955, dioxin and furan emissions were below 40 g I-TEQ/a. They rose between 1955 and 1980 to a level of 485 g I-TEQ/a. Since then they have been dropping thanks to improved exhaust purification technology, as today all municipal waste incineration plants are fitted with a flue gas purification system (BUWAL 2003c). In 2000 they amounted to 70 g I-TEQ/a, whereby almost half of the emissions (30 g I-TEQ/a) were generated by households (BUWAL 1997). In 2005, the dioxin and furan emissions amounted to 18.6 g/a (BAFU 2010c).

Older publications calculated the emissions in 2005 as the mean of the emissions in 2000 and those expected for 2010, i.e. 67.5 g I-TEQ/a (Frischknecht et al. 2009).

Allocation

About one third of the dioxin emissions stem from the disposal sector. The emissions from the illegal waste combustion are allocated to the housing category of the household needs. The dioxin emissions from metal casting belong to the metal industry, whereas those emissions from accidental fires of buildings are related to the occupation of land that is covered with buildings, since these figures represent the sectors' share of the total buildings in Switzerland. Emissions that are related to the consumption of specific fuels are allocated according to the sectoral fuel consumption (FOEN/BAFU 2010c).

22 I-TEQ: International toxicity equivalent is a weighting factor that aggregates the various dioxins and furans in accordance with their respective toxicities. The factor 1 is assigned to the Seveso dioxin 2,3,7,8-TCDD.

A2-14 Lead (Pb)

Environmental relevance

Lead exposure damages animals and plants, and impairs soil fertility. Lead accumulates in food chains. It can impair blood formation and can cause developmental disorders in children (BUWAL 1991, p. 29).

Flow in 2005

Because lead was blended into petrol, lead emissions rose sharply from the 1950s onwards. They peaked at 2160 t/a in 1970. Thanks to the introduction of unleaded petrol, emissions have dropped again since then. Further uses of lead include batteries, paints and lead for bullets. Total emissions figured 226 t/a in 1995. In 2005, the total lead emissions amounted to 26.5 t/a (BAFU 2010c).

Allocation

BAFU (2010c) also gives detailed information about the sources of the lead emissions, on which the allocation to economic sectors and final demand is based. Besides the emissions that are related to fuel consumption, emissions from accidental fires (e.g. of buildings), from the production of tiles, glass, cement, and steel, and from legal and illegal waste incineration as well as from fireworks are also important. The former is allocated according to the occupation of land covered with buildings. The production of glass, tiles and cement belongs to the sector of mineral products, and the production of steel belongs to the metal industry. The legal waste incineration is part of the disposal sector, whereas the emissions from the illegal waste incineration are related to the housing category of household needs. Finally, the emissions from fireworks are allocated to the recreating category of household needs.

A2-15 Cadmium (Cd)

Environmental relevance

Even small quantities of cadmium are toxic to humans and animals if exposure is chronic. Attached to aerosols, cadmium is resorbed particularly readily in the lungs. It is bioaccumulative, and, moreover, disturbs storage of vital metals in the body. Cadmium is also carcinogenic. The consequences of chronic cadmium exposure can include diseases of the respiratory tract, kidney damage, and anaemia due to iron deficiency. Moreover, it is toxic to plants and microorganisms and impairs soil fertility (BUWAL 1991, p. 30).

Flow in 2005

Cadmium emissions peaked at 7 t/a around 1970. As a result of measures taken in waste incineration and in the metal industry, they have dropped substantially since 1980. The main applications of cadmium are alloys and the production of dry batteries and colouring pigments. In 1995 emissions amounted to approx. 2.5 t/a (BUWAL 1995, p. 90).They further decreased to 1.3 t/a in 2005 (BAFU 2010c).

Allocation

Cadmium emissions are related to the consumption of different fuels and allocated accordingly. Furthermore, cadmium emissions arise from accidental fires (e.g. of buildings), from the combustion of heavy refinery heating oil and liquefied petroleum gas in refineries, from the sector of mineral products, from the metal industry, and from the disposal sector (BAFU 2010c).

A2-16 Mercury (Hg)

Environmental relevance

Mercury is highly toxic to humans and animals. It is taken in via the respiratory tract and accumulates in various organs. It is also toxic to plants and microorganisms and impairs soil fertility (BUWAL 1995).

Flow in 2005

Industry and commerce are the principal generators of mercury emissions. In the past, municipal waste incineration plants were a further important source, but their emissions have been reduced substantially through improved flue gas purification. Switzerland reported annual emissions of 1020 kg Hg to the United Nations for 2004.[23] For the year 2005, BAFU (2010c) reports 1139 kg Hg.

Allocation

Mercury emissions are related to the consumption of different fuels (mainly heating oil) and allocated accordingly. Furthermore, mercury emissions arise from accidental fires (e.g. of buildings), in cement production (sector of mineral products) and in steel production (metal industry), as well as in waste incineration and in crematories (disposal sector) (BAFU 2010c).

A2-17 Zinc (Zn)

Environmental relevance

Zinc loads impair plant growth (BUWAL 1991, p. 29).

Flow in 2005

Until the 1970s, zinc emissions came mainly from steelworks and from the unfiltered burning of wastes. Total emissions peaked in 1970 at 1750 t/a. In 1995, approx. 630 t were still emitted, whereby dropping emissions in industry and commerce were partly compensated by rising zinc emissions from road traffic (tyre and road abrasion). A further drop to 560 t/a is taken as the figure for 2005, whereby the transport sector is now the main source, accounting for two-thirds (BUWAL 1995, p. 88). If the trend towards increasing zinc emissions from transport persists, it must be expected that overall zinc emissions rise again, as no further significant reductions are to be expected in industry.

Allocation

The two-thirds of the zinc emissions that stem from traffic are allocated to the different sectors according to their consumption of petrol and diesel. The remainder is split up into a share of emissions from steelworks (metal industry) and emissions from waste incineration (disposal sector).

[23] Personal communication by N. Egli, FOEN, 3 November 2006

A3 Emissions to surface waters

A3-1 Nitrogen

Environmental relevance

Over 90% of anthropogenic total nitrogen in surface waters consists of nitrate and ammonium or ammonia. Sources of nitrogen in waters are agricultural fertilizers and industrial, commercial and household effluents. The figures in this chapter only evaluate the nitrogen loads in surface waters. Nitrogen compounds (notably nitrate), which are first released into groundwater and enter surface waters from there, are assessed separately in the chapter on groundwater.

In present quantities nitrate no longer represents a general problem for the ecology of surface waters in Switzerland, although a few local problems may persist. However, the nitrogen load in the North Sea and other shallow seas is of great importance with regard to eutrophication. The aim, therefore, is to achieve a marked reduction in the nitrogen discharged into the North Sea, including by reducing loads in the Rhine (BUWAL 1996).

Flow in 2005

The assessment of the flow in 2005 is based on the nitrogen discharge into the Rhine catchment according the model developed by Prashun et al. (2005) extrapolated to the whole of Switzerland using the ratio of Rhine catchment runoff to total Swiss runoff.

The nitrogen load for the Rhine catchments amounts to 30 556 t N/a. Runoff via the Rhine amounts to a long-term average of around 38 bn. m³/a, and the total for Switzerland to 48 bn. m³/a. This produces an extrapolated load of 38 597 t N/a for the whole of Switzerland.

Since the reduction target refers only to emissions in the Rhine catchments within Switzerland (see next paragraph on critical flows), the flow in 2005 must cover the same area. According to the OSPAR Commission (2006) the flow in 2005 amounts to 24 827 t N/a.

Allocation

The nitrogen emissions into water are split up according to a study of the Canton of Berne (GSA & GBL 2003), which states that 68.5% of the emissions stem from the primary sector and 31.5% stem from sewage plants, which belong to the disposal sector.

A3-2 Phosphorus

Environmental relevance

The phosphorus load is more critical for lakes (and seas) than for rivers, as in standing waters it is mostly the amount of phosphorus available which represents the limiting factor for algal growth. Algal growth elevated by phosphorus causes sedimentation and the increased aerobic decomposition of this biomass, leading to oxygen deficiency and fish mortality in the deep water of lakes (BLW & BUWAL 1998).

The phosphorus load in lakes varies enormously according to location. Alpine lakes (e.g. Lake Lucerne, Lake Thun) exhibit very low concentrations, whereas lakes in areas of intensive farming can still be severely polluted by the phosphorus that is applied to the fields in manure and synthetic fertilizers. The connection of households and businesses to sewage treatment works and the ban on phosphates in textile detergents has led to a marked drop in the phosphorus load over the last two decades (BLW & BUWAL 1998; BUWAL 2004a).

Phosphorus is released into waters as particle-bound phosphate, mainly through erosion and leaching from cropland. The still substantial contribution of agriculture to the loads is also a consequence of liberal use of fertilizers in the past. Thus agricultural land in Switzerland registers a phosphorus content far in excess of the plants' annual requirements. In integrated production systems it is now only permitted to use as much phosphorus as the crops can take up, which has improved the situation somewhat (BUWAL 2004a). The ChemRRV (Chemical Risk Reduction Ordinance) also contains regulations on permitted applications of compost, fermented material and silage effluent, which should result in further improvement.

Flow in 2005

The amount of phosphorus discharged into surface waters in the whole of Switzerland can only be estimated, as the runoff from agricultural land, which accounts for a significant proportion, is impossible to measure. Phosphorus entering the waters is absorbed by aquatic plants and eventually deposited through sedimentation of the biomass.

Assessment of the flow in 2005 is based on the phosphorus entering the Rhine catchment according to the model developed by Prashun et al. (2005) and extrapolated to the whole of Switzerland using the ratio of Rhine catchment runoff to total Swiss runoff. The most recent figures (2003) are published in OSPAR Commission (2006).

The phosphorus load for the Rhine catchments amounts to 1341 t P/a. Runoff via the Rhine itself amounts to a long-term average of around 38 bn. m^3/a and that from the whole of Switzerland to 48 bn. m^3/a. This produces a phosphorus load of 1694 t P/a for the country as a whole.

Allocation

According to Binder (2009) the shares of phosphorus emissions from agriculture and from sewage plants (disposal sector) are equal.

A3-3 Organic matter (BOD, COD, DOC, TOC)

Environmental relevance

BOD (biochemical oxygen demand), COD (chemical oxygen demand), DOC (dissolved organic carbon) and TOC (total organic carbon) are parameters for the concentration of organic matter in waters. These organic substances originate in part from natural sources and in part from wastewater. In essence all organic substances pollute waters in that they consume oxygen, thus restricting the habitat of the fauna that depends on it. In addition to this, many substances (such as chlorinated organic compounds or endocrine substances) can have specific toxic impacts, which should be recorded separately (Kummert & Stumm 1989; Sigg & Stumm 1989).

The pollution of Swiss waters has fallen in recent decades, owing to measures to improve effluent treatment. Moreover, the legislation (WPO) requires implementation of measures to reduce organic endocrine substances in effluent to a level at which there is no ecological detriment to waters. In most cases the residual load from effluent treatment works is non-critical in terms of the total oxygen available. Of foremost environmental importance, therefore, are persistent, bioaccumulative and toxic organic substances. However, the specific impacts of the substances encompassed by the aggregate parameter “organic matter” cannot be considered here.

The concentration of organic matter in waters can be recorded using the parameters COD, DOC and, where necessary, TOC.

BOD (biochemical oxygen demand)
BOD_x expresses the amount of oxygen consumed by biological activity in water in **x** days. Incubation takes place in the dark, at 20 °C and normally over a period of 5 days (BOD_5). The proportion of hydrocarbons, which break down readily, particularly through microbial degradation, is determined from this. The BOD value is always lower than that for COD. Usually BOD_5 is determined.

COD (chemical oxygen demand)
COD expresses the amount of oxygen required to oxidize organic compounds. In Switzerland COD is used principally to determine the quality of the discharge from water treatment works (effluent parameter). In most other countries pollution of waters with organic substances is assessed in terms of COD. Many life cycle inventories contain figures for COD emissions.

DOC (dissolved organic carbon)
DOC measures the bound organic carbon content of dissolved organic compounds. This measurement produces more exact results than the COD test when dealing with small concentrations such as those in Swiss watercourses (clean water parameter).

TOC (total organic carbon)
TOC is a measure of the total carbon bound in organic molecules. It is made up of dissolved organic carbon and particle-bound organic carbon.

Since many life cycle inventories state COD values, an eco-factor has been derived for it. If necessary DOC can be converted into COD using the estimation factor COD (in g) $\approx$ 3 DOC (in g). A lower estimate for COD can also be derived from BOD, with COD (in g) = BOD (in g). If only the TOC value has been measured, this can be regarded as equivalent to DOC for the purpose of a rough approximation, hence COD can be estimated with COD (in g) $\approx$ 3 TOC (in g) (Brand et al. 1998).

The total load cannot be extrapolated from the COD concentrations at the places where the large rivers flow out of Switzerland, as firstly some of the organic substances are of natural origin and secondly organic substances degrade to some extent relatively quickly in watercourses and do not reach the measuring stations at these runoff points.

The loads from sewage treatment works and agriculture have been determined for the canton of Berne. Dinkel et al. (2004) have extrapolated the total Swiss flow of 47 700 t COD/a from this data.

Flow in 2005

It is assumed that the shares of emissions from agriculture and from sewage plants (disposal sector) are about equal.

Allocation

A3-4 Heavy metals and arsenic

Heavy metals and arsenic damage the aquatic ecosystem by accumulating in organisms, where they can cause growth impairments and metabolic disturbances. They are able to propagate through the food chain. However, these substances do not represent a major problem in Switzerland.

Environmental relevance

Arsenic is carcinogenic to humans (IARC group 1). It causes skin and bladder cancer in particular, but other types of cancers as well, through chronic exposure via drinking water (IARC 1987). Arsenic arises as a by-product of metal extraction, but is also used in industrial processes such as glass production and as gallium arsenide in electronic equipment. In some countries (for example, Bangladesh and Vietnam) even natural sources can lead to concentrations in drinking water that are harmful to health (Lippmann 2000).

Flow in 2005

The total load of heavy metals entering surface waters in Switzerland can be extrapolated from the concentration values measured in the Rhine.

In Weil am Rhein heavy metal concentrations in the water are determined in accordance with NADUF (Swiss National River Monitoring and Survey Programme) regulations (BUWAL et al. 2000), and the heavy metal content of suspended matter is measured according to the International Commission for the Protection of the Rhine (IKSR 2004). In order to compensate for the occasional wide variations in concentration from one year to another and obtain more representative values, the average for the years 2001 to 2004 has been used in each case (Tab. 16).

The following factors could account for any difference between the actual situation and the extrapolated flow:

- the total concentration of heavy metals rises with the concentration of suspended matter, since the metals accumulate there. In the Rhone, which registers comparatively high particle concentrations, concentrations of heavy metals may therefore exceed those in the Rhine.
- the Rhine may exhibit above-average mercury loads on account of the structure of industry in the catchment.
- between entering the water and being measured in Basel the heavy metals undergo some degree of exchange with the sediment. Depending on the concentration ratios in the river and the sediment net heavy metals are either dissolved or deposited.

Tab. 16 > Calculation of the flow of heavy metals based on NADUF concentration figures (mean value for the years 2001 to 2004) at Weil am Rhein monitoring station

	Average concentration in the Rhine [g/s]	Annual flow [t/a]
Arsenic (As)	0.188*	8.6*
Lead (Pb)	0.704	32
Cadmium (Cd)	0.0134	0.61
Chromium (Cr)	0.555	25
Copper (Cu)	1.61	74
Nickel (Ni)	1.84	84
Mercury (Hg)	0.0044	0.20
Zinc (Zn)	3.65	167

* Arsenic values calculated from ICPR (2004) concentration figures and the assumption of 17.9 kg of suspended solids/s (mean value for the years 2001 to 2004 based on NADUF)

Allocation

Not much direct information for the industrial sectors causing these emissions was available. It can be assumed that a part of these emissions is not directly emitted into water, but results as a wash out of air or soil emissions. Some information can be derived from the Swiss database of pollutant release and transfer register SwissPRTR (BAFU 2010a).

Zinc and copper come from roof runoff and the use of pipes made of these metals to carry the drinking water supply. In addition zinc is released through tyre wear and enters waters via road runoff. Copper is also used as a fungicide in vineyards and as a food supplement in pig rearing.

Cadmium is an ingredient of phosphorus fertilizers and pesticides, meaning that agriculture is another source of heavy metals. Chromium arises mainly from the corrosion of chromium steel products. Since the use of leaded petrol has declined and industrial effluent discharges have been cleaned up these have now become the predominant sources of heavy metals (BUWAL et al. 2000). The chromium emissions that arise from the wash out of wood preservatives in power poles are described in the section about emissions to soil.

The allocation of the heavy metal emissions to the different economic sector has been checked for the LCI data established for the import data sets within this study. This reveals that mining, fertilizer application, chemical industry, metalworking and disposal activities are important sources, but several of these activities do not directly take place in Switzerland.

We could allocate the emissions thus only very roughly using the information described above and information from BAFU (2010a). Arsenic emissions are roughly shared between agriculture (45%) and disposal activities (45%) as well as the energy sector (8%) and the chemical industry (2%). For lead, it is assumed that roughly 5% stem directly from the chemical industry and 5% from the disposal sector based on information from BAFU and for the remaining 90% we take the average share of air and soil emissions. Chromium emissions are shared equally between metalworking, the energy sector, the primary sector, and the disposal sector. Nickel emissions are shared equally between the metal industry, the sector of metal products, the chemical industry, the energy sector and the disposal sector. The mercury emissions arise from the chemical industry (40%), the disposal sector (40%), and the energy sector (20%).

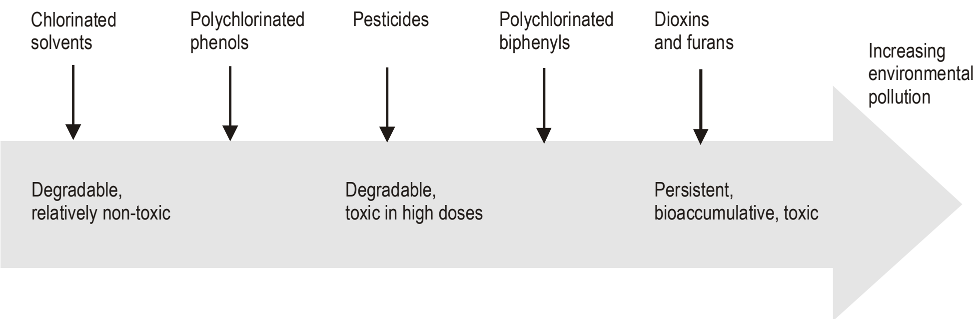
A3-5 AOX (adsorbable organic halogenated compounds)

Environmental relevance

AOX (adsorbable organic halogenated compounds) is an aggregate parameter including halogenated (mostly chlorinated) organic substances. Materials of both anthropogenic and natural origin, such as chlorinated non-aromatic hydrocarbons (e.g. chloroform), chlorinated aromatic hydrocarbons, polychlorinated biphenyls (PCBs) and certain pesticides fall into this group.

The toxicity and environmental impact of the compounds in the AOX group varies widely. An important criterion for toxicity is the ability of the substance to accumulate in an organism. This is possible for fat-soluble substances. The greater the chlorination, the more toxic the substance, as they are fat-soluble and thus bioavailable. Fig. 50 shows the rough classification of the AOXs according to their environmental impacts.

Fig. 50 > Rough classification of various AOXs according to their environmental impacts



Flow in 2005

AOX pollution of surface waters in Switzerland has fallen significantly in recent years and has lost much of its importance regarding water protection. Furthermore, the creation of an eco-factor for AOXs is a compromise. The weighting of very different toxic substances with a common eco-factor can lead to inaccurate statements in respect of environmental pollution. Nevertheless an eco-factor is derived for AOXs, partly because life cycle inventories often still state this value and partly because subdividing AOXs into distinct, homogeneous substance classes or even individual substances is only practicable to a limited extent. In this case too there has been a marked fall in pollution in the intervening period, owing to a ban on its use.

Measurements taken at the Rhine monitoring station at Weil am Rhein (AUE 2005) show AOX concentrations of between 3.2 and 8.5 µg Cl^-/l with a mean value of 6.0 µg Cl^-/l. The substances included in the AOX aggregate parameter degrade by very varying degrees. Extrapolating the concentrations measured to total Swiss loads[24] produces a lower limit of 288 t Cl^-/a for the loads measured.

Allocation

The Swiss Pollutant Release and Transfer Register (BAFU 2010a) contains information about 19 070 kg Cl^- emitted in 2008. According to this source, 27.2% of the AOX emissions are emitted by the sewage and disposal sector, 72.2% by the processing of pulp and paper, and 0.6% by the chemical industry.

A3-6 Chloroform

Environmental relevance

Chloroform is a substance in the AOX group (see previous sub-section), which was formerly in widespread use in dry cleaning, as a solvent, and as a disinfectant, amongst other things. ChemRRO[25] prohibits both the distribution and use of chloroform. Exceptions to this include the use in closed industrial processes, such as in the manufacture of CFC-22. Chloroform is produced as a by-product of chlorination of, for example, drinking water (EPA 2000; IARC 1999; Lippmann 2000).

In animal experiments chloroform emerged as a carcinogen, although to date there is insufficient evidence of this effect in humans. The IARC classifies chloroform as Group 2B (possibly carcinogenic in humans) (IARC 1999).

Flow in 2005

The total load for Switzerland is estimated from the total Swiss runoff (48 bn. m³) and the concentration readings at Weil am Rhein (0.04 µg/l) according to AUE (Amt für Umwelt und Energie, the Basel department for energy and the environment 2005). Based on these values the load amounts to around 1.9 t chloroform/a.

Allocation

The chloroform emissions are allocated to the economic sectors and the final demand with the same shares as the other AOX emissions.

A3-7 PAHs (polycyclic aromatic hydrocarbons)

Flow in 2005

The calculation of Switzerland's total discharge to waters is extrapolated from the concentration in the Rhine at Weil am Rhein monitoring station. The concentration for four PAHs[26] measured gives a reading of < 0.003 µg/l (this is excluding benzo(a)pyrene, as this is assessed separately in the next Section). The estimate is based on 0.003 µg/l, which, with the runoff of 48 bn. m³/a from Switzerland results in a load of 144 kg/a.

Allocation

Since the PAH emissions into water mainly stem from runoff from roads, they are allocated to the different sectors and the final demand depending on their consumption of petrol and diesel.

[24] Assuming a runoff of 48 bn. m³/a for the whole of Switzerland
[25] Swiss Chemical Risk Reduction Ordinance (Chemikalien-Risikoreduktions-Verordnung, ChemRRV)
[26] Benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene

A3-8 Benzo(a)pyrene

Flow in 2005

Sources relevant to water bodies are wood preservatives containing creosote, used for instance on railway sleepers. Creosote contains benzo(a)pyrene, which over time is washed out and enters waters. ChemRRO[27] now prohibits the use of creosote in wood preservatives for territorial purposes, although it is permitted for commercial applications, provided that the benzo(a)pyrene content is less than 50 mg/kg.

The load in waters is estimated from concentration readings at Weil am Rhein. The average concentration measured is 0.001 µg/l (IKSR 2004), which with a runoff of 48 bn. m³ produces an estimated load of 48 kg/a.

Allocation

It is estimated that 1/6th of the BaP emissions stem from runoff from roads which is allocated to the final demand and the economic sectors based on their fuel consumption, 50% of the emissions stem from the economic transport sector (wood preservatives in railway sleepers), 25% stem from housing category of household needs (wood preservatives in buildings), and 1/12th stem from the recreation sector of household needs (cigarettes smoking).

A3-9 Endocrine disruptors

Environmental relevance

Hormones are chemical messengers between tissues and cells that regulate processes in the body. Sex hormones play an important role in reproduction and the development of an organism. Hormones are already effective in very small concentrations (BUWAL 1999; SNF 2002).

Endocrine disruptors are hormonally active exogenous substances, which attack and disrupt one of the various hormone systems. In humans especially, substances which interfere with the reproductive endocrine systems are linked to developmental abnormalities of embryos in the womb, reduced fertility, and breast, testicular and prostate cancer. Fertility disorders have been proven in numerous animal species – aquatic and terrestrial (BUWAL 1999; SNF 2002). There are also indications that elevated amounts of endocrine disruptors (notably PCBs) in otters' prey have led to reproductive problems which have made the long-term survival of this species in Switzerland impossible (BUWAL 1999).

Endocrine disruptors can operate in two ways:

1. They bind to hormone receptors and so imitate (or impede) the effect of the body's own hormones.
2. They disrupt the production or breakdown of the body's own hormones, or inhibit their transportation.

[27] Ordinance on the reduction of risks in dealing with specific particularly hazardous substances, preparations and objects (Verordnung zur Reduktion von Risiken beim Umgang mit bestimmten besonders gefährlichen Stoffen, Zubereitungen und Gegenständen)

Substances which attack the reproductive endocrine system have the potential to cause oestrogenous effects (the same effect as the female sex hormone oestrogen) and androgenous effects (the same effect as the male sex hormone androgen), as well as anti-oestrogenous and anti-androgenous effects (BUWAL 1999).

In humans intake of endocrine disruptors is principally via the digestive tract, the skin or the lungs, while aquatic organisms absorb them mainly from the water. As certain types of hormone receptor occur throughout the animal kingdom, a very large number of species can be affected by a single endocrine disruptor (SNF 2002).

Concentrations of endocrine disruptors have been found which are sufficiently high to trigger oestrogenous (feminizing) effects in male fish (BUWAL 1999), in particular close to the water discharge points of sewage treatment plants.

Hormonal effects have been proven in the case of the following substances and substance groups (BUWAL 1999; SNF 2002):

> natural (e.g. 17β-oestradiol, oestrone) and synthetic oestrogens (e.g. 17α-ethinylo-estradiol)
> phyto- und myco-oestrogens (e.g. isoflavones)
> alkylphenol polyethoxylates (APEOs) and byproducts (e.g. nonylphenol, octylphenol)
> various organochlorate pesticides (e.g. DDT, methoxychlor, lindane und kepone)
> certain industrial chemicals used in plastics (e.g. bisphenol A, PCBs and possibly phthalate)
> various polychlorinated dibenzo-p-dioxins and furans (PCDDs/PCDFs)
> organotin compounds used among other things in antifouling ship paints (e.g. tributyltin (TBT) und triphenyltin (TPT))
> certain UV filter substances contained in sun lotions (presumed in the case of 4-methylbenzylidene camphor)

It should be noted here that there are as yet no standardized and validated tests to identify a chemical as an endocrine disruptor. Many of the chemicals presently on the market have not been tested for effects of this type.

Flow in 2005

The discharge of endocrine disruptors from anthropogenic sources to surface waters can be extrapolated from concentration measurements in the outfall from sewage treatment plants. Based on the estimated average concentration of endocrine disruptors in the runoff from treatment plants in Tab. 17 and the total runoff from all Swiss treatment plants of 1511 million m³/a (BUWAL 2000a) the load for Switzerland is calculated at 5.0 kg E2-eq./a.

Tab. 17 > Concentration data for the oestrogenic potential of three treatment plants and the weighted average from two of these

Treatment plants	Discharge from plants [m³/d]	Oestrogenic potential		
		Minimum [ng E2-eq./l]	Maximum [ng E2-eq/l]	Mean* [ng E2-eq./l]
Rontal **	8200	0.4	(53)	
Glatt	45000	2.4	5.5	3.95
Surental	15000	0.5	2.2	1.35
Glatt & Surental	60000	1.93	4.68	3.30

Source: Aerni et al. (2004)
* own calculation from minimum and maximum values
** not used for the calculation, as the maximum value shown is an anomaly and would have skewed the result.

Allocation

Since the estradiol emissions are directly related to the consumption of medical drugs, they are allocated to the health care category of household demands, even though they usually enter the water reservoirs through a sewage plant.

It has to be noted that these emissions are so far not covered in the LCA background database. Thus, they will not show up with products and services imported to Switzerland.

A4 Emissions to groundwater

More than 80% (1 bn. m³/a) of Switzerland's drinking water supply comes from groundwater (BUWAL 2003a). Groundwater is therefore particularly important and justifies quality requirements relating specifically to its use, which are stricter than for surface water.

The boundaries between groundwater and surface water are very porous. Water, which initially enters groundwater via precipitation and drainage, will sooner or later reach surface waters, either through natural processes or via groundwater use.

Only nitrate is assessed, as this is the only substance for which relevant data is presently available.

A4-1 Nitrate in groundwater

Environmental relevance

Especially in areas where farming practices are intensive nitrate concentrations in groundwater often exceed the required limits for groundwater that is used or reserved for use, and in some cases even exceed the tolerance value for drinking water. Nitrogen fertilizer applied to fields is readily washed from the soil into groundwater.

Flow in 2005

According to BUWAL (1996) the nitrate discharged into groundwater amounts to 34 000 t N/a (1994 figure). As other nitrogen compounds are only present in small quantities, this flow can be used not only for nitrate, but also for nitrogen loads in general.

Allocation

It is assumed that all nitrate in groundwater stems from the primary sector.

A5 Emissions to soil

A5-1 Heavy metals in soils

Environmental relevance

Heavy metals impair plant growth, disturb soil fertility and can accumulate in food chains. A high intake of a range of heavy metals with food (plants build available heavy metal into their biomass) over a long period can lead to chronic poisoning (BUWAL 1995). Moreover, major resource inputs are required to clean up soils contaminated with heavy metals.

The flow in 2005 is extrapolated with the surface area according to the Ordinance on Soil Pollution (Keller et al. 2005). The surface area in the Ordinance has been determined from the categories wooded areas, agriculturally utilized areas and unproductive vegetation in the Swiss Land Use Statistics (BFS 2001) and covers 3.06 million hectares (around three quarters of Switzerland). It has also been taken into account that heavy metal inputs via pesticides, fertilizers and sewage sludge occur primarily on land used for agriculture (around 1.5 million hectares, over which loads may be subject to wide regional variations), whereas deposition from the atmosphere affects all types of land (Tab. 18).

Tab. 18 > Calculation of the heavy metal input into soils based on the values for atmospheric deposition and on direct loading via pesticides, manure, mineral fertilizers and sewage sludge

	Deposition [g/(ha*a)]	Direct input [g/(ha*a)]	Annual flow [t/a]
Lead (Pb)	22	8.25	79.9
Cadmium (Cd)	0.7	0.55	2.98
Copper (Cu)	5.05	68.4	120
Zinc (Zn)	96.8	376	870

Flow in 2005

The flow in 2005 of heavy metals to soils is made up of non-point input via the atmosphere and direct input through fertilizers (especially compost) and plant protection products.

Eight heavy metals together with fluoride have been recorded at 105 different sites by the Swiss Soil Monitoring Network NABO. Of the heavy metals regulated by the Ordinance on Soil Protection (VBBo), only molybdenum is not measured by NABO. The measurements enable an inventory and evaluation of the current heavy metal load in soils to be performed (BUWAL 2000b).

In connection with the NABO monitoring programme Keller et al. (2005) have established detailed substance inventories for lead, cadmium, copper and zinc on 48 selected representative areas of land. The median[28] of these values has been used as the flow in 2005 for heavy metals.

[28] Using the median reduces the influence of individual extreme values (e.g. owing to the application of copper as a pesticide in vineyards) on the calculation of the current flow, compared with the mean value.

Allocation

All lead, cadmium and zinc emissions are allocated to the primary sector. According to von Arx (2006), 74.5% of the copper emissions into soil stem from the primary sector (use of fertiliser and pesticides), 14.1% stem from the abrasion of railways and are allocated to the transport sector, 5.5% stem from bullets used by the army and are allocated to the public administration, and 5.9% stem from the use of pesticides, fertilisers, and impregnated wood in family gardens and home and are allocated to the housing category of household needs.

A5-2 Wash out from power poles

Flow in 2005

In addition to the heavy metal emissions into agricultural soil described above, chromium, copper, boron, and fluoride emissions into industrial soils arise from the wash out of wood preservatives in power poles, as described by Frischknecht et al. (2007a). They calculated the content of chromium, copper, boron, and fluoride in the annual amount of applied wood preservatives in power poles (see Tab. 19). In order to obtain the annual emissions of these elements, the element specific wash out rates in Tab. 19 are applied, which are based on averages of three different publications.

Allocation

The emissions from the wash out of power poles are fully allocated to the energy sector.

Tab. 19 > Calculation of emissions from wash out of wood preservatives in power poles

In addition to the heavy metal emissions into agricultural soil described above, chromium, copper, boron, and fluoride emissions into industrial soils arise from the wash out of wood preservatives in power poles and are recorded according to this table.

	Total content in wood preservative of power poles	Content in wood preservative of power poles (converted to a power pole life time of 30 a)	Wash out rate [1]	Wash out rate [2]	Wash out rate [3]	Wash out rate in this study	Total emissions from wash out of power poles
	t	t/a	%	%	%	%	t/a
Chromium VI	2330	77.67	60%	5%		33%	25.2
Copper	1164	38.80	75%	7%	21.2%	34%	13.3
Boron	260	8.67	95%	90%		93%	8.0
Fluoride	1108.75	36.96	80%	60%		70%	25.9

1: Frischknecht et al. 2007a
2: Schadstoffberatung Tübingen, Retrieved 01.08.2010 from URL: www.schadstoffberatung.de/holzschz.htm
3: Technical book “Holz, Mensch und Natur”, Retrieved 01.08.2010 from URL: www.laermschutz-hs.de

A5-3 Plant protection products (PPPs)

Environmental relevance

According to the Ordinance on plant protection products (Pflanzenschutzmittelverordnung, PSMV)[29], such products include crop protectant, plant development regulators and post-harvest protection products. These can be substances, preparations, organisms or other agents. One of their purposes can be to destroy undesired plants or parts of plants. The eco-factor assessment mainly addresses chemical-synthetic plant protection products. The environmental problems associated with their use are a function of the primary effects, the quantities applied, the rates of degradation and dispersal behaviour (mobility) of the active agents, and the types and behaviour of degradation products and residues.

Plant protection products are applied above all in open arable farming, and in specialist fruit growing and viticulture. Their use on grassland is minimal (BLW 2000). Some pesticides are used by the Swiss railways and by private households.

In a field trial in Denmark Esbjerg et al. (2002) demonstrated not only that the pesticide dose correlates with plant diversity (which is the desired effect, particularly in the case of herbicides), but also that it reduces the diversity of creatures outside the target group, such as spiders, myriapoda and birds.

The movement of soil particles in the wind and atmospheric transport of plant protection products has also led meanwhile to the detection of active agents in mountain lakes and in rain. Human health impacts of these products arise notably from the use of groundwater as drinking water. Furthermore, two thirds of the active agents of plant protection products licensed in Switzerland cannot be routinely analysed (Angehrn 2001).

Flow in 2005

The quantity of plant protection products used is not available classified by substance: detailed application rates are only available for 20 PPPs (von Arx 2005). However, these make up two thirds of the total quantity, so the characterised flow is estimated from these 20 substances and there is a linear extrapolation of the missing third. This delivers an annual flow of 1507 t PPP-eq. The split up is calculated with statistical data for 22 PPPs and own assumption for the rest based on a mix of agricultural production data (Jungbluth et al. 2011a, see Tab. 20).

Allocation

It is estimated that 90% of the pesticides are used in the primary sector, 5% are used by railways and are allocated to the transport sector, and 5% are used in private gardens and are allocated to the housing sector of household needs.

[29] In older ordinances Pflanzenbehandlungsmittel (PBM) (plant treatment product) was used as the umbrella term, with Pflanzenschutzmittel (PSM) (plant protection product) as a sub-category. PBM is now no longer in use and PSM has become the umbrella term.

Tab. 20 > Calculation for the consumption of plant protection agents in Switzerland

	Name	Loca-tion	Infrast	Unit	application mix, pesticides	Total application Mix
	Location				CH	CH
	InfrastructureProcess				0	2005
	Unit				kg	t
Pesticides	2,4-D	-	-	kg	5.01E-7	0.00
	Aclonifen	-	-	kg	9.36E-3	14.20
	Asulam	-	-	kg	4.62E-2	70.10
	Atrazine	-	-	kg	2.37E-2	36.00
	Bentazone	-	-	kg	2.73E-3	4.13
	Carbetamide	-	-	kg	9.17E-3	13.90
	Chlorothalonil	-	-	kg	2.10E-2	31.90
	Chlorotoluron	-	-	kg	8.72E-3	13.22
	Desmedipham	-	-	kg	9.53E-6	0.01
	Ethofumesate	-	-	kg	1.17E-2	17.71
	Fluazifop-p-butyl	-	-	kg	1.35E-4	0.20
	Glyphosate	-	-	kg	1.09E-1	165.40
	Haloxyfop-ethoxyethyl	-	-	kg	3.33E-5	0.05
	Ioxynil	-	-	kg	1.38E-2	20.87
	Isoproturon	-	-	kg	3.05E-2	46.20
	Linuron	-	-	kg	2.76E-3	4.18
	MCPA	-	-	kg	1.13E-2	17.10
	MCPB	-	-	kg	1.40E-1	212.79
	Mecoprop-P	-	-	kg	1.18E-2	17.90
	Metamitron	-	-	kg	2.08E-2	31.50
	Metolachlor	-	-	kg	8.97E-3	13.60
	Metribuzin	-	-	kg	1.41E-3	2.14
	Napropamide	-	-	kg	6.49E-3	9.85
	Orbencarb	-	-	kg	1.02E-2	15.50
	Pendimethalin	-	-	kg	1.69E-2	25.60
	Phenmedipham	-	-	kg	6.52E-3	9.89
	Tebutam	-	-	kg	1.76E-2	26.72
	Teflubenzuron	-	-	kg	9.40E-5	0.14
	Trifluralin	-	-	kg	5.46E-4	0.83
	Triflusulfuron-methyl	-	-	kg	4.75E-6	0.01
	Chlormequat	-	-	kg	1.64E-2	24.90
	Ethephon	-	-	kg	7.15E-3	10.84
	Fenpiclonil	-	-	kg	1.40E-3	2.12
	Metalaxil	-	-	kg	2.29E-5	0.03
	Carbofuran	-	-	kg	1.75E-6	0.00
	Cypermethrin	-	-	kg	4.29E-4	0.65
	Deltamethrin	-	-	kg	9.13E-6	0.01
	Dimethoate	-	-	kg	6.48E-4	0.98
	Lambda-cyhalothrin	-	-	kg	3.19E-5	0.05
	Oils, unspecified	-	-	kg	1.99E-2	30.10
	Pirimicarb	-	-	kg	1.06E-3	1.61
	Oils, biogenic	-	-	kg	2.68E-2	40.70
	Metaldehyde	-	-	kg	9.12E-3	13.83
	Azoxystrobin	-	-	kg	5.31E-5	0.08
	Benomyl	-	-	kg	3.19E-9	0.00
	Captan	-	-	kg	2.60E-2	39.40
	Cymoxanil	-	-	kg	1.07E-4	0.16
	Cyproconazole	-	-	kg	5.70E-5	0.09
	Cyprodinil	-	-	kg	1.03E-2	15.60
	Difenoconazole	-	-	kg	2.19E-3	3.32
	Dimethomorph	-	-	kg	1.32E-4	0.20
	Fenpropimorph	-	-	kg	4.30E-2	65.25
	Folpet	-	-	kg	7.31E-2	110.90
	Fosetyl-aluminium	-	-	kg	2.63E-2	39.90
	Imazamox	-	-	kg	1.09E-5	0.02
	Iprodion	-	-	kg	5.24E-3	7.95
	Mancozeb	-	-	kg	5.27E-2	79.90
	Propamocarb HCl	-	-	kg	4.78E-4	0.73
	Sulfur	-	-	kg	1.24E-1	188.00
	Tebuconazole	-	-	kg	1.14E-2	17.32
	Thiram	-	-	kg	5.67E-9	0.00
	Total				1	1'516.30

Source: calculation ESU-services Ltd.

A6 Resources (energy, raw materials, and land occupation)

While the term "resources" in a broad sense might include clean air, biodiversity or landscapes, within the framework of LCA it is used in a narrow sense, i.e. use of energy, material, biological, water and land resources.

A6-1 Energy resources

The Federal Constitution (Art. 89) states the goal of an efficient and environmentally sound energy supply in the same sentence in which it calls for a reliable and economical supply: *"Within their powers, the Confederation and the Cantons shall strive to ensure a sufficient, diversified, reliable, and economical energy supply compatible with the protection of the environment, and the economical and efficient use of energy."*

Not only the available quantities of non-renewable energy carriers – such as oil, gas and uranium – are limited. The renewable resources are also limited. The sun, the driving force behind most renewable energies, only supplies a limited quantity of energy to the Earth per unit time. Moreover, a part of this energy is required to keep Ecosystem Earth running, e.g. for the biogenic production of oxygen, pollination and pollen dispersal by wind, maintenance of the hydrological cycle, provision of daylight, etc. Furthermore, when solar energy is converted into renewable energy carriers, the efficiency is often only a few percent. It is therefore not known which proportion of renewable energy can be utilized sustainably. It can at least be concluded that an upper utilization limit also applies to renewables. It is therefore appropriate to assign an eco-factor both to renewable and non-renewable energy carriers.

While technical efficiencies are often low when renewables are converted into final energy, especially when solar radiation is converted into biomass, due to the remaining ecological benefits the energy not utilized technically does not in fact dissipate uselessly. This is why renewables are assessed not on the basis of primary energy content, but on the basis of final energy.

In contrast, where non-renewable energy carriers deliver no further ecological benefit, the entire energy contained in the resource should be utilized wherever possible, which is why the eco-factor is applied to the primary energy content.

For renewable and non-renewable energy resources alike, the assessed energy corresponds to the energy yield – the energy content of the biomass harvested, the rotation energy in the case of wind and hydropower generators, the electrical energy delivered to the inverter in photovoltaic installations, the thermal energy delivered to the heat storage system in the case of solar collectors, and the energy quantity extracted from the geosphere in the form of crude oil, raw hard coal, lignite, natural gas and fissile uranium.

Aggregate energy statistics (BFE 2004) present the energy balance of Switzerland according to energy carriers (Tab. 21). This encompasses territorial production as well as imports and exports. The normalisation flow comprises the characterised flow. For calculation of the total flow in 2005, renewable and non-renewable energy consumption is multiplied by the corresponding characterisation factors (⅓ and 1). This results in a flow of 1030 PJ-eq./a (Tab. 21).

Flow in 2005

The flow in 2005 corresponds to the primary energy consumption of Switzerland and figures 1169 PJ/a (Tab. 21).

Within the inventory of this study we only include primary energy carriers extracted in Switzerland as a domestic input. All fossil and nuclear fuels are imported to Switzerland and thus they are considered within the calculation of foreign emissions and resource uses.

Tab. 21 > Primary energy consumption in Switzerland according to 2003 energy statistics (BFE 2004), and its conversion into characterised primary energy consumption

	Non-renewable energy [PJ]		Renewable energy [PJ]		Primary energy consumption [PJ]	Primary energy consumption [PJ-eq.]
Mineral oil	537	100%	-	0%	537	537
Nuclear fuels	283	100%	-	0%	283	283
Hydropower	-	0%	164	100%	164	55
Gas	110	100%	-	0%	110	110
Coal	6	100%	-	0%	6	5.9
Wood and charcoal	0	0%	23	100%	23	7.5
Municipal and industrial wastes	23	50%	22	50%	45	30
Solar, wind, biogas, ambient heat	-	0%	13	100%	13	4.2
Electricity exports	-148	91%	-16	9%	-164	-153
Electricity imports	150	98%	3	2%	152	150
Total	960	82%	209	18%	1169	1030

Source: calculation ESU-services Ltd. with BFE 2004

Allocation

The consumed energy resources of hydropower energy are allocated to the sector of energy and water distribution, whereas the energy harvested with biomass is allocated to the primary sectors. The solar, and geothermal energy are allocated to different sectors and household (BFS 2009; 2011). Fossil and nuclear resources are not extracted in Switzerland and thus they only show up with the import of goods.

A6-2 Land occupation

Flow in 2005

The land-use statistics of 1992/97 (BFS 2001) break down the area of Switzerland, which totals 41 286 km², into four broad types of use:

1. 6.8% settlement and urban areas (buildings, transportation areas, recreational and green urban areas, landfills, building sites)
2. 36.9% agriculturally utilized areas (grassland, arable land, orchards)
3. 30.8% wooded areas (forest, shrub forest, woods)
4. 25.5% unproductive areas (rock, ice, lakes, rivers, glaciers)

The Swiss Spatial Planning Act (Raumplanungsgesetz) prescribes that soil resources should be used prudently and urban sprawl should be countered. Settlement area is expanding nonetheless. According to the Swiss land-use statistics of 92/97, the overall settlement area is growing at a rate of around one square metre per second, mostly at the expense of agricultural land in the Swiss plateau (the "Mittelland" region of Switzerland). In remote areas, agricultural land that is no longer managed is transformed again into wooded areas. While the unproductive areas are subject to constant change, their overall area remains roughly constant (BFS 2001).

According to the BFS (2001), the settlement area of Switzerland, which totals 2791 km², is composed as follows:

> 49.3% building areas
> 32.0% transportation areas
> 7.2% industrial areas
> 5.8% special urban areas (utility facilities, quarries/mines and dumps, construction sites)
> 5.7% recreational and green urban areas

Land transformation not included

Growth in settlement area is driven by a growing population, in combination with growing levels of land take per person. The target of the Swiss Federal Council set out in the 2002 strategy for a sustainable Switzerland is to meet further demand wherever possible by means of inward development, i.e. improved utilization of existing settlement areas (Schweizerischer Bundesrat 2002). Land transformation activities have not been considered in the inventory, as they are not assessed in the ecological scarcity method.

Allocation

The building area is allocated to the housing sector of household needs. Recreational and green urban areas belong to the sector of recreation, culture and sport. Special urban areas are allocated equally as mineral extraction sites to the sector of mining and quarrying and as dumpsites to the disposal sector. Traffic area occupied by the road network is allocated to the different sectors depending on their fuel consumption whereas the traffic area from the railway network is allocated to the transport sector. The industrial area is distributed to the different economic sectors in relation to their investment in the construction sector. The different categories of agricultural and forestry areas are allocated entirely to the primary sector.

A6-3 Gravel extraction

Environmental relevance

Gravel is a *sui generis* resource: On the one hand a construction material, and on the other hand a material important to the protection and formation of groundwater. Not all physical gravel occurrences are extractable – permissible land uses set limits.

Gravel is used mainly in the construction sector, notably as a concrete aggregate and in road and railway subgrades. The quality of gravel deposits can vary widely. High-grade alluvial gravels are found especially on valley floors, while morainic mounts often have a mixed composition, making gravel extraction more costly (Jäckli & Schindler 1986; Kündig et al. 1997).

Gravel resources replenish very slowly. Only around 1% of Switzerland's annual gravel consumption is formed anew in rivers in the same period. Moreover, the geological gravel deposits are reduced by competing demands such as housing construction, groundwater protection and, in some cases, forest protection. As a result, the extractable quantity is substantially smaller than the resource (Jäckli & Schindler 1986). In the canton of Zug, for instance, it is assumed that if extraction intensity remains at the same level the utilizable gravel reserves suffice for only 18 years (Raumplanungsamt Kt. Zug 2005).

Flow in 2005

The gravel production of Swiss gravel works depends to some degree upon construction sector activity, and has ranged between 30 and 40 million t over the past 20 years, with a maximum around 1990. In the year 2000, 34 million t were extracted (Rubli et al. 2005); this is taken as flow in 2005.

Allocation

All extracted gravel belongs to the economic sector of mining and quarrying.

A6-4 Freshwater consumption

Environmental relevance

In some regions of the world freshwater is scarce, while in others there is a surplus. Switzerland is in the comfortable position of having access to more than enough clean water. Nonetheless, the Federal Council (Schweizerischer Bundesrat 2002, p. 9) demands that *"(...) natural resources be utilized with due regard to future generations"* and specifies this by demanding that, among other things, *"(...) the consumption of renewable resources (e.g. farmed biomass, water) is kept below the level at which they can regenerate or below the natural level of availability".* The same document also notes the global freshwater problem, citing the OECD.

In accordance with the OECD (2004) and FAO (2005) we understand water consumption to mean all extractions of freshwater for production or consumption processes. Water consumption does not include water used by hydroelectric facilities to generate electricity.

Flow in 2005

According to the FAO (2005), the flow in 2005, i.e. the quantity of freshwater consumed annually in Switzerland, is 2.57 km^3/a (around 350 m^3 per capita and year or 1000 litres per capita and day). This includes not only consumption for potable water, but also water extractions to irrigate agricultural areas and for use in industrial processes. According to the FAO (2005) the available annual resource in Switzerland is 53.5 km^3.

Allocation

With data from FAO (2010), Weber & Schild (2007) and BWG (2003) it is estimated that 55% of the water is used in the sector of water and energy distribution and 15% is used in the primary sector. The remainder is allocated to the chemical industry (15%), the sector of mining and quarrying (5%), the sector of manufacturing wearing apparel (5%) and the sector of manufacturing metal products (5%).

A7 Wastes

The following sections provide more information for different types of wastes. Wastes in above-ground landfills are assessed on the basis of their carbon content. Certain hazardous wastes and radioactive wastes are stored underground.

Allocation

All emissions from waste incineration and wastewater treatment are allocated to the sector of waste management services. It is not possible to follow up the origin of the waste and assign specific emission factors to different economic sectors or final demand.

A7-1 Carbon in material consigned to bioreactive landfills

The Swiss Environmental Protection Act stipulates that no wastes that may cause long-term problems can be stored in landfills in Switzerland. The indicator for the reaction potential of waste is its carbon (C) content. The goal is to minimize the C flow to landfills. The experts at FOEN therefore consider this to be the key critical aspect when consigning material to bioreactive landfills.

Flow in 2005 and allocation

The flow in 2005 comprises the quantity of carbon stored through the waste in bioreactive landfills and slag compartments. According to FOEN estimates, slags contain an estimated 4% C, while the average for other wastes consigned to bioreactive landfills (excluding slags) is 15%.[30] Wastes consigned to landfills for inert materials or to landfills for stabilized residues contain practically no reactive organic material. 661 500 t slags are consigned annually to bioreactive landfills, plus 473 000 t other wastes (figures for 2002: BUWAL 2003c). This yields the flow of 97 410 t C/a in 2005 which is allocated to the disposal sector.

A7-2 Hazardous wastes in underground repositories

The greater part of the hazardous wastes arising in Switzerland (around 1.1 million t per year) is treated within the country. Around one third can be incinerated, while the rest is, wherever possible, recycled, consigned to physical-chemical treatment or otherwise stored in a landfill for stabilized residues. Soil removed when cleaning up contaminated sites is the principal source of hazardous waste, accounting for around one quarter of the quantity (BUWAL 2003c, pp. 42–43).

Hazardous wastes are only exported in exceptional cases; this accounts for around 10% of the total hazardous waste quantity. One third of the exported quantity is made up of the filter dusts of municipal waste incineration plants, which are stored in underground repositories. Their storage in underground repositories has been declining slightly since 1996, as the acid scrubbing process is increasingly being deployed. When this process is used, it is no longer necessary to store filter dust in underground repositories (BUWAL 2003c, p. 44).

[30] Personal communication by M. Tellenbach, FOEN, 15 July 2006.

Flow in 2005 and allocation

The Swiss waste statistics give the quantity of wastes stored in underground repositories. This comes to 36 900 t/a in 2002, and is exported in its entirety (BUWAL 2003c, p. 44) and is allocated to the disposal sector. There are no underground repositories in Switzerland.

A7-3 Radioactive wastes in final repositories

The Swiss strategy for the disposal of radioactive wastes is to aim for the interim to reduce the quantities and harmfulness of residues and then to isolate these permanently through final storage. The Swiss Nuclear Energy Act (Kernenergiegesetz, Art. 30 para 2) requires for the radioactive wastes that arise that *"The radioactive wastes arising in Switzerland must be disposed of within the country as a matter of principle"*. In addition, the Act stipulates a moratorium on reprocessing spent fuel elements from July 2006 to 2016.[31]

Originally two final repositories were envisaged – one for spent fuel elements, high-level wastes (HLW) and long-lived medium-level wastes (LMLW), and a second for low-level and medium-level wastes. Following rejection of the Wellenberg as a site for low-level and medium-level wastes, the option of building one single deep repository is now also under review.

The planned capacities required for the repository are determined on the basis of the estimated quantities of radioactive wastes including their encasements. Improved reprocessing processes will tend to reduce the volumes. On the other hand, extending the service life of nuclear power plants from the original term of 40 to 60 years increases repository capacity requirements. NAGRA[32] now also bases its calculations of required volumes on plant service lives of 60 years (192 GW scenario).

Based on this scenario, some 8300 m³ spent (and conditioned) fuel elements, some 1000 m³ HLW from reprocessing and 4360 m³ (cement waste option; 3460 m³ in the case of the vitrification option) LMLW arise. One option calculated assumes an additional 2900 m³ LMLW. Overall, the deep repository thus needs to accept around 16 000 m³ long-lived high-level and medium-level wastes (volume incl. encasements) (NAGRA 2002).

According to the plans drawn up in 1996, the repository for short-lived low-level and medium level wastes is to have a capacity of 100 000 m³. Of this, 42 000 m³ are wastes from nuclear power plant decommissioning, 11 000 m³ from plant operation, 24 000 m³ from reprocessing and the remaining 23 000 m³ from research and medicine (of which 14 000 m³ from the decommissioning of the PSI proton accelerator). This volume was estimated on the basis of a 40-year service life of nuclear power plants and a 70-year collection period for wastes from medicine and research (Prêtre 1996). Extrapolation to a service life of 60 years implies a required storage volume of around 115 000 m³ (volume incl. encasements).

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[31] Nuclear Energy Act, Art. 106 para 4 "Spent fuel elements may not be exported for reprocessing for a period of ten years from 1 July 2006 onwards. During this period, they are to be disposed of as radioactive wastes."

[32] NAGRA is the national cooperative for radioactive waste storage (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle) in Switzerland

The hazardousness of radioactive wastes depends upon their persistence (half-life), and on the type and intensity of their radiation. The Swiss strategy for a final repository classes the various types of radioactive waste in two categories:

1. Short-lived low-level and medium-level wastes
2. Long-lived medium-level wastes (LMLW), high-level wastes (HLW) and spent fuel elements

The former are relatively short-lived, and already present a minor hazard after a shorter period. A requisite shut-in time of around 500 years is assumed (KFW 2002; PSI 1996).

The shut-in time of long-lived wastes is much longer. It is assumed that these need to be stored safely for at least 100 000 years (EKRA 2000; PSI 1996).

Flow in 2005

The quantity of radioactive wastes (incl. encasements) currently arising is taken from the ecoinvent report on nuclear power (Dones 2003). The net capacity of Swiss nuclear power plants figured 2.96 GW in 2002 (Dones 2003, table 9.1), which results in a flow of 1230 m^3/a in for low-level and medium-level wastes, and 218 m^3/a for high-level wastes (HLW).

Allocation

The high radioactive wastes are allocated entirely to the energy sector, whereas low-level radioactive wastes occur not only in nuclear power plants, but also in medicine, industry and research. Based on NAGRA (2008; 2009), 76% of the low- and medium-level wastes are allocated to the energy sector for the wastes from nuclear power, 12% are allocated to the educational sector that covers research and 1% is allocated to the health sector for the radioactive wastes from medicine. 3% are allocated to the sector of medical and optical instruments and watches, 2% are allocated to each of the following sector; mineral products, metal products, refineries and chemical industry.

> Annexe B: Documentation of data in the EcoSpold format

B1 Introduction

In order to allow other persons to use the data established for this project the EE-IOA data are transformed for further calculations into the EcoSpold format v1. This format is based on XML. It can be transformed to EXCEL or HTML format and be further processed in LCA software as e.g. SimaPro (PRé Consultants 2009).

The format has been developed in the framework of the ecoinvent 2000 project (Hedemann & König 2003). Here we use the format that is used for ecoinvent data v1 and v2 (ecoinvent Centre 2010).

All EcoSpold data are only available in electronic format for download via the following webpage *www.bafu.admin.ch/uw-1111-e*.

The published data cover the full unit process raw data for the Swiss input-output table (Tab. 23 and Tab. 24). The data for imported goods and services (Tab. 7) are provided as system processes. Thus, it is possible to make the full calculations e.g. in the SimaPro software. The unit process raw data for SITC categories of imports (Tab. 7) are also provided in the EcoSpold format, but they cannot be imported to an LCA software because they link to proprietary data of the ESU data on demand (Jungbluth et al. 2011a). These data can be directly purchased from ESU-services Ltd.

B2 Naming conventions

So far there are no clear rules for the naming of input output datasets in the ecoinvent database. Therefore we developed the names of datasets according to the examples shown in Tab. 22.

Names of imported goods are derived from the information in Tab. 6. For industry sectors we distinguish between domestic and foreign production. Sectors of final demand are also separately inventoried for imported and domestic products.

Tab. 22 > Naming convention used for ecoinvent datasets in the EcoSpold format

Examples of names used for major categories of EcoSpold datasets in this study. We can distinguish datasets describing the imports of certain goods, datasets describing domestic production sectors, and data for consumption items. Then we have also datasets describing e.g. the total private and public consumption as well as total exports. We have datasets describing the imports of services and a calculation of the total Swiss balance.

Name	Location	Category	SubCategory	unit
SITC-00, live animals other than animals of division 03, import	CH	trade statistics	import	kg
SITC-01, meat and meat preparations, import	CH	trade statistics	import	kg
G01b05, primary sector	CH	input output	swiss production	CHF2005
G10b14, mining and quarrying	CH	input output	swiss production	CHF2005
private consumption, C01, nutrition	CH	input output	swiss consumption	a
private consumption, C02, clothing	CH	input output	swiss consumption	a
exports, EXP, export	CH	input output	swiss consumption	a
total, private consumption, 2005	CH	input output	swiss consumption	a
total, public consumption, 2005	CH	input output	swiss consumption	a
G51b52, wholesale and retail trade	GLO	input output	imported production	CHF2005
G80, education	GLO	input output	imported production	CHF2005
total, consumption, 2005	CH	input output	swiss consumption	a
total, final demand, 2005	CH	input output	swiss consumption	a

Source: ESU-services Ltd. and Rütter+Partner

B3 Monetary unit

The transactions in the input-output table are recorded in monetary units of Swiss Francs (CHF) with the reference year 2005. It has to be noted that the production recorded for economic sectors does not refer directly to the price of products delivered by these sectors. Taxes and subsidies, which are not added or subtracted by the company have to be subtracted from the price of the product before the environmental impacts can be calculated with the EE-IOA.

CHF2005

For the consumption categories this is considered in the calculation by not only accounting for the money spend by households for certain products, but also by the money spent on public services.

B4 Examples of ecoinvent datasets

In this chapter we show examples of EE-IOA data in the EcoSpold format. All examples show only parts of the full dataset.

Tab. 23 > Unit process raw data for IOT data and direct emissions in the production sectors

The unit process raw data for the primary production sector describe the inputs and outputs per CHF of products provided by this sector. They are established based on the IOT and the investigation for the split up of direct emissions. Furthermore they include the import of goods and services. The figure shows only an extract of more than 200 lines with inputs and emissions to this production sector.

Name	Location	Infrastructure Process	Unit	G01b05, primary sector	UncertaintyType	StandardDeviation95%	GeneralComment
Location				CH			
InfrastructureProcess				0			
Unit				CHF2005			
G01b05, primary sector	CH	0	CHF2005	0.00E+00	1	1.11	(1,1,1,1,1,3); IOT original
G10b14, mining and quarrying	CH	0	CHF2005	4.72E-04	1	1.11	(1,1,1,1,1,3); IOT original
G15b16, food industry	CH	0	CHF2005	6.17E-02	1	1.11	(1,1,1,1,1,3); IOT original
G17, textile	CH	0	CHF2005	1.31E-04	1	1.11	(1,1,1,1,1,3); IOT original
G91b92, recreation, culture and sport	CH	0	CHF2005	1.66E-04	1	1.11	(1,1,1,1,1,3); IOT original
G93b95, private services	CH	0	CHF2005	5.74E-05	1	1.11	(1,1,1,1,1,3); IOT original
Carbon dioxide, in air	-	-	kg	5.45E-01	1	1.22	(4,2,1,1,1,3); BFS (2009); calculated with emissions from primary sector,
Carbon dioxide, fossil	-	-	kg	7.26E-02	1	1.07	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005), carbon monoxide and carbon dioxide in stratosphere subtracted
Carbon dioxide, biogenic	-	-	kg	1.60E-02	1	1.07	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Dinitrogen monoxide	-	-	kg	7.33E-04	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Methane, biogenic	-	-	kg	1.20E-02	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Sulfur hexafluoride	-	-	kg	1.15E-09	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Methane, tetrafluoro-, R-14	-	-	kg	2.51E-09	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	-	-	kg	1.69E-06	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Gravel, in ground	-	-	kg	0.00E+00	1	1.09	(2,1,1,1,1,3); BUWAL (2003c)
SITC-00, live animals other than animals of division 03, import	CH	-	kg	6.78E-05	1	1.55	(2,3,1,5,4,3); foreign trade statistic for import combined with IOT for imported goods and correction factor for residence principle
SITC-97, gold, non-monetary (excluding gold ores and concentrates), import	CH	-	kg	1.05E-09	1	1.55	(2,3,1,5,4,3); foreign trade statistic for import combined with IOT for imported goods and correction factor for residence principle
G50, motor vehicle trade	GLO	-	CHF2005	3.14E-05	1	1.55	(2,3,1,5,4,3); IOT for imported services
G85, health and social work	GLO	-	CHF2005	1.24E-04	1	1.55	(2,3,1,5,4,3); IOT for imported services

Source: calculation ESU-services Ltd. and Rütter+Partner

Tab. 24 > Unit process raw data for IOT data and life cycle inventories for final consumption

The unit process raw data for final consumption are in principle built up similarly to the datasets for production sectors. But, they are recorded for one year and not per Swiss franc. We see again the purchases of Swiss products and services, direct emissions due to e.g. the combustion of fuels, the import of goods and services directly going to private consumption.

Name	Location	InfrastructureProcess	Unit	private consumption, C01, nutrition	UncertaintyType	StandardDeviation95%	GeneralComment
Location				CH			
InfrastructureProcess				0			
Unit				a			
G01b05, primary sector	CH	-	CHF2005	2.89E+09	1	1.11	(1,1,1,1,1,3); IOT original
G10b14, mining and quarrying	CH	-	CHF2005	1.51E+07	1	1.11	(1,1,1,1,1,3); IOT original
G91b92, recreation, culture and sport	CH	-	CHF2005	0.00E+00	1	1.11	(1,1,1,1,1,3); IOT original
G93b95, private services	CH	-	CHF2005	0.00E+00	1	1.11	(1,1,1,1,1,3); IOT original
Carbon dioxide, in air	-	-	kg	0.00E+00	1	1.22	(4,2,1,1,1,3); BFS (2009); calculated with emissions from primary sector,
Carbon dioxide, fossil	-	-	kg	0.00E+00	1	1.07	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005), carbon monoxide and carbon dioxide in stratosphere subtracted
Methane, fossil	-	-	kg	0.00E+00	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Sulfur hexafluoride	-	-	kg	0.00E+00	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Methane, tetrafluoro-, R-14	-	-	kg	0.00E+00	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	-	-	kg	0.00E+00	1	1.50	(1,1,1,1,1,3); BFS (2009) (NAMEA-air for 2005)
Gravel, in ground	-	-	kg	0.00E+00	1	1.09	(2,1,1,1,1,3); BUWAL (2003c)
SITC-00, live animals other than animals of division 03, import	CH	-	kg	1.14E+06	1	1.55	(2,3,1,5,4,3); foreign trade statistic for import combined with IOT for imported goods and correction factor for residence principle
SITC-97, gold, non-monetary (excluding gold ores and concentrates), import	CH	-	kg	0.00E+00	1	1.55	(2,3,1,5,4,3); foreign trade statistic for import combined with IOT for imported goods and correction factor for residence principle
G50, motor vehicle trade	GLO	-	CHF2005	0.00E+00	1	1.55	(2,3,1,5,4,3); IOT for imported services
G85, health and social work	GLO	-	CHF2005	0.00E+00	1	1.55	(2,3,1,5,4,3); IOT for imported services

Source: calculation ESU-services Ltd. and Rütter+Partner

B5 Industries and final demand categories in the IOT

The results of this study are available in an Excel-File (Ergebnisse_RP_THG_UBP.xls), that can be downloaded via the following webpage *www.bafu.admin.ch/uw-1111-e*.

Tab. 25 > Aggregates of industries and goods used in this study

This table shows the aggregates of industries and goods used in this report. In table 27 the aggregation scheme is shown.

Industry aggregates

1	Primary sector
2	Electricity, gas, water
3	Basic material production
4	Refineries
5	Chemical industry, plastics processing
6	Investment goods industry
7	Consumption goods industry
8	Transport services
9	Waste management services
10	Other services

Aggregates of goods

1	Goods of the primary sector
2	Food, beverages and tobacco
3	Textile products
4	Mineral oil products
5	Chemicals and plastic products
6	Other consumption goods
7	Electrical and machinery goods
8	Vehicles
9	Electricity, gas and water
10	Construction services
11	Trade services
12	Hotel and restaurant services
13	Transport services
14	Public services
15	Education services
16	Health services
17	Waste disposal services
18	Other services

Source: depiction ESU-services Ltd. and Rütter+Partner

Tab. 26 > Categories of final demand in the EE-IOT

This table shows the categories of final demand as used in this study. They follow the internationally used COICOP classification (see http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl= 5).

Final demand category	Remarks
Consumption of private households	
• Nutrition and tobacco	Food, beverages and tobacco
• Clothing and footwear	
• Housing, energy, water (electricity, gas and other fuels for heating)	Effective and imputed rents, maintenance and repair, water supply and misc. services, electricity, gas and other fuels for heating
• Furnishings, household equipment etc.	Furniture and furnishings, carpets and other floor coverings; household textiles; household appliances; glassware, tableware and household utensils; tools and equipment for house and garden; goods and services for routine household maintenance
• Health	Medical products, appliances and equipment; outpatient services; hospital services; health expenditures by government and non-profit institutions
• Mobitlity (Transport, incl. fuels for personal transport)	Purchase of vehicles; operation of personal transport equipment; transport services
• Communication	Postal services; telephone and telefax equipment; telephone and telefax services
• Recreation and culture	Audio-visual, photographic and information processing equipment; other major durables for recreation and culture; other recreational items and equipment, gardens and pets; recreational and cultural services; newspapers, books and stationery; package holidays; expenditures by government and non-profit institutions for recreation and culture
• Education	Expenditures by private households and by government for education
• Restaurants and hotels	
• Miscellaneous goods and services	Personal care; personal effects; social protection; insurance; other financial services; other services; consumption expenditures of non-profit institutions serving households
Residual government consumption	Government consumption after reallocation of certain expenditures to private consumption, e.g. expenditures for public order and safety, defence, general public services
Residential investment	Investment in residential buildings
Government investment	Investment expenditures by government (e.g. road infrastructure)
Change of inventories and net addition of valuables	Balance items
Export	

Sources: Nathani et al. 2008, Rütter + Partner

Tab. 27 > Industries included in the EE-IOT for Switzerland

This table contains the production sectors (resp. goods) included in the EE-IOT and the number of the sectoral aggregate they are allocated to for the presentation of the results in this report. The industry classification follows the NOGA (2002) classification, that is compatible with the international classification NACE rev. 1.1 (see www.bfs.admin.ch/bfs/portal/de/index/infothek/nomenklaturen/blank/blank/noga0/publikationen.html). Our classification of goods follows the CPA classification which is compatible with the NOGA classification.

NOGA code	Notation	Industry aggregate (see Tab. 25)	Aggregates of goods (see Tab. 25)
01t05	Agriculture, hunting, forestry, fishing and fish farming	1	1
10t14	Mining and quarrying	3	7
15t16	Manufacture of food products, beverages and tobacco	7	2
17	Manufacture of textiles	7	3
18	Manufacture of wearing apparel, dressing and dyeing of fur	7	3
19	Leather and footwear	7	3
20	Manufacture of wood	3	6
21	Manufacture of pulp and paper	3	6
22	Publishing, printing	7	6
23	Refineries	4	4
24	Chemical industry	5	5
25	Manufacture of rubber and plastic products	5	5
26	Manufacture of other non-metallic mineral products	3	6
27	Manufacture of basics metal	3	6
28	Manufacture of fabricated metal products	6	6
29	Manufacture of machinery and equipment	6	7
30t31	Manufacture of office and electrical machinery and computers	6	7
32	Manufacture of communication equipment	7	7
33	Manufacture of medical and optical instruments, watches	7	7
34	Manufacture of motor vehicles	6	8
35	Manufacture of other transport equipment	6	8
36	Manufacture of furniture, manufacturing	7	6
37	Recycling	9	7
40t41	Electricity, gas, steam and distribution of water	2	9
45	Construction	6	11
50	Sale, maintenance and repair of motor vehicles	10	11
51t52	Wholesale and retail trade	10	11
55	Hotels and restaurants	10	12
60t62	Transport	8	13
63	Auxiliary transport activities, travel agences	8	13
64	Post and telecommunications	10	18
65	Financial intermediation	10	18
66	Insurance and pension funding	10	18
70a97	Real estate, rental income of private households	10	18
71a74	Other business activities	10	18
72	Informatics	10	18
73	Research and development	10	18

NOGA code	Notation	Industry aggregate (see Tab. 25)	Aggregates of goods (see Tab. 25)
75	Public administration	10	14
80	Education	10	15
85	Health and social work	10	16
90	Sewage and refuse disposal, sanitation and similar activities	9	17
91t92	Recreational, cultural and sporting activities	10	18
93t95	Private households with employed persons, other service act.	10	18

Source: calculation ESU-services Ltd. and Rütter+Partner

> Review of the Study by Infras Ltd.

Our task

The aim of our task was to compile the review of the present study "Environmental Impacts of Swiss Consumption and Production" applying the standards of environmental information for a True and Fair View[33]. We believe, along with the Federal Office for the Environment, that these standards form a suitable basis for our review.

Our method of procedure

Within the framework of the review we supported the compilation of the report by taking a critical stance. We also examined the end result on the basis of the standards for a true and fair view. This examination related to

- the form of the report,
- the choice of methodologies,
- the formal procedure in application of the methods,
- the appropriateness of the underlying assumptions and
- the depiction of both the methodological procedure and the results.

The review was commissioned by the Economics Section of the Federal Office for the Environment (FOEN), Berne.

However, only random checks could be carried out as to the correctness of the data bases and the individual calculations, the fitness for purpose of the underlying assumptions and the quantitative results. Our review can therefore guarantee to a large extent formal correctness and fitness for purpose, along with the orders of magnitude and the plausibility of the final results and their presentation, but not the complete mathematical and factual correctness of the study.

Responsibility for content of the report

The compilers of the study "Environmental Impacts of Swiss Consumption and Production" – ESU-services and Rütter + Partner – are responsible for the content of the report, the accurate application of the methods and for the factual correctness of the information included in the report as far as described in their liability statement.

Our responsibility

In accordance with the task described above, our responsibility consists of applying the standards accurately and to the best of our knowledge in reviewing the quality of the study "Environmental Impacts of Swiss Consumption and Production".

In carrying out our task we are responsible solely to the commissioning body – the Economics Section of the FOEN – in accordance with the agreed scope of the task.

Our evaluation

We can confirm that the study broadly conforms with the standards for a true and fair view. Where discrepancies from the standards were found, they were reported back during the compilation of the study and mostly (where this was possible) removed. We have listed in the table below some further discrepancies.

[33] The standards were worked out within the framework of a study by Schwegler/Iten/Grünig/Boteler 2011: Qualitätsanforderungen an Umweltinformationen für eine True and Fair View (forthcoming).

Tab. 28 > Review of the Study by Infras Ltd.

Quality standards for environmental reports with a True and Fair View	Evaluation of the study "Environmental Impacts of Swiss Consumption and Production" by ESU-services and Rütter + Partner
Key quality standards	
1) Relevance for decisions to be influenced (e.g. by the results calculated with the respective method)	The study depicts to a large extent (as far as is possible in view of time and financial restraints and the availability of reliable data) all relevant information regarding its goal – to research environmental impacts of Swiss consumption and production as the basis for environmental policy decisions. It considers a large number of important environmental impacts (emissions, waste and resource uses). Because some basic data or impact assessment methodology is lacking, individual relevant environmental impacts could not be included (noise) or only in a simplified form (biodiversity).
2) Total picture in focus: Transmission of a true and fair view of the actual situation, therefore it should consider all relevant environmental impacts, • along the whole life cycle of products and services and • if possible at the place they occur	The study presents a picture that largely corresponds to the actual situation: It takes a comprehensive view of the relevant environmental impacts of consumption and production, i.e. both the direct environmental impacts in Switzerland and also the indirect environmental impacts from imports. Application of the NAMEA accounting principle makes it possible to establish the responsible sector for every Swiss emission. Methodological constraints: The EE-IOT attributes environmental impacts from upstream sectors to the sectors according to the economic value of the services used and not according to the environmental impacts the pre-products cause in a purely physical sense. This leads to certain distortions, especially when heterogeneous sectors are viewed with reference to the environmental intensity of their goods (e.g. the primary sector). Nevertheless the method is suited in principle to preparing information for political decisions. Distortions because of limited data availability: The LCA data for the assessment of imports are usually based on data from Switzerland or from countries that are significant for imports. Since region-specific LCA data are not available for all relevant imports, the risk of underestimation was minimised: first, there was a tendency for higher data sets to be selected, secondly, many LCA data are older than 2005, so that the assessments tend to be set higher. Thirdly, a significant number of imports are re-exported so that estimation uncertainties are only relevant to a limited extent. In the study the environmental impacts of waste export to other countries were not taken into account. For that reason the indirect environmental impacts of Swiss consumption and production are underestimated at this point.
The following requirements are a pre-requisite for 1) and 2)	
3) Reliability: • Trustworthiness (e.g. external assurance) • scientific soundness • free from manipulation	Plausibility: The study is plausible to a high degree. In particular, it states which information and assessments are uncertain and the estimates that were necessary. Scientific soundness: The study was professionally compiled and is based, as far as is possible, on up-to-date scientific findings. The methods applied, such as NAMEA and LCAs, are widely used and scientifically recognised. The assessment methods are also relatively widely known and largely accepted. The data material is based as far as possible on official statistics and studies that meet high scientific standards. Where there were estimates or assessments for which there were no scientifically or internationally recognised bases this was transparently explained and justified. Free from manipulation: Because of the high degree of transparency of the study and the critical support during its compilation (by the support group and the Joint Review on the part of INFRAS) a conscious manipulation can be largely ruled out.
4) Transparency: • traceability • verifiability	The study describes mostly transparently the underlying definitions, methods, calculation processes and estimates made. In the interests of intelligibility it does not present details. Exact reproducibility and verifiability are assured as the whole detailed methodological and statistical material will be made available on publication of the study.
5) Comprehensibility	The study describes the methods and the calculation processes as clearly as is possible for this complex topic: The main results of the study are described in the summary of the report with a high degree of clarity. The detailed results, calculation processes and bases are also clearly presented in the report for an interested public. In the interests of intelligibility and for reasons of space the study does not however depict every individual calculation step and individual data points. The intelligibility of the individual detailed steps for experts is guaranteed by the fact that the detailed calculations, including adequate explanations, will be made available on publication of the study.

Quality standards for environmental reports with a True and Fair View	Evaluation of the study "Environmental Impacts of Swiss Consumption and Production" by ESU-services and Rütter + Partner
6) Coherence and comparability: • coherence (consistency) • continuity • standardisability • scalability, expandability and connectivity	Coherence or consistency: The study connects as far as possible methods and data that are based on similar definitions, approaches and accounting boundaries. Where this was not possible this was explicitly made clear. It might be useful to estimate the effects of these unavoidable inconsistencies on the overall result. There are inconsistencies particularly with respect to the following points: The methods EE-IOA and LCA are only consistent to a limited degree (different time horizons, system boundaries, treatment of inventory stocks). In particular allocation principles diverge on the allocation of environmental impacts to sectors and product groups: LCAs allocate sometimes in a physical manner and the IOT always according to economic product values. These inconsistencies were unavoidable however, since at the present time no better systematic data bases are available for estimating the environmental impacts of imports. Because of limited data availability the study uses data from different periods: NAMEA and foreign trade data mostly come from the year 2005. They are calculated with estimated data from 2005 when no suitable data from 2005 are available. For the following environmental impacts the 2005 estimates were based on data from the year 2000: particulate matter (II): diesel soot, benzene, dioxins and furans (PCDD/PCDF), organic matter (BOD, COD, DOC, TOC), heavy metals and arsenic, benzo(a)pyrene, endocrine disruptors, gravel extraction, waste, wash out from power poles; plant protection products (PPPs), heavy metals in the ground. The 2005 estimates for zink, nitrate and land use are based on older data from the 1990's. The LCA data are from the reference years 2000–2010. Environmental and energy statistics in Switzerland are often based on different system boundaries and methodological bases, e.g. on the territorial principle instead of on the residential principle, which makes a difference for transport-related emissions in particular. The conversion of data was only possible to a limited extent and required estimates and compromises. Continuity: It is a pilot study in which a method is developed and applied for the first time to Switzerland. For this reason it is natural that no comparative information from previous periods is available. The study is however in principle arranged so that continuity is possible. Scalability: The EE-IOA & LCA method is used in the study for the Swiss national economy as a whole, for sectors and for product groups. The LCA method was designed especially for the product level and is in principle also applicable to the company level. Standardisability, expandability and connectivity: The study was compiled so that it is comparable to studies from other regions and countries and thus allows comparisons of the situation in Switzerland with other countries and regions of the world. The possibility of a practical application in other countries and regions is mainly a question of the availability of statistical data of sufficient quality. The study is designed so that it can be expanded e.g. by further environmental impacts. Life cycle inventories set up in this study can be combined with other life cycle impact assessment methods.
7) Availability of information (sources)	The final report, the methodology and the data underlying the calculations are made available to the different user groups where this seems reasonable.
8) Information and data are up to date	The reference year 2005 is a good compromise between the requirements of supplying results that are as up-to-date as possible and at the same time having available the highest quality and most complete data possible.

Conclusion

The study by ESU-services and R+P conveys an overall picture of the environmental impacts caused by Switzerland's consumption and production that corresponds to the actual situation. It therefore conveys a true and fair view in accordance with the current level of knowledge. Furthermore, it shows which consumption and production sectors cause which share of the total environmental impact, and also which share of the environmental impact is caused in Switzerland and which abroad.

> Index

Abbreviations

CHF
Swiss francs currency

EE-IOT
environmentally extended IO analysis

EE-IOT
environmentally extended IO table

Gt
Gigatonnes (1E9 tonnes)

IOT
Input-Output table

kt
Kilotonnes (1000 tonnes)

LCA
life cycle assessment

LCIA
life cycle impact assessment (classification, characterisation, weighting and aggregation of emissions and resource uses)

MM
million

Mt
Mega tonnes (1000 000 tonnes)

NAMEA
national accounting framework including environmental accounts

SCP
sustainable consumption and production

SUT
supply and use tables

SIOT
symmetric input-output tables

SwissPRTR
Swiss database of pollutant release and transfer register

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> Glossary

Tab. 29 > Glossary of important terms used in this study

Within this project certain terms are used according to the following description. In general we use as far as possible for all environmental issues the terms and definitions that are well known in the field of life cycle assessment and thus e.g. in the ISO standard 14040ff (International Organization for Standardization (ISO) 2006a). It has to be noted that neighbouring scientific fields such as e.g. environmental economics sometimes define these issues in a different way. Economic terms and definitions are based on the usual phrases used in the fields of economic and environmental accounting.

Deutsch	English	Definition or illustrative examples
Konsum-perspektive	consumption perspective	In the consumption perspective a country is responsible for the emissions caused by its domestic final demand. This includes emissions in other countries for the production of goods imported into Switzerland and excludes domestic emissions for the production of goods exported to other countries. To each good of final demand, total emissions are allocated, including indirect emissions in the supply chain of the good.
Direkt	direct	Emissions emitted and resources used directly by a company or a household.
Inländisch	domestic	Used here as synonym for residence or territorial principle depending on the context of the use.
im Ausland, Graue,	Embodied or abroad	e.g. emissions that are emitted abroad. Sometimes also termed as grey or foreign emissions.
Emissionen und Ressourcen-verbrauch	emissions and resource uses	Physical flows caused by an economic activity that can lead to environmental impacts.
Umweltwirkungen	environmental impacts	Impacts on ecosystems, human health and availability of resources for future generations resulting from emissions and resource uses. Environmental impacts are calculated within the life cycle impact assessment and are expressed in terms of environmental indicators.
Umweltindikator	environmental indicator	Figure that evaluates potential environmental impacts due to emissions and resource uses (e.g. global warming potential, or ecological scarcity points).
Güter	goods	Products and services together are named here as goods. They are delivered by production sectors for intermediate and final demand as well as for exports.
Ausländisch	foreign	Used for everything produced or emitted by non-Swiss residents.
Indirekt	indirect	Emissions and resource uses during the life cycle of a good or service.
Produktions-perspektive	production perspective	In the production perspective a country is responsible for its domestic emissions. To each economic actor (households and enterprises) only the direct emissions are assigned.
Inlandprinzip	residence principle	Sum of all direct emissions by Swiss companies and households. These emissions might also take place outside the Swiss territory during activities of Swiss companies or households outside Switzerland (e.g. air emissions by Swiss transport companies in foreign countries).
Territorialprinzip	territorial principle	Sum of all direct emissions by companies and households located within the territory of a specific country (e.g. national greenhouse gas emissions). In this study this refers to the Swiss territory if not stated otherwise.
Ein den tatsächlichen Verhältnissen entsprechendes Bild	True and Fair View	A "true and fair view" of environmental economic reporting systems conveys a reliable and intelligible picture of the actual environmental impacts of national economies, companies and products. In particular all relevant environmental aspects along the whole life cycle of products are shown. The calculations and assessments of environmental impacts are disclosed in a transparent fashion (Source: Schwegler et al. forthcoming)
-	*environmental pressure*	This term is not used in this study because definition is unclear and does not fit in the framework of life cycle assessment. Instead we use the more appropriate distinction between emissions and resource uses on the one side and environmental impacts (as a results of these emissions and resource uses). Defined for the DPSIR framework of the EEA (Kristensen 2004): "human activities exert 'pressures' on the environment, as a result of production or consumption processes, which can be divided into three main types: (i) excessive use of environmental resources, (ii) changes in land use, and (iii) emissions (of chemicals, waste, radiation, noise) to air, water and soil." According to the DPSIR framework of the EEA, the changes in the physical, chemical or biological state of the environment determine the quality of ecosystems and the welfare of human beings. In other words changes in the state may have environmental or economic 'impacts' on the functioning of ecosystems, their life supporting abilities, and ultimately on human health and on the economic and social performance of society (Kristensen 2004)[34]
-	*environmental burden*	Synonym for environmental impact mainly used in the DPSIR framework. Not used in this study.

Own definitions

[34] http://enviro.lclark.edu:8002/rid=1145949501662_742777852_522/DPSIR%20Overview.pdf

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