treeze Ltd., Kanzleistrasse 4, CH-8610 Uster, www.treeze.ch

Environmental hotspots in the supply chain of Swiss companies

Final report

Authors

Carsten Nathani[2], Rolf Frischknecht[1], Pino Hellmüller[2], Martina Alig[1], Philippe Stolz[1], Laura Tschümperlin[1]

[1] treeze Ltd.

[2] Rütter Soceco AG

Commissioned by

Federal Office for the Environment FOEN

Uster, 05 January 2021

Imprint

Title	Environmental hotspots in the supply chain of Swiss companies
Authors	Carsten Nathani[2], Rolf Frischknecht[1], Pino Hellmüller[2], Martina Alig[1], Philippe Stolz[1], Laura Tschümperlin[1]

[1] treeze Ltd., fair life cycle thinking
Kanzleistr. 4, CH-8610 Uster

www.treeze.ch

Tel. +41 44 940 61 91
Fax +41 44 940 61 94
info@treeze.ch

[2] Rütter Soceco AG
Weingartenstrasse 5, 8803 Rüschlikon

www.ruetter.ch

Tel. +41 44 724 27 70
Fax +41 44 724 22 78
carsten.nathani@ruetter.ch

Commissioner	Federal Office for the Environment FOEN), Economics and Innovation Division, CH 3003 Bern The FOEN is an agency of the Federal Department of the Environment, Transport, Energy and Communications (DETEC).
Project supervision FOEN	Sibyl Anwander
Project lead FOEN	Susanna Fieber
Advisory group FOEN	Adrian Aeschlimann, Andreas Gössnitzer, Andreas Hauser, Frank Hayer, Josef Känzig, Niklas Nierhoff
Note	This study was prepared under contract to the Federal Office for the Environment (FOEN). The contractor bears sole responsibility for the content.
Liability Statement	Information contained herein have been compiled or arrived from sources believed to be reliable. Nevertheless, the authors or their organizations do not accept liability for any loss or damage arising from the use thereof. Using the given information is strictly your own responsibility.
PDF download	http://treeze.ch/fileadmin/user_upload/downloads/Publications/Case_Studies/Lifestyles/629_UHU_FinalReport_EN_v1.8.pdf
Data provision	The entire database used for this study is published on the treeze website and is available for further assessments at http://treeze.ch/projects/case-studies/lifestyles/environmental-hotspots-in-the-supply-chain-of-swiss-companies/ The life cycle inventories are offered in the ecospold v1 (xml) format and the impact assessment methods are provided in the SimaPro csv format. A detailed read-me with information on how to implement and use the data is available at the given address as well.
Version	629_UHU_FinalReport_EN_v1.9.docx, 05.01.2021 11:39:00
Citation	Nathani, C., Frischknecht, R., Hellmüller, P., Alig, M., Stolz, P., Tschümperlin, L. 2019: Environmental hotspots in the supply chain of Swiss companies. Rütter Soceco AG & treeze Ltd., Rüschlikon & Uster.

Abbreviations and Acronyms

BAVC	Bundesarbeitgeberverband Chemie
CHF	Swiss franc
CSR	Corporate Social Responsibility
EE-IOT	Environmentally extended Input Output Table
EE-MRIO	Environmentally-extended multi-regional input-output-analysis
EU	European Union
Eq.	Equivalent
ERM	Enterprise risk management
ESG	Environmental, social and governance
FOEN	Federal office for the environment
FTE	Full time equivalents
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
ICT	International Comparison Program
IG BCE	Industriegewerkschaft Bergbau, Chemie, Energie
IOT	Input Output Table
KBOB	Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren
Kt	Kiloton
LCA	Life cycle assessment
LCI	Life cycle inventory
MRIOT	Multi-regional input-output table
Mt	Megaton
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
NMVOC	Non-methane volatile organic compounds
NRP	National Research Program
OECD	Organisation for Economic Co-operation and Development
PDF	Potentially disappeared fraction
PPM	Parts per million
PPP	Purchasing power parity
REFF	Ressourceneffizienz Schweiz
SDG	Sustainable Development Goal
SITC	Standard International Trade Classification
TOC	Total organic carbon
TRAIL	Trade-information and LCA
UBP	Umweltbelastungspunkt
US	United States of America
VCI	Verband der chemischen Industrie e.V.
WTO	World Trade Organisation

Content

Summary

With this study, the Federal Office for the Environment (FOEN) would like to promote effective environmental management in Swiss companies by increasing the awareness for the environmental relevance of the supply chains. At present, most of the environmental goals of Swiss companies relate to their own production activities. However, effective corporate environmental management and reporting crucially depends on identifying the most important levers in the supply chain. For small, open economies like Switzerland who are strongly involved in global trade, the importance of the supply chains is particularly high. To enable companies to reduce their life cycle based environmental impacts in a targeted manner, identifying the most relevant value-added stages and processes with regard to their environmental impacts is of crucial importance. If these so-called environmental hotspots are known, companies can focus their efforts for resource-efficient innovations, their corporate environmental management and also reporting on these areas.

In order to support Swiss companies to efficiently and effectively reduce their environmental footprints, this study analyses the environmental impacts of selected Swiss industries including their supply chains and the use phase of their products, if relevant. The environmental hotspots in the supply chains are identfied and options for reducing the environmental footprints of Swiss companies are presented.

For calculating the environmental footprints of the Swiss industries, environmentally extended input-output analysis was applied. Two input-output-based approaches were used, namely an environmentally-extended multi-regional input-output-analysis (EE-MRIOA) and environmentally-extended input-output-analysis of a single country combined with trade data and LCA (IO-TRAIL). In the first approach, the Swiss EE-IOT 2008 was used for the calculation of environmental impacts in Switzerland and combined with EXIOBASE for the calculation of environmental impacts in foreign countries. The second approach was used to complement the analysis with results for the environmental footprint according to the ecological scarcity method that cannot be calculated with the EE-MRIO database.

In a first step a screening of all Swiss industries was performed. Eight industries were then selected for further detailed analysis. These industries are: meat production, production of chemical products, production of machinery, real estate services and construction, health and social work, food trade, trade with clothing, textiles and footwear and trade with household devices.

The six environmental indicators greenhouse gas footprint, biodiversity footprint, eutrophication footprint, water footprint, air pollution footprint and environmental footprint were analysed. Industry-specific target values that can serve the industries as starting point for their reduction targets were derived from the planetary boundaries given for each environmental indicator and related to the economic industries analysed.

The analysis of economic impacts demonstrated how supply chains span across industries and countries for all analysed industries. Significant shares of total value added are induced in foreign countries. In all industries analysed, most of the environmental impacts do not occur in the industry itself, but in its supply chain.

The food related industries food trade and meat production cause the highest environmental impacts per gross output, which shows the high environmental intensity and relevance of food products. For these industries particularly relevant are the eutrophication and biodiversity loss footprints. Also relatively high environmental impacts per gross output exhibits the industry textiles trade, where the water and the greenhouse gas footprints are especially relevant. Other industries clearly have their hotspots in greenhouse gas emissions and air pollution, especially real estate services, machinery and household equipment trade. For the chemical and the health and social work industries the greenhouse gas footprint is most important.

With regard to the relevance of supply chain stages, the biodiversity, the water and the eutrophication footprints are dominated by raw material extraction and production, respectively. For the greenhouse gas and the air pollution footprint also other supply chain stages can be important, usually the intermediate suppliers between raw material extraction and direct suppliers. The effect of the industry itself is mostly small, if not negligible.

Measures to reduce the environmental impact of Swiss industries should therefore imperatively include the supply chains. As a first step, transparency over the supply chain should be created as far as possible. This allows the identification of hotspots in the supply chain and the development of targeted measures adapted to the respective manufacturer or raw material producer. There are various options for implementing environmental improvements in the supply chains: Specific environmental requirements can be taken into account in purchasing criteria and specifications. Cooperation with suppliers can lead to knowledge transfer and capacity building among suppliers worldwide. Product design changes (e.g. longer lifespans, lower material consumption or the use of more sustainable product components) can be an important lever for reducing environmental impacts in the supply chain. For industries related with food production or food trade, agriculture is the most important stage to be addressed. Reducing food waste has major leverage effects.

A crucial area affecting all industries is energy supply. In order to reduce greenhouse gas emissions below the limits of the earth’s carrying capacity, it is essential to replace fossil fuels with renewable energy sources at all stages of the supply chain and in the respective industry itself. This should be accompanied by measures to increase the energy efficiency. This applies not only to production but also to the use phase.

1 Background and project goal

1.1 Background

The 2030 Agenda for sustainable development, adopted by the member states of the United Nations in 2015, sets the globally applicable framework for national and international efforts to find shared solutions to the world's greatest challenges, amongst others climate change and environmental degradation. Sustainable development goal 12 aims at ensuring sustainable consumption and production patterns. It encourages companies to adopt sustainable practices and to integrate sustainability information into their reporting cycle (United Nations 2015). The CSR-Guidelines of the European Union demand that among other subjects, enterprises should have in place a process to integrate environmental concerns into their business operations with the aim of identifying, preventing and mitigating possible adverse impacts, also in their supply chains (European Commission 2011). Directive 2014/95 of the European Union (European Commission 2014) requires large companies to include a "non-financial statement" in their management report, which contains information on the effects of its activities on environmental issues. The World Business Council on Sustainable Development (WBCSD) states that four of the top five business risks are societal or environmental and prompts companies to include environmental, social and governance (ESG)-related risks into their enterprise risk management (ERM; COSO & WBCSD 2018).

With this study, the Federal Office for the Environment (FOEN) would like to promote environmental management in Swiss companies by identifying key sustainability issues and possible fields of action.

An enterprise has several basic options to reduce the life cycle environmental impacts caused by its products. It can reduce

- the direct environmental impacts related to its own production activities,
- the environmental impacts of the supply chains by changing the design of the products,
- the environmental impacts of enterprises in its supply chain through negotiation or choice of suppliers,
- the environmental impacts during use of its products (if there are any) and
- the environmental impacts of its products' disposal.

At present, most of the environmental goals of Swiss companies relate to their own production activities (Daub et al. 2016). However, effective corporate environmental management and reporting crucially depends on identifying the most important levers in the supply chain. For small, open economies like Switzerland who are strongly involved in global trade, the importance of the supply chains is particularly high. Frischknecht et al. (2018a) show that a significant proportion of the environmental impacts of Swiss consumption and production occurs abroad. This means that a great share of the environmental impacts of products manufactured in Switzerland are caused by precursor products manufactured in other countries. To enable companies to reduce their life cycle based environmental impacts in a targeted manner, identifying the most relevant value-added stages and processes with regard to their environmental impacts is of crucial importance. If these so-called environmental hotspots are known, companies can focus their efforts for resource-efficient innovations, their corporate environmental management and also reporting on these areas.

This is amongst others also increasingly acknowledged by the Global Reporting Initiative (GRI), who demands materialy disclosures in sustainability reports to reflect the organization's significant economic, environmental and social impacts.

1.2 Project goal and research questions

The overarching project goal is to contribute to increasing the awareness of Swiss companies for the environmental relevance of their supply chains in addition to their own direct environmental impacts, to identify environmental hotspots in their supply chains and to present options for Swiss companies to reduce their environmental footprint.

To reach this goal the environmental impacts of selected Swiss industries are analysed by including their supply chains and the use phase of their products, if relevant. Environmentally relevant industries are identified on the basis of selected footprint indicators. In doing so, the entire value chain from the extraction of raw materials through pre-production and direct suppliers to the environmental impacts in Swiss companies is examined. For products that are delivered to end customers and cause relevant environmental impacts during their use, the use phase is also taken into account. The drivers for the environmental impacts of the environmentally relevant industries are analysed in detail and carefully checked for plausibility. Options for improvement measures are being identified to support Swiss companies to efficiently and effectively reduce their environmental footprints.

The project provides answers to the following questions:

- Which industries cause particularly high environmental impacts considering their complete supply chain and the use phase of their end consumer products?
- Which industries are particularly important with regard to their supply chain based environmental impacts, their economic significance or their environmental improvement potential?
- Where in the value chain of selected industries do the environmental impacts occur?
- How big is the share of domestic environmental impacts? In which countries do the environmental impacts occur caused by imports of raw materials and products?
- Which raw materials, products and processes are responsible for a significant share in the environmental impacts of selected industries?

- Do the environmental footprints of the industries analysed in depth surpass the planetary boundaries or not?
- How do the Sustainable Development Goals (SDGs) relate to the relevant environmental impacts of industries?
- What measures help to efficiently and effectively reduce the environmental impacts of the industries analysed in depth?
- Which indicators are suitable to monitor the success of measures taken by the industries analysed in depth in reducing their environmental impacts by optimising production processes, supply chains and/or product designs?

1.3 Structure of this report

The methodology used is documented in Chapter 2. Chapter 3 contains the results of the process to select the industries for detailed analysis and Chapter 4 shows detailed results for the selected industries. Chapter 5 contains the synthesis of the results shown in the previous chapters, and Chapter 6 gives the conclusions and an outlook.

2 Methodology

2.1 Overview

In this project the environmental footprint of an industry is defined as the total environmental impacts caused by an industry's products from resource extraction to the factory (exit) gate. In the case of end user products causing relevant environmental impacts the use phase is also considered[1]. The post-consumer disposal stage is disregarded due to missing data on the actual disposal of each industry's products. Disposal services as intermediate inputs however are included in the supply chain. The scope thus includes the

- direct environmental impacts of the industry itself,
- environmental impacts of the industry's complete supply chain, i.e. all economic activities from resource extraction to the factory (entry) gate of the industry's enterprises and
- the environmental impacts occurring during the entire use phase of the industry's end user products (if relevant).

[1] In contrast to other studies, the term "footprint" in this study thus does not cover the entire life cycle of a product (cradle to grave), but only its production (cradle to gate) and - if relevant - its use.

Whereas the calculation of environmental footprints of single enterprises is often done with life cycle assessment, calculating the environmental footprints of whole industries calls for a different approach due to their large heterogeneity with regard to companies, products and supply chains, which can involve many different industries and countries. Environmentally extended input-output analysis allows for analysing the impact of economic activities on environmental impacts at the industry level and for tracing supply chains across industries and countries. Two input-output-based approaches can be distinguished, namely

- environmentally-extended multi-regional input-output-analysis (EE-MRIOA, used e.g. by Jungmichel et al. 2017) to analyse environmental hotspots in the supply chains of German industries and
- environmentally-extended input-output-analysis of a single country combined with trade data and LCA (IO-TRAIL[2]).

Both approaches are used in this study to complement each other's strengths and limitations. The two methodologies are described in Subchapter 2.2, their respective databases in Subchapter 2.3.

In this study six environmental indicators are used to characterise the environmental footprints of the Swiss industries. They are described in Subchapter 2.4. The industries' environmental footprints refer to the current situation. Industry-specific target values that can serve the industries as starting point for their reduction targets are derived from the planetary boundaries given for each environmental indicator and related to the economic industries analysed. Subchapter 2.5 explains the derivation of these reduction targets.

In a first step a screening of all Swiss industries is performed to select eight industries for further detailed analysis (cf. chapter 3 for details and the screening results). The screening includes an estimation of all industries' six environmental footprints and the collection of other information used in the industry selection process (e.g. industry size and growth, share of small and medium enterprises). Eight industries are then selected based on a set of objective criteria as well as having a good mix of different industries in mind.

In a second step a detailed assessment of the eight selected industries is then performed including

- a detailed analysis of the environmental footprints,
- an assessment of their environmental impact reduction requirements based on a comparison to planetary boundaries and

2 TRAIL: Trade-Information and LCA

- the elaboration of options and measures to reduce the environmental footprints, of monitoring indicators to evaluate progress and of instruments and guidelines that may prove helpful to companies.

The methodological approach chosen for the calculation of industry footprints and the assessment of reduction requirements are described in the following subchapters.

2.2 Calculation of industries' environmental footprints

As mentioned above two approaches were used to calculate the industries' environmental footprints. The EE-MRIO approach was used as the primary approach since it allows to quantify the contribution of industries and countries to the footprint. The IO-TRAIL approach was used to complement the analysis with results for the environmental footprint according to the ecological scarcity method that cannot be calculated with the EE-MRIO database.

2.2.1 Environmentally-extended multi-regional input-output-analysis

The environmental footprints of industries are analysed using environmentally-extended multi-regional input-output tables (EE-MRIOT). This approach is widely used in applied economics to analyse global value chains and in environmental economics, e.g. to assess the consumption footprint of nations.

An EE-MRIOT consists of an economic core (MRIOT) that is extended with environmental indicators. The MRIOT records the flow of goods and services between countries at the industry level. It consists of three submatrices (cf Figure 2.1),

- a matrix of interindustry flows of goods and services (mrIOT[3] in the figure),
- a matrix of flows from industries to final demand (consisting of consumption of private households, non-profit organisations and government as well as gross capital formation; mrFinalDemand in the figure),
- a matrix of factor inputs in industries mainly consisting of gross value added (mrFactorInputs).

The MRIOT disaggregates the global economy into several countries and regions and each country or region into several industries. Each entry of the interindustry matrix contains the flow of goods and services from a specific industry in a specific country to a specific industry in a specific country.

[3] mr: multi-regional

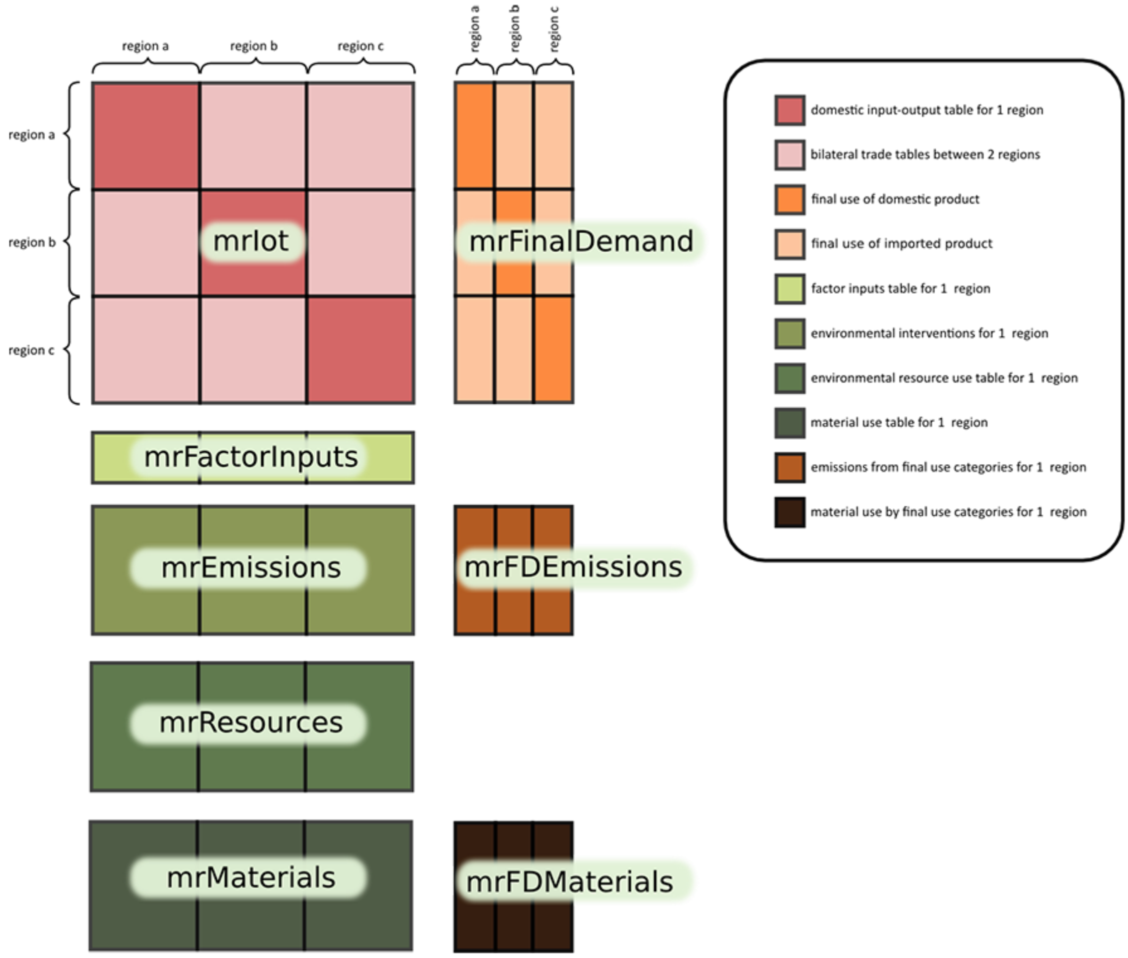

Figure 2.1: Scheme of an environmentally extended multiregional input-output table (Source: http:/www.exiobase.eu)

This economic table is extended with an environmental part, which contains country- and industry-specific data on direct environmental impacts (emission of pollutants and use of resources; matrices mrEmissions, mrFDEmissions, mrResources[4], mrMaterials and mrFDEmissions in the figure). The environmental impacts of each industry (and private households) in each country are recorded and allow to calculate industry specific environmental impact intensities, measured as environmental impact per unit of industry output.

[4] The term «resources» is used in the Exiobase database for land use, whereas the term «materials» is used for the use of other resources like raw materials and water

This MRIOT allows to calculate the environmental footprint of any industry in any country, including its complete supply chain until the factory exit gate. The use phase needs to be calculated separately. The main calculation steps are the following:

- The focal industry's output is multiplied with the so-called Leontief inverse derived from the interindustry matrix of the MRIOT. This calculation delivers the output in each industry in each country induced by the focal industry's output (i.e. the industry's complete supply chain across industries and countries). The result is adjusted to eliminate double-counting of intermediate inputs of the focal industry.
- The industry output in each country is multiplied with the industry specific environmental impact intensities to yield the total environmental impacts in each industry in each country. The total of environmental impacts across industries and countries is equal to the environmental footprint of the focal industry.

In this study we used a variation of this approach. In EXIOBASE, the EE-MRIOT used in this project, the data for Switzerland are based on the official Swiss IOT for 2008. In a recent project a new version of the Swiss IOT 2008 was developed, that includes substantial disaggregation and improved data quality for the environmentally relevant energy, transport and food sectors and a wide range of environmental data (Nathani et al. 2016, Frischknecht et al. 2015). We therefore used a two-step approach, combining the new Swiss EE-IOT for the calculation of environmental impacts in Switzerland and EXIOBASE for the calculation of environmental impacts in foreign countries. In this two-step approach the calculation steps are as follows:

- Starting with the total production output of the focal industry, the total output and gross value added induced in other Swiss industries are calculated with the Swiss EE-IOT. The results are again adjusted to eliminate double-counting of intermediate inputs of the focal industry.
- The environmental impacts in Swiss industries are then determined by multiplying the output with industry-specific environmental impact coefficients as reported in the Swiss EE-IOT.
- The calculation also yields the imports by product group that are induced in the supply chain of the focal industry. These imports are then distributed to source countries. For this a table of product-group specific country shares was developed, distributing imported product groups to source countries. The table was derived from the Swiss foreign trade statistics (for source countries of goods), the Swiss balance of payments and the OECD-WTO Balanced Trade in Services Statistics (for source countries of services). The table distinguishes between imported product groups used for intermediate consumption and for final consumption.
- The imports by product group and source country are then fed into EXIOBASE, which is used to calculate the total output in all industries in all countries induced by these imports and the total environmental impacts caused by these for-

eign production activities. The environmental impacts are quantified using the selected footprint indicators described in Subchapter 2.4.

A further adaptation of the approach refers to the inclusion of investment goods into the supply chain calculations. In input-output tables only the use of intermediate inputs in industries is recorded and included in the calculation of output multipliers. The use of investment goods in industries is recorded in total as depreciation in the factor inputs matrix, but not allocated to supplying industries. We therefore roughly estimated the use of investment goods in the industries by distributing each industry's depreciation to product groups. The estimation of the investment matrix in the Swiss EE-IOT is explained in Nathani et al. (2018). It includes the estimation of each industry's depreciation (distinguishing between buildings and other equipment) and the distribution of depreciation to supplying industries (e.g. construction, machinery, planning) with shares from the final demand matrix and assuming same shares for all investing industries, since specific data are not available. In the Exiobase MRIOT each industry's depreciation is recorded but it is not differentiated between buildings and other equipment. We therefore assumed that depreciation of the real estate services industry can be fully allocated to construction and that depreciation of other industries can be allocated to supplying industries according to the shares from the final demand matrix (after deduction of the above-mentioned construction values).

The investment matrix was then included in the calculation of multipliers that are used to determine total output effects.

The following Table 2.1 displays the elements of this approach.

Table 2.1: Elements of the adapted EE-MRIOT approach (Source: own depiction)

	Results		
	Output and value added	**Imports into Switzerland**	**Environmental impacts**
Focal industry	Swiss EE-IOT		Swiss EE-IOT
Domestic suppliers	Swiss EE-IOT		Swiss EE-IOT
Imports into Switzerland (by country of origin)		Swiss EE-IOT, Swiss and OECD trade statistics	-
Suppliers in foreign countries	EE-MRIOT		EE-MRIOT

The results of these calculations are

- total economic output and gross value added in all industries and all countries caused by the focal Swiss industry's production activities,
- total environmental impacts in all industries and all countries caused by the focal Swiss industry's production activities.

The economic and environmental impacts are structured by supply chain stages, distinguishing between the focal industry itself, direct suppliers to the focal industry, resource extraction industries and other industries of the supply chain. Resource extraction industries are defined as agriculture (NOGA 2002: 01), forestry (NOGA 2002: 02), fishery (NOGA 2002: 05) and mining and quarrying (NOGA 2002: 10 - 14). When direct suppliers belong to the resource extraction industries, they are recorded in the latter group, not as direct suppliers.

In a different perspective the environmental impacts are allocated to the direct suppliers. Thus each direct supplier is presented with its total (cradle to exit gate) environmental footprint. In this perspective the total environmental footprint of the focal industry comprises its direct environmental impacts and the environmental footprints of its direct suppliers. This perspective allows the companies from an industry to prioritise the suppliers that they should address for optimisation measures.

2.2.2 Environmentally-extended input-output-analysis combined with trade data and LCA (IO-TRAIL)

The second approach was originally developed to estimate the environmental footprint of Swiss consumption (Jungbluth et al. 2011). It relies on two elements,

- the above mentioned Swiss EE-IOT, but with a different representation of imports,
- LCA data to calculate the environmental impacts of imported products.

In this version of the Swiss EE-IOT the representation of imports distinguishes between goods and services. The use of imported goods by industries and final demand is recorded in physical units and follows the SITC classification used in trade statistics. This allows to link the imported goods to LCA data that are used to calculate the environmental impacts and are available in physical units. The import of services is recorded in monetary units.

The Swiss EE-IOT was used as described above to calculate domestic production, value added and environmental impacts induced by the focal industry in the domestic industries. It was also used to determine the induced imports by product group.

The environmental impacts of imported products were calculated with LCA data. In a first step, a representative product mix from the LCA database was chosen for each imported product group and linked to the import volume. Approximately 400 product groups are distinguished. The environmental impacts of imported services were determined with data used in Jungbluth et al. (2011).

With regard to the investment effect, investment goods were included in the calculation of supply chain effects with the Swiss EE-IOT in the same way as mentioned above and also in the LCA data used to determine the environmental impacts of imported products.

The following Table 2.2 displays the elements of this approach.

Table 2.2: Elements of the IO-TRAIL approach (Source: own depiction)

	Results	
	Production and value added	**Environmental impacts**
Focal industry	Swiss EE-IOT	Swiss EE-IOT
Domestic suppliers	Swiss EE-IOT	Swiss EE-IOT
Suppliers in foreign countries	-	Products: LCA software Services: Data from Jungbluth et al. (2011)

The results of these calculations are total environmental impacts caused by the focal industry's production activities, distinguishing between the focal industry itself, Swiss industries from the supply chain and foreign industries from the supply chain. A further differentiation by supply chain stage (resource extraction industries and other industries, respectively) and source country is not possible.

2.2.3 Environmental impacts during the use-phase

Due to the importance of energy and water consumption and emissions during the use phase, the production perspective for selected products that are in demand by end customers and for which the environmental impacts of the use phase are considered relevant has been extended to include the use phase.

The use phase of products used by other industries (and not by private or public households) was not allocated to the manufacturer's supply chain, but to the supply chain of the (industry) users of these products. The operating energy and emissions from the use of machines, for example, were included in the energy and mass flow of the industries using these machines. Electricity use during use phase was modelled with the Swiss electricity mix 2014 ("Versorgungsmix", including electricity production in Switzerland and imports, see Messmer & Frischknecht 2016b).

Energy and water consumption, emissions to air, water and soil and land use were taken into account over the entire service life of products. While the industries' environmental footprints, based on the Environmental IOT and Exiobase, depict the supply chains in 2007/2008, today's products were considered for calculating the environmental impacts of the use phase, taking into account data availability. In this way, the improvements in energy efficiency achieved in the last about 10 years are taken into account.

The industries for which the use phase has been taken into account are listed in Table 2.3.

Table 2.3: List of industries where the use phase of the products has been taken into account

Number	Industry name
23	Manufacture of coke, refined petroleum products
24 w/o 24.4	Chemicals and chemical products*
30, 31	Manufacture of office machinery and computers + Manufacture of electrical machinery and apparatus n.e.c.
32	Manufacture of radio, television and communication equipment and apparatus
40g	Gas supply
45 / 70, 97	Construction / real estate services*
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel

* industries analysed in depth

The environmental impacts during the use phase of the products were calculated using life cycle assessment data. They were related to one year in order to be able to compare them with the environmental impacts of the annual production of the industry in question.

2.3 Data basis

2.3.1 Overview

To calculate environmental footprints with the approaches described above we used three databases:

- the environmentally extended IOT for Switzerland, developed in the framework of the NRP 69 project “Sustainable agri-food systems” (Nathani et al. 2016, Frischknecht et al. 2015)
- the EE-MRIOT Exiobase (Stadler et al. 2018) and
- the KBOB life cycle inventory data DQRv2:2016, based on ecoinvent data v2.2.

These databases are described in the following sections.

2.3.2 Environmentally extended IOT Switzerland 2008

To calculate environmental impacts within Switzerland, a Swiss EE-IOT was used that was recently developed in the framework of the NRP 69 project “Sustainable agri-food systems” (Nathani et al. 2016, Frischknecht et al. 2015). Compared to the official Swiss IOT, it is characterised by a larger number of industries (roughly 100 vs. 50), especially detailed with regard to the energy, transport, agriculture and food industries that are particularly relevant from an environmental perspective. Furthermore the quality of the data representing these industries was improved. The economic part of the IOT is complemented with roughly 100 environmental indicators (emissions of pollutants and resource uses) of industries and private households that can be aggregated to various midpoint and endpoint indicators (including the Swiss eco-points according to the ecological scarcity method 2013). The reference year of the Swiss EE-IOT is 2008. The industry classification follows NOGA 2002.

The Swiss EE-IOT distinguishes between the use of domestic and imported products in industries and final demand. Imported products are recorded both in monetary and physical units. This allows linking the Swiss EE-IOT both to Exiobase (monetary units) and to LCI data (physical units).

2.3.3 Environmentally extended multiregional Input-Output-Table Exiobase

Exiobase is a multiregional IOT that has been developed by European research consortiums in various projects. Compared to other MRIOTs (e.g. GTAP, WIOD, OECD) it is characterised by high sectoral detail and a large set of environmental indicators.

Exiobase contains data covering 44 countries, including the EU 27 countries, other OECD countries and large emerging countries and five aggregated world regions. 200 branches and product groups are distinguished, which is substantially more than other MRIOT databases offer. In total, Exiobase contains data on 417 environmental indicators that represent emissions and resource use by industries and private households. It covers the years 1995 to 2011. The previous version Exiobase 2 refers to the year 2007. Whereas Exiobase 3 has advantages with regard to time series and the quality of the environmental data, we found that its economic data (e.g. sectoral output) partly show significant deviations from official national accounting data and input-output tables. On the other hand the economic data in Exiobase 2 show smaller deviations from official data on average, especially with regard to Switzerland's main trading partners. Since our aim was to link Exiobase with the Swiss EE-IOT, we used Exiobase 2 for the economic data. Due to the more advanced representation of the environmental indicators, we used the environmental data from Exiobase 3.4. Both Exiobase versions show the same number of industries and product groups and a similar number of countries[5]. Therefore it was possible to combine the two data sets.

In this project data for the reference year 2007 were used to ensure compatibility between economic and environmental data and proximity to the reference year of the Swiss EE-IOT (2008). The industry classification of Exiobase follows NACE rev. 1.1, which is similar to the Swiss classification NOGA 2002.

[5] Exiobase 2 excludes Croatia.

2.3.4 KBOB life cycle inventory data DQRv2:2016

The data basis used to model the imports in the IO-TRAIL approach is the KBOB LCI data DQRv2:2016 (KBOB et al. 2016). These data are based on ecoinvent data version 2.2 (ecoinvent Centre 2010). Updated data on transport services (Frischknecht et al. 2016) and on the Swiss electricity mixes 2014 (Messmer & Frischknecht 2016b) have been added to the KBOB LCI data DQRv2:2016. In addition, data from the World Food Life Cycle Inventory Database (Nemecek et al. 2015) representing many of the imported food products were embedded in the KBOB Life Cycle Inventory data DQRv2. These data have been regionalised in a project on the environmental footprint of the consumption of Switzerland from 1996 to 2015 (Frischknecht et al. 2018a). In addition, a number of LCI data, in particular datasets representing power production and mining of minerals and metals have been adapted by including country-specific land and water flows (see Frischknecht et al. 2018b). Remaining gaps in the KBOB LCI data were filled with life cycle inventory data from the company's own LCA database (treeze Ltd. 2017).

2.3.5 Methodological assumptions and limitations

Estimating the environmental footprint of industries is a highly complex issue that requires large amounts of data. The main reasons for this level of complexity include the heterogeneity of industries comprising many different companies with individual supply chains, the complexity of supply chains in a global economy spanning across many industries and countries and the variety and industry- and country-specificity of emissions and resource uses induced by production activities and their environmental impacts.

The tools used in this project to trace these highly complex supply chains are sophisticated, but still come with certain methodological assumptions and limitations that are briefly summarised in the following.

With regard to the EE-MRIOT, the main assumption used in IO modelling is that the industries and product groups are assumed to be homogeneous. This means that each industry produces a homogeneous product mix that is delivered to all industries and final demand categories. Resource and emission intensities of industries are constant for all destinations of industry products. Since industries are the lowest level of aggregation in the IOT it is not possible to represent heterogeneity with regard to input and output structures or resource and emission intensities below the industry level (e.g. emission intensities of export-oriented companies vs. companies oriented towards the domestic market). Due to this homogeneity assumption, modelling with Exiobase generally assumes that the environmental footprint of the exports of a specific industry in a specific country equals the average environmental footprint of the exporting industry.

The use of an EE-MRIOT entails the monetary allocation principle as opposed to the physical allocation principle mostly used in LCA. This means that the environmental footprint of an industry in a supply chain is allocated to its upstream “customers” according to their monetary share in the industry’s output.

These assumptions also apply analogously to the IO part of the IO-TRAIL approach (Swiss EE-IOT).

The imports modelled with LCA data in the IO-TRAIL approach refer to typical products of the corresponding SITC category. These categories are the lowest level of aggregation. This means that the imports do not necessarily reflect the products actually imported by a particular industry, but the production mix in the corresponding SITC category to which the imported products of that industry belong.

2.3.6 Data quality and uncertainties

In recent years significant resources have been invested to improve EE-MRIOT and LCA databases that are able to cover the global supply chains, but the data are still prone to uncertainties. With regard to the Swiss EE-IOT the following uncertainties are relevant for the study at hand:

The Swiss IOT represents an estimation of the flows of goods and services in Switzerland. It is classified by the Swiss OFS as an experimental statistics, since certain basic statistics used in other European countries to build IO tables are missing in Switzerland. This especially holds for commodity statistics and for statistics on the intermediate inputs of companies. While the sum of intermediate inputs is based on the official production account, the intermediate inputs of industries in the Swiss IOT are estimates based on input structures of similar industries in other European countries. In the construction process of the Swiss IOT the input structures can be subject to adjustments if necessary to balance disequilibriums between product supply and demands. In the Swiss EE-IOT 2008 the data quality of food, energy and transport data have been improved and based on Swiss statistics (cf. Nathani et al. 2013, Nathani et al. 2016). Yet, it is still important in the context of this project to check the plausibility of the industry inputs before using them in the calculations, e.g. by comparing them to input structures in other countries.

With regard to imported goods, the total imports are well-founded on trade statistics (with larger uncertainties for services than for goods), but the allocation of imported products to using industries and final demand categories is uncertain. In the development of the Swiss EE-IOT 2008 (Nathani et al. 2016) we have used detailed data from the Swiss foreign trade statistics and correspondence tables between detailed import commodity codes and use categories from the OECD to distinguish between intermediate and final uses of imported goods. We have then applied the commonly used proportionality assumption to further distribute goods for intermediate use to using industries. Thus the use of imported goods by industries is an estimate with uncertainties.

The allocation of emissions and resource uses to industries is for a larger part well-based on environmental statistics, but partly based on auxiliary indicators such as monetary or physical output or employment.

The imports in the IO-TRAIL approach have been modelled with LCA data. The latest available, regionalised data from the KBOB LCI database DQRv2:2016 (KBOB et al. 2016) and the World Food Life Cycle Inventory Database (Nemecek et al. 2015) have been used for this purpose. However, regionalised data sets could only be used for the most important products in terms of volume from the main import countries. The remaining products and countries of origin were modelled using non-regionalized data sets. Since regionalisation mainly affects biodiversity loss and water consumption and these two indicators were calculated using the EE-MRIO approach, this has no major impact on the uncertainty of the results.

The composition of the aggregated import groups according to the SITC categories could have a larger impact. If the composition of the imported products of a specific industry deviates greatly from the composition of the respective SITC group, this can lead to distortions in the environmental intensity of the respective imported products. This uncertainty was minimized by comparing the results according to the IO-TRAIL method with the results according to the EE-MRIO approach and verifying the contributing direct suppliers and imports.

With regard to the EE-MRIOT Exiobase, to our knowledge the available information on global production activities and their environmental impacts has largely been used in several large-scale projects to construct the database. Yet the following data uncertainties remain and are relevant for this study:

The quality of data on economic output and gross value added differs between countries. While the data quality of values is rather high at the aggregate sectoral level, data uncertainties can be larger for sectorally disaggregated data. This is especially true for emerging and developing countries.

The uncertainties increase with regard to the quality of input-output tables that depict the flows of goods and services within countries. Even though data quality has increased over the past years there still exist large differences between countries regarding the timeliness, disaggregation level, quality and international comparability of input-output tables. Exiobase uses elaborate algorithms to integrate the existing data into a coherent framework while minimising information loss.

Regarding import and export data past analysis has shown that significant differences can exist between bilateral trade data that trade partners report. Empirical research projects have aimed at reconciling trade data and these reconciled data have been included in Exiobase but uncertainties still remain.

Regarding environmental data, the available international statistics on resource use and emissions have extensively been exploited in the construction of Exiobase. Yet uncertainties exist in the allocation of emissions and resource use to single industries, especially with regard to emerging and developing countries and the five rest-of-the-world regions in Exiobase, where emission intensities have partly been roughly estimated by using auxiliary indicators such as value added.

We have dealt with these uncertainties by

- checking the plausibility of the input structures of the eight Swiss industries analysed in detail and adjusting the input structures in two cases (‘chemical industry’ and ‘health and social work’),

- capping the environmental intensities of industries in the aggregated world regions to the maximum of countries included in the database. Our first results have shown that the aggregated world regions have a strong influence on results. Since the data uncertainties for environmental intensities are especially large for these regions, we have introduced the caps. Therefore the results may partly be underestimated.

Even though the data used in this study are probably the best available to analyse the environmental impacts of supply chains at the industry level, due to the high complexity of global supply chains and environmental impacts and the mentioned data uncertainties, the results of the calculations should be regarded as estimates for Swiss industries that help identify the possible hot spots in their supply chains. Yet, at the company level, the supply chains and their environmental impacts can differ strongly from the industry averages presented in this study. Therefore companies can use the results as hints for identifying environmental hot spots, but they still need to analyse their own supply chains in detail to be able to improve their environmental performance.

This project uses data for the reference year 2008, since this is the reference year for the most recent Swiss EE-IOT. Exiobase data with the reference year 2007 are used to match the Swiss data. The most recent reference year, for which Exiobase data are publicly available, is 2011. Such a time lag is not unusual for EE-IOTs due to the fact that large amounts of data need to be collected and processed into a common framework. The use of this reference year could have the following impact on the results:

- At the time of completion of this report the share of emerging countries (esp. China) in the Swiss industries' supply chains is probably larger than in 2008. Thus our results may underestimate the environmental footprints of Swiss industries if we assume that emerging countries have larger environmental footprints than developed countries.
- On the other hand technical progress may have reduced the environmental intensities of industries since 2008, thus leading to an overestimation of results and reducing the former effect.

The imports modelled with LCA data in the IO-TRAIL approach refer to the latest available data and generally reflect current practices. However, in the event of major changes in practice or decisive technical progress in recent years, the environmental impact could be under- or overestimated. This uncertainty lies within the general uncertainty range of the LCA data.

2.3.7 Data provision

The entire database described above is published on the treeze website and is available for further assessments at http://treeze.ch/projects/case-studies/lifestyles/environmental-footprints-of-switzerland-developments-from-1996-to-2015. The life cycle inventories are offered in the ecospold v1 (xml) format and the impact assessment methods are provided in the SimaPro csv format. They are licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. In order to download the data, interested people are required to register and login. A detailed read-me with information on how to implement and use the data is available as well.

2.4 Environmental indicators

2.4.1 Greenhouse gas footprint

The climate change effect of greenhouse gases is expressed by the Global Warming Potential (GWP) according to the 4th Assessment Report of the Intergovernmental Panel on Climate Change (expressed in kg CO_2-equivalents according to IPCC 2007). The indicator covers the so-called “Kyoto-Substances” CO_2, CH_4, N_2O, PFC, HFC, SF_6 and NF_3. The climate-impacting ozone-depleting substances regulated by the Montreal Protocol are not included. The additional warming effects of the stratospheric emissions from aircrafts are taken into account according to Fuglestvedt et al. (2010) and Lee et al. (2010). Allocated to the emission of one kilogram of CO_2 emitted by an aircraft, the global warming potential of the vapour trails generated by aircraft, the induced clouds and the water vapour emitted is 0.95 kg CO_2-eq. The global warming potential of CO_2 emissions from burning kerosene by aircrafts is thus 1.95 kg CO_2-eq/kg. The software used for calculating the environmental footprints distinguishes CO_2 emissions according to where they are emitted (upper troposphere and stratosphere vs. on ground and lower troposphere). According to the updated Life Cycle Inventories of Messmer and Frischknecht (2016a), CO_2 emissions at cruising altitude account for 70 % of total emissions for an average flight. For this reason, a global warming potential of 2.35 kg CO_2-eq/kg is used for the CO_2 emitted by aircraft in the upper troposphere and lower stratosphere, while the global warming potential of the CO_2 on the ground and in the troposphere is 1.0 kg CO_2-eq/kg. Related to a flight with 70 % of the emissions at cruising altitude, the rest near the ground, this again results in the 1.95 kg CO_2-eq./kg, which apply to aircraft emissions in general.

2.4.2 Biodiversity footprint

Land use is one of the major causes of biodiversity and species loss. The indicator “potential species loss from land use” (Chaudhary et al. 2016) quantifies the damage potential of land use on biodiversity. The indicator quantifies the loss of species in amphibians, reptiles, birds, mammals and plants by the use of arable land, permanent crops, pasture, intensively used forest, extensively used forest and urban areas. The indicator weights endemic species higher than species that are common. Species loss is determined in relation to the biodiversity of the natural state of the area in the region concerned. The indicator aggregates the regional loss of commonly occurring species and the global loss of endemic species into “globally lost species”. By that, the indicator aggregates differing impact intensities into a common unit, similar to the unit “kg CO_2-equivalents” used to aggregate greenhouse gas emissions (see above). The biodiversity footprint is expressed in equivalents of potentially globally lost species per million species (micro PDF·a). The indicator covers only a small share of all endangered species listed on the “red list”. This indicator was recommended by the UNEP SETAC Life Cycle Initiative as best available indicator for the time being ("interim recommendation"; Chaudhary et al. 2015; Chaudhary et al. 2016; Frischknecht & Jolliet 2016).

2.4.3 Eutrophication footprint

The release of nitrogen into the environment causes a wide range of problems. The most obvious of these is marine eutrophication ("over-fertilization" of the Oceans): The indicator used in this study quantifies the amount of nitrogen that potentially enters the oceans through the emission of nitrogen compounds in water, air and soil and thus may contribute to over-fertilization (Goedkoop et al. 2009). Nitrogen quantities are taken into account according to their marine eutrophication potential (kg N-equivalents).

2.4.4 Water footprint

The water footprint describes the extent to which a Swiss industry uses the global freshwater resources, taking into account the prevailing water scarcity in the production regions. The water footprint is quantified using the water scarcity indicator AWARE, recommended by the UNEP SETAC Life Cycle Initiative (Boulay et al. 2017). The AWARE indicator is based on the assumption that decreasing water availability in a region increases the likelihood that other users will be deprived in their access to water. The indicator quantifies the available water quantity per catchment area by subtracting the water requirements of humans and ecosystems from the amount of naturally available water.

2.4.5 Air pollution footprint

Air pollution and in particular fine particles have a major impact on human health and well-being. Thus the air pollution footprint is characterised with primary and secondary particles and the associated effects on human health, such as respiratory diseases (Goedkoop et al. 2009). The emissions of the particulate matter precursors NO_X, SO_2 and NH_3 are converted to kg PM_{10}-equivalents according to their potential to form particulate matter.

2.4.6 Environmental footprint (UBP-method 2013)

The method is based on Switzerland's legally or politically defined environmental goals (distance to target) and evaluates resource extraction (energy, primary resources, water, land), pollutant inputs into the air, water and soil, waste and noise (Frischknecht & Büsser Knöpfel 2013). The indirect additional climate change effects of stratospheric emissions from aircrafts are taken into account (see Section 2.4.1). The method is also called the Ecological Scarcity Method (UBP) and is used by numerous Swiss companies.

2.4.7 Normalisation

In order to illustrate the relevance of the environmental footprints of the selected industries, the share of their environmental footprints in the respective global environmental footprint was determined for each industry and expressed in parts per million (ppm). Additionally, the share of the gross production value of the selected industries in global gross production value was calculated. A comparison of the share in environmental footprints with the share in gross production value indicates whether the industry's environmental footprint intensities are above or below average.

2.5 Target values for industries based on planetary boundaries

2.5.1 Global limit values

Based on the planetary boundaries (Steffen et al. 2015), global limit values (or "budgets") for footprints are deduced. For determining those limit values the methodological approach from Dao et al. (2015) was adopted and applied to the environmental indicators analysed in this study. In addition, new and further findings from Steffen et al. (2015) were taken into account.

Limit values based on planetary boundaries are defined for the greenhouse gas, biodiversity, eutrophication and air pollution footprints. Planetary boundaries are usually defined on a global level[6]. Water availability and scarcity depends very much on the geographic location. Water shortage in one region cannot be compensated by excess water in another region. Thus we refrained from defining a planetary boundary for the water footprint.

According to the calculations of Dao et al. (2015), the global yearly limit for greenhouse gas emissions is 12.3 Gt CO_2-eq per year. For agricultural nitrogen losses, the global yearly limit equals to 47.6 Mt (Dao et al. 2015). For the biodiversity and the air pollution footprints, the global limits were set according to Frischknecht et al. (2018a):

For biodiversity, Steffen et al. (2015) propose to define the naturally occurring loss of species as an estimate and quantify the globally tolerable loss of species per year with less than 10 species per million species (with an uncertainty range of 10 to 100 species per million species). With a starting point in the year 500 as a reference state of unaffected nature[7], by 2008 some 15,000 species would have been lost naturally. This value was therefore used as limit value for comparison with long term potential global species loss due to land use.

---

[6] For more information about the concept of planetary boundaries, see https://www.stockholmresilience.org/research/planetary-boundaries/

[7] Beginning of large-scale deforestation and thus the man-made loss of biodiversity in Central Europe.

For the air pollution footprint, determining a limit value based planetary boundary is also difficult, as the extent of the overall impact on human health depends heavily on where the particles or their precursors are emitted. The comparison of the current annual emissions of PM10 and the particulate matter precursors NOX, NH_3 and SO_2 in Switzerland with the amounts in compliance with Switzerland's Ordinance on Air Pollution Control (OAPC; LRV 2009) (both converted into particulate matter equivalents) results in a reduction requirement of around 39%. As a conservative assumption, we can also apply this reduction requirement to foreign emissions and set the necessary global reduction at 39 %.

Table 2.4 shows an overview of the yearly emission budgets available for each indicator, the worldwide emissions during the year 2008 and the necessary reduction. The reference year 2008 was used to ensure compatibility with the Swiss EE-IOT (see Chapter 2.3.3).

Table 2.4: Yearly emission budgets, global emissions in the year 2008 and the necessary reduction at global level for each environmental indicator analysed

Environmental indicator	Unit	Limit value for global footprint [reference year]	Current global environmental footprint (2008)	Necessary reduction (global level)	Source
Greenhouse gas footprint	Mt CO_2-eq./a	12‘300	50‘800	76%	Dao et al. 2015
Biodiversity footprint	10^{-6} PDF*a/a	15‘000	88'901	83%	Steffen et al. 2015; Frischknecht et al. 2018a
Eutrophication footprint	Mt N/a	47.6	55.6	14%	Dao et al. 2015
Air pollution footprint	Mt PM_{10}-eq/a	65.3	106.3	39%	Frischknecht & Büsser Knöpfel 2013

2.5.2 Concepts deriving "One Planet" target values for industries

In order to be able to make a statement on the compatibility of the environmental footprint of a particular industry with the limits of the earth's carrying capacity, the budgets available have to be divided between the different industries and countries. Several different approaches are conceivable to do this. Sabag Muñoz and Gladek (2017) categorize the existing approaches into

1. Egalitarian approaches (equal share)
2. Approaches based on economic throughput

3. Approaches based on economic capacity and efficiency
4. Historical approaches (taking into account responsibility for previous impacts or the need for a continuous access for resources).

Similarly, Höhne et al. (2014) propose the categories of (1) Equality (2) Cost effectiveness (3) Capability and (4) Responsibility. Criteria like equality and responsibility suggest that there is no single and objectively "correct" way of allocating (Sabag Muñoz and Gladek 2017). Whatever allocation principle is chosen, the results on the need for reduction must be seen as a starting point for discussion, not as authoritative target values.

When choosing the allocation approach, it is important to take into account the perspective adopted. For example, the socially ideal principle of egalitarianism is currently impossible to implement in a company context (Sabag Muñoz & Gladek 2017).

In this project we focus on industries and aim at providing a science base to support companies in their process of setting environmental targets. Considering all feasible alternatives, the best way forward for companies would be to establish impact ceilings based on demand trends, sectoral performance and best practices, and costs of impact abatement. These impact ceilings and target settings should ideally be developed and determined under the stewardship of civil society organisations (Sabag Muñoz & Gladek 2017). An example of such a civil society organisation is the Science Based Target initiative[8], which helps companies to determine how much they must cut their greenhouse gas emissions, with the overall goal of keeping global temperature increase below 2° C. The Science Based Target initiative differs between two main approaches to allocate emissions at company level (CDP et al. 2017):

1. Convergence, where the emissions intensities of all companies from a given industry converge to that required by a global 2° C pathway by 2050; and
2. Contraction (related to intensities or absolute amounts), where all current sources of emissions reduce at the same rate disregarding cost, equity, or growth factors.

The convergence of emission intensity approach assumes that the emission intensity of all companies within a given industry converges towards the respective planetary boundary based intensity (e.g. 2° C carbon intensity) of that industry at a rate that ensures the sectoral budget is not exceeded. This method can only be used with emissions scenarios that disaggregate emissions at the sector level. So far, such emission scenarios have only been available for selected industries in the area of greenhouse gas emissions (see CDP et al. 2015).

The contraction approach can be applied to emission *intensities* or *absolute* emissions.

---

8 www.sciencebasedtargets.org, visited on 13.2.2018.

- The contraction of emission *intensity* approach assumes that all companies within the same level of disaggregation (i.e. industry, region or globally) reduce their emission intensity at a parallel rate that ensures the respective planetary boundary based budget (e.g. 2° C carbon budget (industry, region or global)) is not exceeded. The rate of contraction is a function of the emission budget and the expected level of activity for the sector or region concerned. Activity can be expressed using economic (e.g. value added) or physical (e.g. ton of product) indicators. The challenge with intensity approaches is effective modelling of the denominator (e.g. Euro GDP) to ensure the emission budget is not exceeded (CDP et al. 2015).

The contraction of *absolute* emissions assumes that all companies within the same level of disaggregation (i.e. sector, region or globally) reduce emissions at the same rate. The rate of contraction is purely a function of the overall reductions implied in the corresponding emissions scenario. Using this approach, all companies have to reduce their emissions by the same amount. The contraction of absolute emissions approach has been applied in this study and is used for allocating the above mentioned global budgets to the different industries. It corresponds to the grandfathering principle[9]: Industries with high initial (actual) environmental impacts will be allowed higher target values than industries with low initial environmental impacts. However within a given industry the individual companies are attributed the same target values in a given year.

2.5.3 Implementing the contraction approach

The contraction of absolute emissions approach was implemented as follows:

- First, the current absolute environmental footprints (i.e. including the whole supply chain, and the use phase in the sectors “construction” and “equipment trade”) of the Swiss industries were quantified.
- Then the industry-specific target values were determined by multiplying the respective relative global reduction requirement with the current absolute environmental footprint of each Swiss industry.

Specific Swiss reduction requirements are available for the greenhouse gas and the eutrophication footprints (see Table 2.5). For these two footprints the industry-specific target values were derived using a weighted average of the Swiss and the global reduction requirements. The weighting was based on the respective shares of domestic and foreign emissions, i.e. the industry specific reduction requirements are composed of the sum of the share of emissions occurring in Switzerland, multiplied with the specific Swiss reduction requirements and the share of emissions occurring abroad, multiplied with the relative global reduction requirements.

---

[9] It is argued that those who have been using a resource have a higher need to continue using it, basically creating inertia on existing use patterns (Sabag Muñoz & Gladek 2017).

The industry's target values as well as their current environmental footprints were finally divided by the respective global environmental footprints (see also Section 2.4.7).

Table 2.5: Necessary reduction at global and Swiss level for each environmental indicator analysed

Environmental indicator	Unit	Necessary reduction (global level)	Necessary reduction (Swiss level)	Source
Greenhouse gas footprint	Mt CO_2-eq./a	76%	80%	Global: Dao et al. 2015; CH: Frischknecht & Büsser Knöpfel 2013
Biodiversity footprint	10^{-6} PDF*a/a	83%		Steffen et al. 2015; Frischknecht et al. (2018a)
Eutrophication footprint	Mt N/a	14%	34%	Global: Dao et al. 2015; CH: Frischknecht & Büsser Knöpfel 2013
Air pollution footprint	Mt PM_{10}-eq/a	39%		Frischknecht & Büsser Knöpfel 2013

The planetary boundaries concept was not applied on the water footprint. An alternative approach was followed, which acknowledges regional differences in water scarcity. For each industry, a ranking was established listing the countries which contribute most to the water footprint. For each country on this list, the share of renewable water resources currently being used was then specified. Countries with a high contribution to the water footprint and at the same time a high amount of renewable water resources already in use (close or higher than 20 %, which is the tolerable pressure on renewable water resources according to OECD (2003))are considered those where action on the water footprint is of high priority.

2.5.4 Uncertainties regarding planetary boundaries

The above described derivation of planetary boundaries for individual industries is associated with a number of uncertainties. The yearly global emission budgets used for defining the planetary boundaries refer to threshold values determined by science, based on a large agreement from the scientific community, but the uncertainty range still is large. This is due to due to a) the use of global data sets with medium accuracy in comparison with data generally used at country level, and b) the process of setting limits based on expert advices and/or policy decisions due to lack of other data (Dao et al. 2015).

As the global limit value used for Climate Change (based on Dao et al. 2015) reflects only a 50 % chance to stay below a 2°C increase by 2100 compared with pre-industrial level, the necessary reduction in greenhouse gas emissions should in reality be higher than calculated in this study. Furthermore since the limit value in Dao et al. (2015) was for the reference year of 2015 and has since then been exceeded, the world's remaining available greenhouse gas budget is continuously shrinking. In the long term only a complete decarbonisation of the energy supply seems to be in line with aiming at the 2°C goal and the aspirational goal of 1.5 °C, as agreed on in the Paris Agreement. For future calculations of global footprint limits we recommend to base on scenarios providing at least a 66 % probability of reaching a 2°C increase.

The planetary boundary for the biodiversity footprint is based on information on the maximum tolerable global species loss. This value shows an uncertainty range of 10 to 100 species per million species. In this study, the lower value of 10 species per million species was used in accordance with the precautionary principle.

Determining a planetary boundary for air pollution is difficult because the extent of the effects on human health depends heavily on where the particles or their precursors are emitted. In this study, the Swiss reduction requirement in accordance with the Ordinance on Air Pollution Control was applied across the board to foreign emissions. However, the level of the limit thus set is very uncertain and should be verified or determined more precisely through in-depth analysis.

Nitrogen surpluses are distributed unevenly around the globe. Whereas some regions (e.g. Europe) have large nitrogen excesses, other regions (e.g. Africa) lack nitrogen for food production. A global perspective, as adopted in this study, has limited significance, even though the different reduction targets of Switzerland compared to global reduction targets have been taken into account. As for air pollution, for sound statements a more comprehensive analysis taking into account regionalised impact factors would be necessary.

3 Results of industry screening

3.1 Results of industry screening

The aim of the industry screening was to generate an empirical basis for selecting eight industries for further detailed analyses.

In a first round we calculated the six environmental footprints described in Subchapter 2.4 for all industries of the Swiss EE-IOT. In order to also address trade companies, we additionally determined the environmental footprints of 4 traded consumer product groups (food, textiles, household equipment and vehicles). These comprise the direct environmental impacts of the respective trade subsector as well as the environmental footprints of domestic and imported products consumed by households, including the use phase in the cases of household equipment and vehicles[10].

The results obtained were the basis for the selection of the focus industries which are analysed in more detail (cf. Chapter 4). The selection was mainly based on the following criteria:

- Relevance of the environmental footprint: all industries were ranked according to each footprint. On the one hand in absolute terms, on the other hand in terms of intensities with respect to the gross value added of the industries. The top 5 placements of every industry were then counted;
- additional criteria with regard to the footprints such as the ratio of the emissions by the industry itself to the emissions within the supply chain or the share of emissions during the use phase;
- supplementary industry information such as the industry size in terms of gross value added and employment as well as their respective growth rates during the last decade;
- another aim of the selection process was to pick a good mix of industries covering industrial sectors as well as service sectors.

Certain industries that are less in the focus of this project were excluded from the selection process. The following Table 3.1 contains an overview of the industries excluded and the reasons for exclusion.

Based on the results of the screening and further criteria we proposed a selection of industries to be studied in detail which was subsequently narrowed down in the discussion with the FOEN.

Many agri-food industries were among the top-ranked industries in terms of environmental footprints. To allow for industry diversity in the project, only one food processing industry was selected (processed meat).

---

[10] In this project the environmental footprint of an industry is defined as the total environmental impacts caused by an industry's products from resource extraction to the factory (exit) gate. The use phase is considered in the case of end user products causing relevant environmental impacts.

Table 3.1: Overview of industries excluded in the selection process

Industry	Reason for exclusion
Agriculture	Large (direct) environmental footprints which are already addressed by national environmental policy. The environmental relevance of the supply chain as compared to the direct impacts of agriculture is rather low in comparison to other industries.
Manufacture of coke, refined petroleum products	The ratio of impacts within the supply chain to the impacts of the industry itself is rather low in comparison to other industries.
Pharmaceutical products	Poor representativeness in Exiobase due to aggregation with the chemical industry.
Electricity, gas, steam and hot water supply	The ratio of impacts within the supply chain to the impacts of the industry itself is rather low in comparison to other industries.
Sewage and refuse disposal, sanitation and similar activities	Disqualifies as „key industry“, as impacts are taken into account when assessing the footprints of other industries.

From the service sector several trade subsectors were selected:

- Food trade is the largest subsector of the trade sector and moreover it is also one of the highest ranked industries in terms of environmental footprints (top 5 placements in all footprint rankings).
- In textile trade, supply chain management is already being discussed and a great potential for improvement in terms of environmental impacts is expected.
- With regard to equipment trade, the use phase is important in terms of environmental footprints due to electricity consumption, which makes the industry interesting for the detailed analyses.

Real estate activities were selected in order to analyse them jointly with the construction sector, since the two industries are highly intertwined.

The final set of chosen industries is displayed in Table 3.2. The table also covers some of the information on which the selection was founded, in particular the ranks of the industries with regard to the environmental footprints.

Table 3.2: Results of Industry screening. * Values refer to wholesale and retail trade as a whole, not to trade subsectors

Industry		Gross value added	Greenhouse gas footprint	Biodiversity footprint	Water foot-print	Air pollution footprint	Eutrophica-tion footprint	Total Envi-ronmental footprint[11]	Share of env. impacts in supply chain	Env. impacts in use phase?	Share in GDP	Share of em-ployment in SME
		Rank	Rank	Rank	Rank	Rank	Rank	Rank				
15.1	Processing of meat	39	16	3	13	6	3	16	99%	no	0.2%	69%
24 w/o 24.4	Chemical industry, w/o pharmaceutical industry	15	6	8	5	7	11	7	91%	no	1.2%	33%
29	Manufacturing of machin-ery and equipment	7	7	14	12	3	17	6	99%	yes[12]	2.3%	68%
45	Construction	3	1	6	3	1	10	2	70%	yes	5.1%	95%
70, 97	Real estate activities incl. private households	1	10	13	11	12	13	20	98%	yes	9.3%	-
85	Health and social work	4	4	7	6	5	9	14	96%	no	6.3%	68%

[11] rank 1: distributed electricity; rank 3: wholesale and retail trade

[12] machinery is used in other industries; thus use phase of this machinery is part of other industries‘ footprints

Industry		Gross value added	Greenhouse gas footprint	Biodiversity footprint	Water foot-print	Air pollution footprint	Eutrophica-tion footprint	Total Envi-ronmental footprint[11]	Share of env. impacts in supply chain	Env. impacts in use phase?	Share in GDP	Share of em-ployment in SME
		Rank	Rank	Rank	Rank	Rank	Rank	Rank				
51-52	Food trade	16	3	1	1	2	1	6	-	no	14.9%*	97%*
51-52	Textiles trade	32	19	18	9	19	18	66	-	yes[13]	14.9%*	97%*
51-52	Equipment trade	42	36	40	36	34	46	58	-	yes	14.9%*	97%*

13 Use phase of clothes can also contribute significantly to the environmental impacts. Energy and water use of washing machines is included in use phase of household devices.

3.2 Comparison with the results of the REFF-study

The results of the industry screening have been compared to the results of the REFF-study (Kissling-Näf et al. 2013) based on the greenhouse gas footprints[14]. On the one hand, the results of the REFF study were compared directly with the results of this study, and on the other hand with the results according to the EE-IOT 2008 (Frischknecht et al. 2015). This allowed us to estimate the effect of the use of Exiobase instead of LCA data for modelling the foreign supply chains. For both comparisons, the use phase has not been included for consistency reasons (use phase not included in REFFF-study).

The REFF-study aimed at identifying the central fields of action for increasing the resource efficiency in Switzerland by adopting different perspectives (Swiss final demand, Swiss economy as well as materials and goods categories). The main target group was policy makers, and the goal was to identify appropriate measures and instruments for increasing the resource efficiency in Switzerland and derive the need for adapting the legal basis if necessary.

The present study focuses on the environmental footprints of Swiss industries. The main target group are Swiss companies and industry associations, where the efficient use of resources should be promoted. The study aims at identifying the environmentally relevant Swiss industries by taking into account the whole supply chain. To this end, the Swiss industry as a whole and selected key industries are analysed in detail. The contributions of the individual stages of the value chain and individual countries/regions are identified.

The REFF-study is based on the EE-IOT 2005, which was developed by Jungbluth et al. (2011), and on life cycle assessment data (modelling imports and exports). In comparison to the EE-IOT 2005, the EE-IOT 2008 used in this study has been updated and substantially disaggregated. The Swiss EE-IOT 2008 was combined with Exiobase, an environmentally extended multi-regional IOT.

Nevertheless, both studies yield similar results. In terms of absolute greenhouse gas emissions, the most important industries remained unchanged: In both studies, the ‘chemical industry’ (for consistency reasons including pharmaceutical industry) causes most greenhouse gas emissions. In addition, both studies show the same industries in the top seven positions, albeit in slightly different order, namely: ‘chemical industry’, ‘transport’, ‘manufacture of food products, beverages and tobacco’, ‘construction services’, ‘electricity distribution’, ‘agriculture, hunting, forestry, fishing and farming’ and ‘wholesale and retail trade, repair’. Twelve of the fourteen most important industries in

[14] In contrast to the Ecological Scarcity method, which was used in Kissling-Näf et al. 2013 and which has since been revised, the characterisation factors to calculate greenhouse gas emissions (global warming potentials) have remained largely unchanged.

the REFF-study are also among the fourteen most important industries in this study. Not between the top fourteen industries in this study are ‘services of hotels and restaurants’ and ‘other non-metallic mineral products’.

The different ranking of the above mentioned industries is mainly explained by differences in their greenhouse gas emission intensity as their total economic output remained fairly stable. The emission intensity of ‘other non-metallic mineral products’, for example, decreased by 25 %. Both the emissions of the industry itself and its suppliers decreased by the percentage mentioned, but the large share of emissions occurs in the supply chain.

In general, the emissions intensities of the economic industries changed in both directions. For most industries, the emissions in the supply chain are far more important than the emissions of the industries themselves. The changes in the supply chain are partly due to the more detailed and regionalised modelling, but also due to the use of Exiobase for modelling the foreign supply chains.

4 Detailed results for selected industries

4.1 Overview

In this chapter the results of the detailed analysis of eight selected industries are presented. Each subchapter referring to an industry is structured as follows:

- brief introduction of the industry,
- economic impacts along the industry’s supply chain,
- environmental impacts along the industry’s supply chain presenting the environmental hotspots with regard to supply chain stages, industries, countries and the direct suppliers to be addressed by the industry. Apart from an overview for each footprint indicator, one selected indicator is analysed in depth;
- comparison with planetary boundaries and priorities for reduction measures,
- measures for reducing the industry’s environmental footprint.

Additional results for other than the selected environmental indicator are presented in detail in annex A and summarised in the industry chapters.

It should be noted that the industry results contain numerous double-counting between the industries, since almost every industry supplies products to almost every other industry. Therefore the industry footprints cannot be added up to determine the environmental footprint of the total economy.

In order to enable a comparison of the shares of the different supply chain stages between the industries examined, the supply chain is summarised in the following four value-added stages for the presentation of the results: ‘raw material extraction’, ‘remaining upstream chains’, ‘direct suppliers’ and ‘industry itself’.

Resource extraction industries are defined as agriculture (NOGA 2002: 01), forestry (NOGA 2002: 02), fishery (NOGA 2002: 05) and mining and quarrying (NOGA 2002: 10 - 14). When direct suppliers belong to the resource extraction industries, they are recorded in the latter group, not as direct suppliers.

In a different perspective the environmental impacts are allocated to the direct suppliers. Thus each direct supplier is presented with its total (cradle to exit gate) environmental footprint. In this perspective the total environmental footprint of the focal industry comprises its direct environmental impacts and the environmental footprints of its direct suppliers. This perspective allows the companies from an industry to prioritise the suppliers that they should address for optimisation measures.

4.2 Meat processing

4.2.1 Introduction

The industry 'Meat processing'[15] includes production and preserving of meat (employing 37 % of the industry's workforce) and the further processing of meat to meat products such as sausages (employing 63 %).

The Swiss meat processing industry employed 14'485 persons (FTE) in 2015. This corresponds to 0.4 % of the entire swiss workforce (cf. Table 4.1). With an average annual growth rate of 1.1 % between 2011 and 2015 the industry grew slightly faster than the economy as a whole with regard to employment.

Table 4.1: Employment in the meat processing industry (Source: FSO – STATENT)

Year	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	13'873	0.4%		
2015	14'485	0.4%	1.1%	1.0%

4.2.2 Economic impact

The total value added induced by the Swiss meat processing industry (including the supply chain) amounts to 6'012 Mio. CHF[16]. Figure 4.1 shows its distribution along the different supply chain stages. The industry itself generates 19 % of the induced value

15 Code 10.1 according to NOGA 2008, code 15.1 according to NOGA 2002

16 These and the following economic data refer to the year 2008.

added, whereas the fraction of value added imputable to direct suppliers is 7 %. The largest share with 50 % is generated by industries classified as 'remaining upstream chains'. A share of 24 % is due to the raw material extracting industries in the supply chain. It should be noted that direct suppliers stemming from agriculture (i.e. cattle husbandry) are allocated to the raw materials extraction group, not to direct suppliers.

In order to understand where - in geographical terms – the value added induced by the Swiss meat production industry is generated, Figure 4.2 shows the shares of countries in total value added induced by Swiss meat processing. Within the country shares the supply chain stages are distinguished.

The upper section of the figure displays the share of value added generated by the industry itself (19 %) as well as the shares generated within domestic (48 %) and foreign (33 %) parts of the supply chain. Thus two thirds of the value added generated within the supply chains are created in Switzerland while the rest is created abroad.

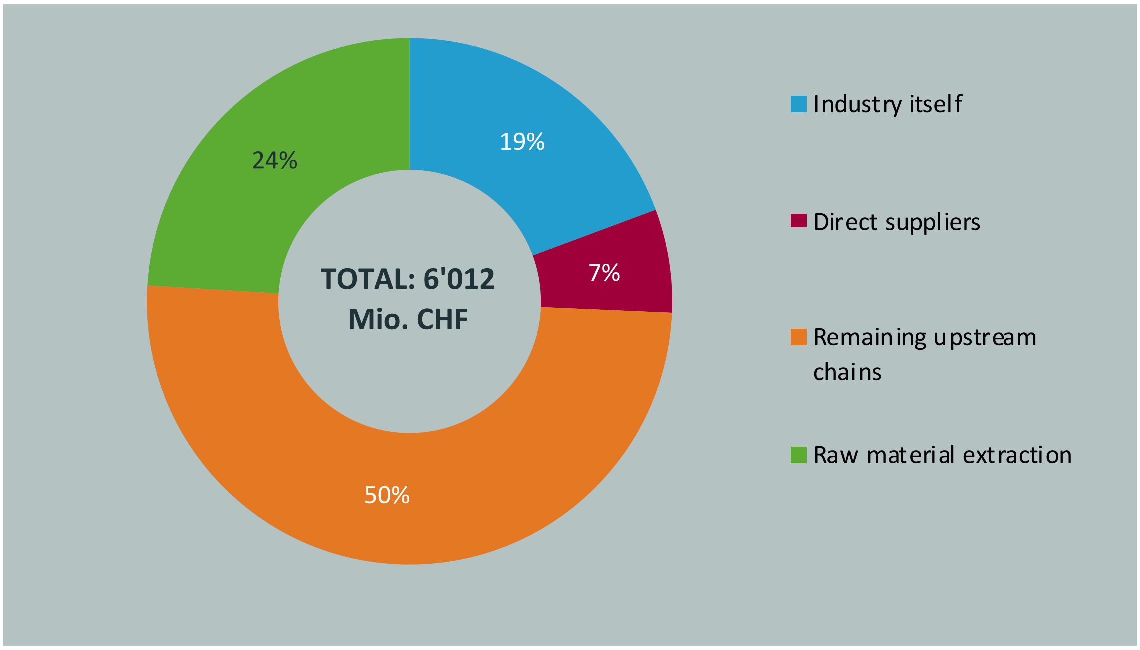

Figure 4.1: Total gross value added induced by the Swiss industry 'Meat processing', differentiated by supply chain stages (Source: Calculations Rütter Soceco)

Within the Swiss supply chains, the shares of value added generated by raw material supplying industries (i.e. agriculture) and industries in the remaining upstream chains are of similar size, whereas in the foreign supply chains the share of the remaining upstream chains is substantially larger than that of raw material suppliers. Furthermore, the share of value added to be attributed to direct suppliers is generally low, especially abroad. This is also due to the fact that agriculture as a direct supplier of the meat production industry is recorded in the raw material extraction group. The results show that Swiss meat processing largely relies on domestic raw materials, which is a result of border protection in agriculture and food production.

The lower part of Figure 4.2 displays the share of foreign countries in the total value added generated by meat processing (lower scale). Germany has the largest share with 9 %, followed by France, the USA and Italy with shares between 2 % and 3 %. Among the other top ten countries are mainly European countries with the exception of China and Canada. Countries outside the top ten account for 10 % of total value added. The suppliers from foreign countries are mainly intermediate suppliers (termed as remaining upstream chains) located between the direct suppliers and raw material extraction. The shares of direct and of raw material suppliers are significantly lower.

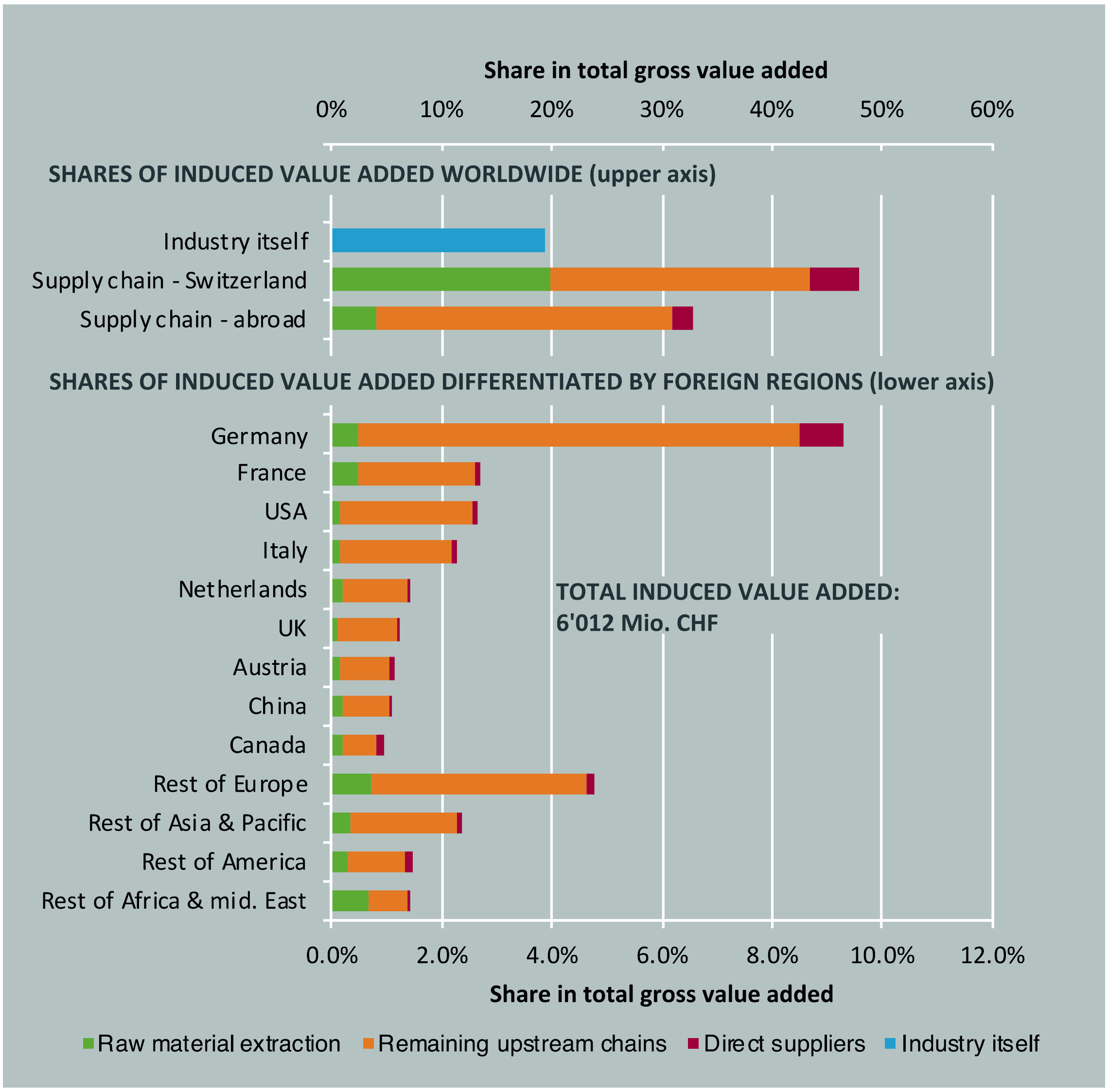

Figure 4.2: Total gross value added induced by the Swiss industry 'Meat processing', differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

4.2.3 Environmental impacts

4.2.3.1 Overview

Table 4.2 contains an overview of the total environmental footprints caused by the Swiss meat processing industry, including its supply chain. On the one hand the footprints are reported in absolute terms, on the other hand as intensities in relation to direct gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

Table 4.2: Environmental footprints caused by the Swiss industry 'Meat processing', including its supply chain (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Per M CHF gross output	Per M CHF gross value added
Greenhouse gas footprint	kt CO_2 eq	4'419	0.81	3.80
Biodiversity footprint	nano PDF*a	11'301	2.07	9.72
Water footprint	Mm3	1'361	0.25	1.17
Air pollution footprint	t PM10 eq	16'635	3.05	14.31
Eutrophication footprint	t N eq	21'865	4.01	18.80
Environmental footprint	G-eco Pt.	11'039	2.02	9.49
Gross output (industry itself)	M CHF	5'457		
Gross value added (industry itself)	M CHF	1'163		

Figure 4.3 displays the share of supply chain stages in total impact as well as the share of the industry in the global impact for each footprint apart from the total environmental footprint (and value added/gross production value for comparison reasons). It thus shows how much of the total environmental impact induced by meat production stems from the Swiss industry itself, how much is caused in the supply chain and how relevant each indicator for the Swiss meat processing industry is.

The results show that the environmental impacts of the Swiss industry 'meat processing' itself is negligible with shares between 0 % and 2 %, depending on the environmental indicator, while it contributes 19 % to total value added. Thus the supply chain is responsible for almost all of the environmental impacts. Most of the impacts stem from raw material suppliers, i.e. agriculture in this case, that contribute almost one quarter to total value added. Its shares are slightly lower for the greenhouse gas (75 %) and the air pollution (87 %) footprints compared to the other footprints with shares between 91 %

and 98 %. The share of direct suppliers is also negligible, while the remaining upstream chains, with a share of 50 % of total value added, are significant for the greenhouse gas footprint (21 %) and also contribute to the water (8 %) and the air pollution (12 %) footprints. This result mirrors the short supply chain of meat processing on one hand and the large environmental intensity of animal-based agriculture on the other hand.

The Swiss meat processing industry has large footprints, especially for eutrophication (see Figure 4.3; share of the respective footprints in the global footprints compared to the share of the gross production value of the Swiss meat processing in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.2.4.

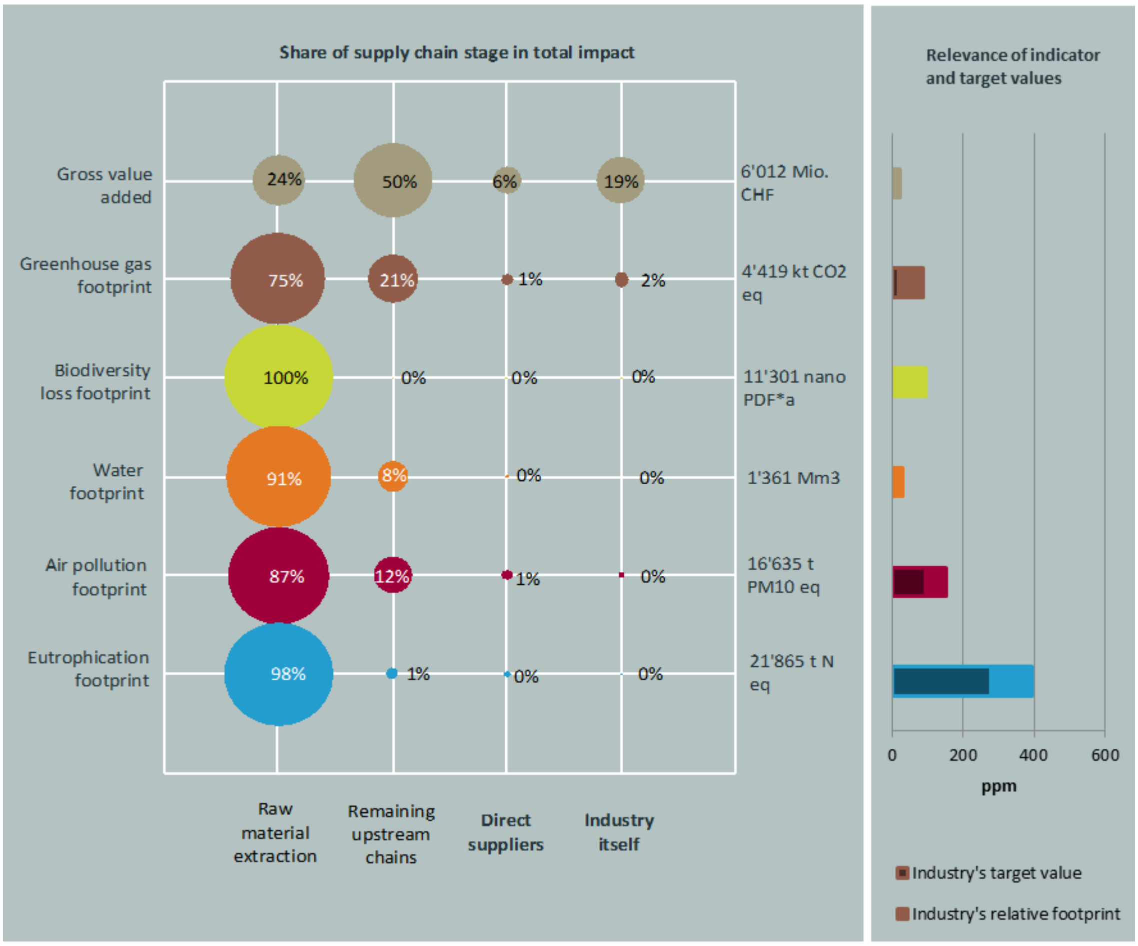

Figure 4.3: Environmental footprints caused by the Swiss industry ‘Meat processing’ by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

4.2.3.2 Focus on eutrophication footprint

As mentioned above, the eutrophication footprint was chosen as the focus footprint for the Swiss meat processing industry. As seen in Table 4.2 the global amount of eutrophying emissions induced by the meat processing industry adds up to 21’865 t N eq.

Figure 4.4 highlights which industries (aggregated over all countries) emit the eutrophying emissions along the supply chain of the Swiss meat processing industry.

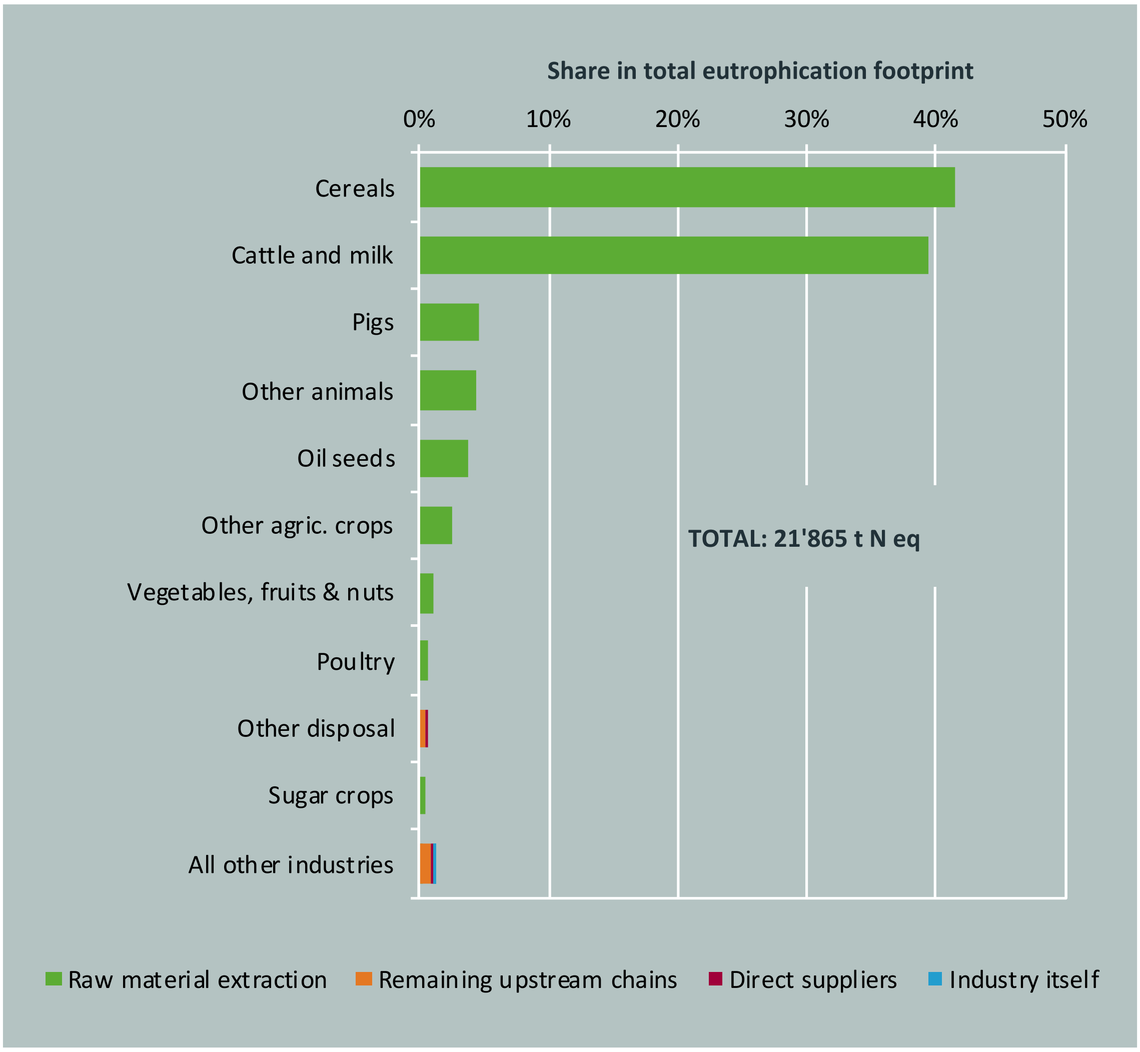

Figure 4.4: Eutrophication footprint of the Swiss meat processing industry by supply chain stage and supplying industries (Source: Calculations Rütter Soceco)

The largest emitters are ‘cereals growing’ and ‘cattle and milk farming’[17] in agriculture, that both respectively account for approximately 40 % of eutrophying emissions. Cereals are needed as feeding stuff for animal husbandry. Growing of pigs, poultry and other animals lead to significantly less eutrophying emissions than ‘cattle and milk farming’. Agriculture as the main raw material supplier dominates the eutrophication footprint. The other supply chain stages are not relevant.

Figure 4.5 illustrates how the responsible companies are distributed across supply chain stages and countries. The diagram shows that over 70 % of the footprint are due to emissions in Switzerland, while the remaining emissions take place abroad. The country differentiation reveals Germany, France, Canada and the US to be the largest foreign polluters in the supply chain of Swiss meat production. This is mainly due to cultivation of feed crops and other animal feed for meat mainly imported from Switzerlands neighbouring countries. Canada and the US are included as important suppliers of feed crops.

[17] ‘Cattle and milk farming’ stands for the emitting industry that combines beef and dairy cattle. The environmental impact of milk production is not attributed to the meat, but is considered as a whole. The environmental impact of the "cattle and milk" sector is expressed per CHF gross production and includes meat and dairy cows.

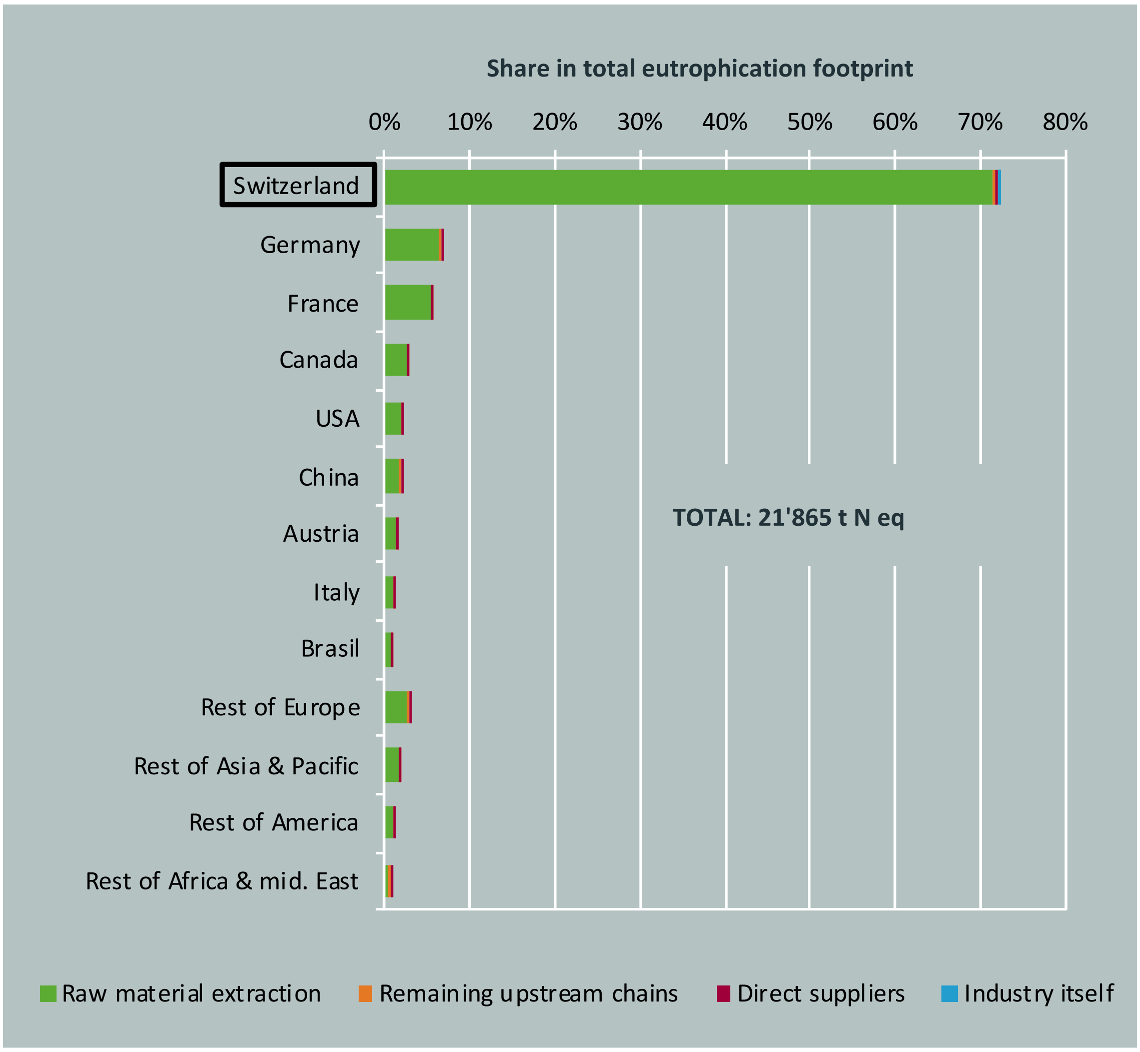

Figure 4.5: Eutrophication footprint caused by the Swiss meat processing industry, differentiated by supply chain stages and countries (Source: Calculations Rütter Soceco)

From a practical point of view it is useful to understand which direct intermediate inputs purchased by Swiss meat processing are responsible (to what extent) for the total eutrophication footprint caused by the industry within the supply chains. This allows the companies to identify, which of their suppliers they should access with which priority in order to optimise the environmental performance of their supply chain. The analysis presented in Figure 4.6 allocates the eutrophying emissions caused by the Swiss meat processing industry within the supply chain to domestic and foreign direct suppliers. Thus each direct supplying industry is presented with its own eutrophication footprint, including all emissions along its own supply chain. The emissions of the industry itself are shown for comparison reasons.

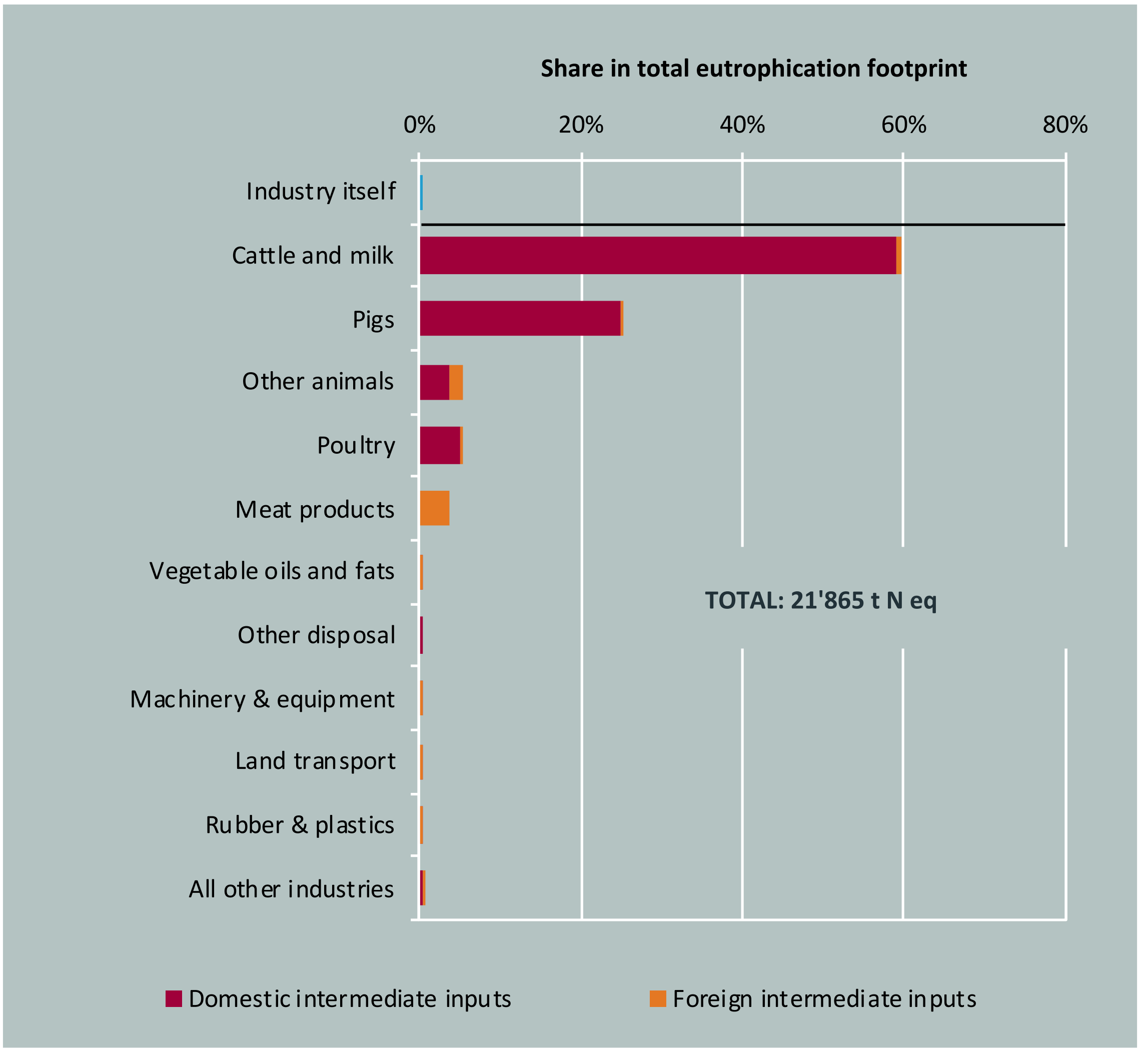

Figure 4.6: Eutrophication footprint of Swiss meat production allocated to its direct suppliers (Source: Calculations Rütter Soceco)

The eutrophication footprint of meat processing is almost completely linked to purchases of animal products from agriculture, with cattle accounting for 60 %, pigs for almost a quarter, while the relevance of poultry and other animals is much smaller. Intrasectoral purchases from meat production also play a small role. The eutrophication footprint can largely be allocated to domestic direct suppliers. This regional proximity should make it easier for the Swiss meat production industry to optimise its supply chain.

4.2.3.3 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

For the greenhouse gas footprint, the results show that two thirds of the emissions occur in Switzerland. Regarding industries, cattle farming has a high relevance with 50 % of total greenhouse gas emissions and energy and mining industries show up among the top ten industries. Cultivation of cereals is much less relevant than for the eutrophication footprint. The results for the air emission footprint are largely similar. Almost 75 % of the total footprint occur in Switzerland. Cattle and pig farming are the most important single industries responsible for air pollution, with other industries each causing less than 5 % of the footprint. Regarding the biodiversity loss footprint, Switzerland accounts for more than 55 % of the total footprint. Tropical countries with a larger biomass loss potential (e.g. Brazil and Indonesia) have larger shares than for the other footprints due to extensive grazing of their cattle or land use for cultivating feed crops. The AWARE water footprint is less concentrated than the other footprints, i.a. it spreads across a larger number of countries. Countries with extensive irrigation and/or high water scarcity (e.g. China, US and India) have the largest shares in the footprint (between 9 % and 16 %). In these countries even a low economic involvement in the supply chains can lead to large water footprints due to their large water footprint multipliers. Switzerland ranks fourth with 6 % of the water footprint. With regard to industries, growing of animal feeds like cereals, oil crops and other agricultural crops has the largest relevance.

4.2.3.4 Environmental footprint according to the ecological scarcity method

The total environmental footprint according to the method of ecological scarcity (Frischknecht & Büsser Knöpfel 2013) of the Swiss industry ‘Meat processing’ is 11’062 billion eco-points. Slightly more than half of it is generated by the direct suppliers in Switzerland; another third stems from imported goods (Figure 4.7). The remaining suppliers in Switzerland (all suppliers without direct link to the Swiss meat processing industry) cause 14 % of the total environmental footprint. The industry itself generates only 1 % of its total footprint, with virtually all of this being caused by fossil CO_2-emissions.

In contrast to the previous figures, raw material production is not presented separately but is allocated to the other stages of the value chain. The much higher proportion of direct suppliers is explained by the great importance of agriculture (animal and feed production), which is assigned to raw material production in previous figures but is among the direct and indirect suppliers here.

Figure 4.7: Environmental footprint in eco-points caused by the Swiss industry ‘Meat processing’ by supply chain stages and imports (Source: Calculations treeze)

Figure 4.8 shows the ten most important contributing direct suppliers to the total environmental footprint (including the supply chain) of the Swiss industry ‘Meat processing’. They explain more than 95 % of the total environmental footprint of the Swiss meat processing industry.

The most important contributions come from the fattening of the animals used in this industry. The fattening of non-dairy cattle has the highest contribution (40 %), followed by the fattening of pigs (23 %) and dairy cattle (15%). In all these industries, the largest part of their environmental footprint occurs in Switzerland. For non-dairy and dairy cattle, the emissions from livestock farming (ammonia, methane and nitrate) contribute most to their environmental impacts. The second highest contribution comes from the production of feedstuffs (above all feed cereals) in Switzerland and abroad. For pigs, the feed production (feed cereals and soybeans) has the greatest impact, followed by the emissions from livestock farming (ammonia, particulates and methane).

9 % of the total environmental footprint stem from the import of meat and meat products. About 40 % of this impact is caused by the cooling of the products, the greatest share of the rest by the fattening of the animals.

The fattening of poultry contributes 4 % to the total environmental footprint, followed by the fattening of other animals (3 %). For poultry, the feed production (feed cereals and soybeans) contributes most to its environmental footprint. The rest is caused by direct emissions (ammonia, dinitrogen monoxide and methane) and the electricity use during livestock farming. For the other animal products, the emissions from livestock farming (ammonia, nitrate, methane and dinitrogen monoxide) are the main contributors.

The remaining direct suppliers such as ‘Electricity distribution’, ‘Road transport’ and ‘Disposal services’ contribute little to the total environmental impacts of the Swiss industry ‘Meat processing’.

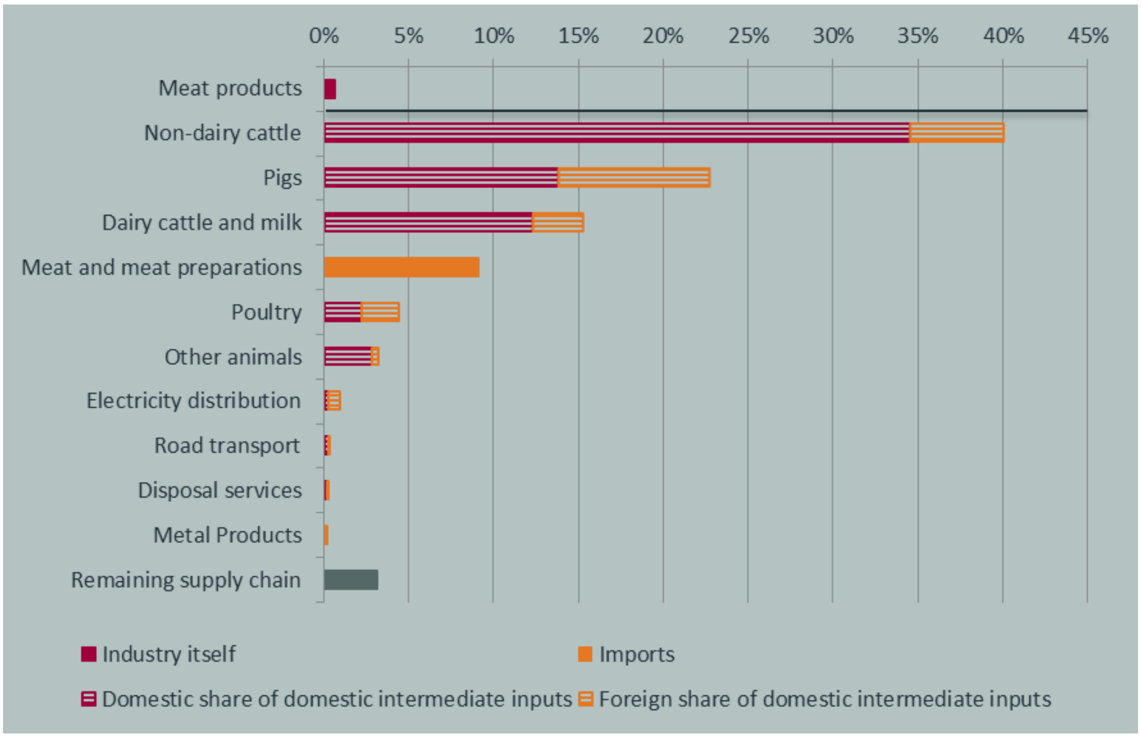

Figure 4.8: Environmental footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry ‘Meat processing’ (Source: Calculations treeze)

4.2.3.5 Conclusion

The environmental impacts of the Swiss industry ‘Meat processing’ are dominated by the agricultural stage, namely animal and feed production. The share of the industry itself in its environmental impacts is virtually negligible.

The most important contributions to the eutrophication and the total environmental footprint stem from feed production (above all cereals) and animal farming. In particular cattle farming (dairy and non-dairy cattle) is associated with high emissions. The second most important animal category is pigs, followed by poultry and other animals.

The non-agricultural industries contribute little to the environmental impact of the Swiss meat processing industry. Whereas land transports, disposal services and machinery/metal products are amongst the ten most important direct contributors for both the eutrophication and the total environmental footprint, the electricity used only shows up for the total environmental footprint and ‘vegetable oils and fats’ as well as ‘rubber & plastics’ only for the eutrophication footprint.

Both in terms of the eutrophication footprint and the total environmental footprint, the largest share of emissions is generated in Switzerland. This is in contrast to many other industries, where most of the emissions are generated abroad. The geographical proximity between emissions and the triggering industry simplifies cooperation and offers opportunities for the joint development of measures to reduce environmental pollution in the supply chain of the meat industry. On the other hand, the agricultural sector in Switzerland is strongly influenced by Swiss agricultural politics, which reduces the degree of flexibility for individual companies or farmers.

4.2.4 Comparison with the planetary boundaries

Figure 4.9 shows the share of the environmental footprints of the Swiss industry 'Meat processing' in the respective global environmental footprints as well as the relative reduction needs. Of the environmental impacts analysed, the Swiss meat production industry contributes most to eutrophication. The second largest contribution is to the air pollution footprint, whereas the contributions to the biodiversity and greenhouse gas footprints are similar. The industry's shares in the global environmental impacts generally exceed its share in global gross production value.

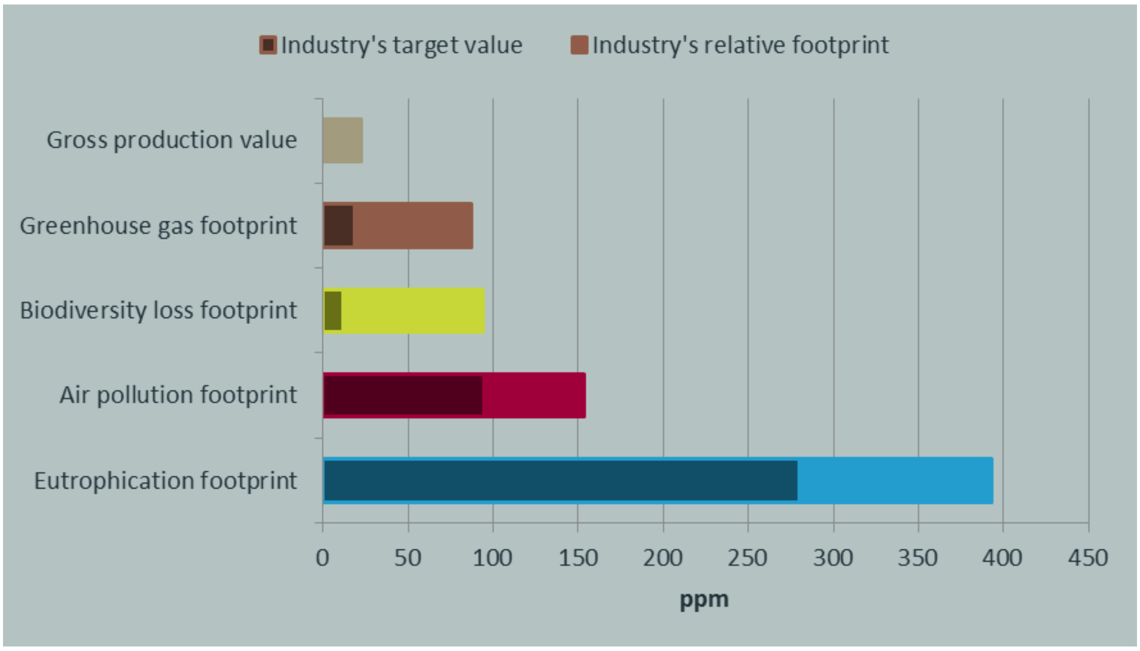

Figure 4.9: Share of environmental footprints caused by the Swiss industry 'Meat processing' in global environmental footprints and respective planetary boundaries (Source: Calculations treeze)

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, for the Swiss 'Meat processing' industry the eutrophication and the biodiversity footprints are identified as priority field of actions, followed by the greenhouse gas footprint.

Table 4.3 shows the water footprint of the Swiss industry ‘Meat processing’, differentiated after country, and the share of renewable water supply used in the respective country. 9 % of the water footprint of the ‘Meat processing’ industry occurs in India, where 37 % of the renewable water supply is already used. In China, where 16 % of the water footprint of the ‘Meat processing’ industry takes place, the sustainably useable share of 20 % is almost reached. Another 15 % of the water footprint of the meat processing industry occurs in the United States, where already 16 % of the renewable water supply are used. In Italy and Spain, where 6 % and 4 %, respectively, of the water footprint of Swiss ‘Meat processing’ industry take place, the sustainably usable amount of water is already surpassed. In these countries, there is a need for action regarding the water footprint of the ‘Meat processing’ industry.

Table 4.3: Water footprint of Swiss industry ‘Meat processing’ differentiated after country and share of renewable water supply used in the respective countries

Country	Share of renewable water supply used	Water footprint industry ‘Meat processing’ [Mm^3]	Share of total water footprint of the industry ‘Meat processing’
China	20%	213	16%
United States	16%	209	15%
India	37%	125	9%
Switzerland	5%	84	6%
Italy	24%	83	6%
Spain	29%	49	4%
France	15%	29	2%
Turkey	17%	14	1%
Mexico	17%	12	1%
Greece	13%	10	1%
Remaining countries and unspecified regions		533	39%

4.2.5 Measures for reducing environmental impacts

4.2.5.1 Focal areas for measures

For the meat processing industry most of its impacts occur in the upstream chain, namely during animal fattening. Therefore, measures should focuse on that area:

- The greatest leverage is achieved by reducing the number of animals used. Through the utilization of the whole animal (nose-to-tail) food losses can be avoided and the meat output per animal is maximized.

Furthermore, the environmental impacts of animal production itself should be reduced. To achieve this, the meat processing industry must address its suppliers and commit them to reducing their environmental footprint. Since - in contrast to many other Swiss industries - a large part of the supply chain is located in Switzerland, such cooperation is easier to implement than in other industries. As described above (see chapter 4.2.3), the most important areas to be adressed are direct animal emissions and feeding:

- Site-appropriate production (no import of additional feed) prevents local nutrient surpluses.
- Emissions from farmyard manure and farmyard manure storage should be reduced as far as possible with appropriate measures (regular removal of manure, keeping the running surfaces clean, covered storage, inclusion of biogas plants, etc.).
- Through appropriate breeding and demand-oriented feeding the feed efficiency can be enhanced. A high feed efficiency reduces the amount of feedstuff needed; both for roughage eaters and monogastric animals.
- Also the use of by-products and wastes as feedstuff (e.g. whey, grinding and peeling products, possibly also food waste) reduces the expenses for feed production.
- Ruminants can create valuable proteins from grasslands that are not suitable for human consumption. In order to realize this advantage, ruminants should not be fed on concentrated feed, but only on grass from land that is not arable.
- When using concentrated feed, care should be taken to ensure environmentally friendly production (e.g. analogue to sustainable soy with “soja netzwerk schweiz”). For the composition of the feed mixtures, components with the lowest possible environmental impacts should be chosen (e.g. alternative protein feed sources).

In meat processing the energy use contributes most to its environmental impacts. Therefore, measure to enhance the energy efficiency and use of renewable energy sources should be applied.

4.2.5.2 Monitoring parameters

The development of the environmental impacts of the meat processing industry could be monitored with the following indicators:

- Amount of animal origin wastes relative to amount of edible meat products produced

- Amount of feedstuff used totally and suitable for human consumption per kilogram of meat produced / Amount of arable land used per kilogram of meat produced
- Amount of imported (non-local) feedstuff used per kilogram of meat produced
- Development of methane, nitrous oxide and ammonia emissions from animal husbandry according to official Swiss reporting
- Amount of electricity used per kg of meat produced and share of renewable electricity
- Amount of fossil fuels used per kg of meat produced

4.2.5.3 Instruments and guidelines

The following instruments help in finding and implementing appropriate measures to reduce the environmental impacts in meat production:

- Promotion of the utilization of the whole animal (nose to tail)
  - https://www.schweizerfleisch.ch/dossiers/nose-to-tail-mehr-als-filet-entrecote-und-co/alles-ueber-nose-to-tail.html
  - https://www.allofit.ch/
- Measures for reducing direct animal emissions:
  - Overview and current state of research: https://www.agroscope.admin.ch/agroscope/de/home/aktuell/dossiers/tieremissionen.html
  - Ammonia emissions: http://www.ammoniak.ch/home/
- Sustainable feedstuff:
  - Soy: https://www.sojanetzwerk.ch/
  - Protein feedstuff in general: https://www.eiweissforum.de/
- Measures for reducing greenhouse gas emissions from agriculture:
  - https://agrocleantech.ch/de/
  - http://www.emission-impossible.ch
- Agricultural biogas plants:
  - https://oekostromschweiz.ch/
  - https://www.biomassesuisse.ch/
- Guidelines for Sustainability Assessment of Food and Agriculture Systems (SAFA):
  - http://www.fao.org/nr/sustainability/sustainability-assessments-safa

4.3 Production of chemical products

4.3.1 Introduction

The industry ‘Production of chemical products’[18] excludes the pharmaceutical industry. The Swiss chemical industry is characterised by the production of specialty chemicals while the importance of environmentally intensive basic chemical production (e.g. of plastics, fertilisers) is rather low. It includes the following activities:

- Manufacture of basic chemicals (26 % of employed persons),
- Manufacture of pesticides and other agro-chemical products (6 % of employed persons),
- Manufacture of paints, varnishes and similar coatings, printing ink and mastics (15 % of employed persons),
- Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations (20 % of employed persons),
- Manufacture of other chemical products (31 % of employed persons),
- Manufacture of man-made fibres (2 % of employed persons).

The Swiss chemical industry employed 27’100 persons (FTE) in 2015. This corresponds to 0.7 % of the entire Swiss workforce. However, employment has declined between 2011 and 2015 (see Table 4.4).

Table 4.4: Employment in the chemical industry (Source: FSO – STATENT)

Year	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	29'487	0.8%		
2015	27'100	0.7%	-2.1%	1.0%

4.3.2 Economic impact

The total value added induced by the Swiss chemical industry amounts to 20’339 Mio. CHF[19]. Figure 4.10 shows how it is distributed across the different supply chain stages. The industry itself contributes 31 % to the induced value added and a share of 17 % stems from its direct suppliers. While the largest share is generated by the supply chain

[18] Code 20 according to NOGA 2008, code 24 excl. 24.4 according to NOGA 2002.

[19] These and the following economic data refer to the year 2008.

stages ‘remaining upstream chains’ (45 %), the fraction of value added imputable to raw material extracting industries (7 %) is much smaller.

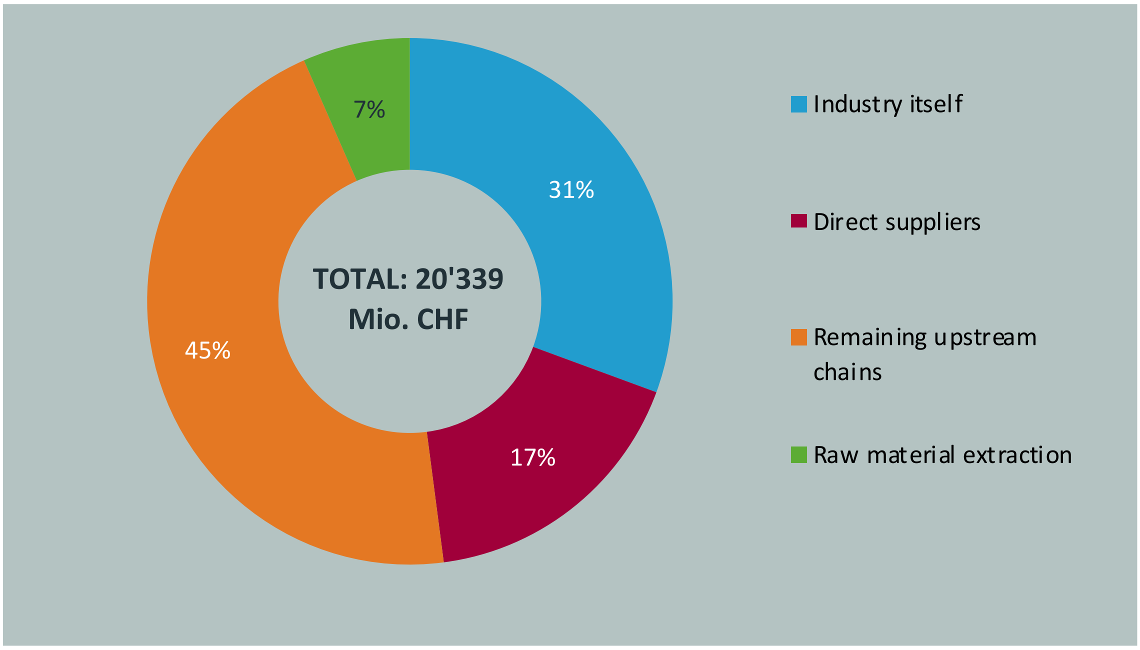

Figure 4.10: Total gross value added induced by the Swiss industry ‘Production of chemical products’, differentiated by supply chain stages (Source: Calculations Rütter Soceco)

In order to understand where - in geographical terms – the value added induced by the Swiss chemical industry is generated, Figure 4.11 shows the shares of induced value added differentiated by countries and supply chain stages.

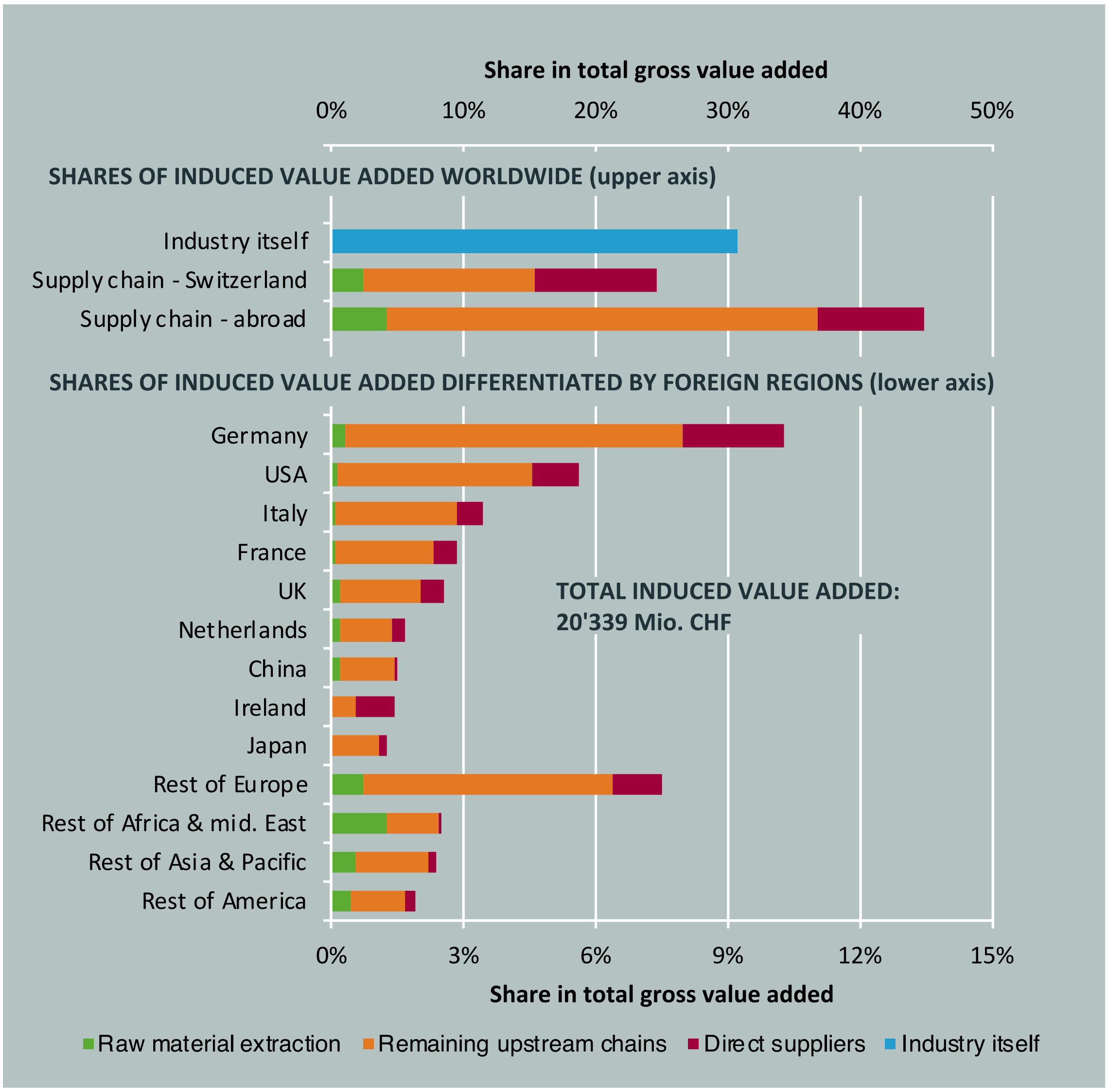

Figure 4.11: Total gross value added induced by the Swiss industry 'Production of chemical products', differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

The upper section of the figure displays the share of value added generated by the industry itself (31 %) as well as the shares generated within domestic (25 %) and foreign (44 %) parts of the supply chain. Thus more than half of the total value added is generated in Switzerland while the rest is created abroad.

Within the Swiss supply chain, the share of value added generated by direct suppliers is smaller than that of industries in the remaining upstream chains, whereas in the foreign supply chains the share of the direct suppliers is substantially lower. In addition, the share of value added induced in raw material extraction industries in foreign supply chains is slightly larger than in Swiss supply chains.

The lower part of Figure 4.11 displays the share of foreign countries in the total value added generated by the chemical industry (lower scale). Germany has the largest share in value added with 10 % and the US follow with more than 5 %. Other top ten countries are European countries, China and Japan. Countries outside the top ten account for 14 % of total value added. In terms of supply chain stages, it is noticeable that the largest portions of value added in raw material extraction industries are generated in Africa and the middle east, the rest of America and Asia, whereas there is almost no value added created in raw material extracting industries amongst the most European countries.

4.3.3 Environmental impacts

4.3.3.1 Overview

Table 4.5 contains an overview of the total environmental footprints caused by the Swiss chemical industry[20]. The footprints are reported in absolute terms and as intensities in relation to gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

[20] Environmental footprints are shown without the emissions occurring in the use phase. Although chemical emissions can have a significant impact on the environment, there is little detailed quantitative information on the sources and material loads of individual chemicals. For this reason, no reliable statement could be made about the environmental impacts in the use phase of the chemical industry and the use phase is therefore not presented.

Table 4.5: Environmental footprints caused by the Swiss chemical industry (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Per M CHF gross output (only production)	Per M CHF gross value added (only production)
Greenhouse gas footprint	kt CO_2 eq	8'681	0.50	1.39
Biodiversity footprint	nano PDF*a	10'849	0.63	1.74
Water footprint	Mm3	3'663	0.21	0.59
Air pollution footprint	t PM10 eq	14'315	0.83	2.30
Eutrophication footprint	t N eq	8'825	0.51	1.42
Environmental footprint	G-eco Pt.	13'844	0.80	2.22
Gross output (industry itself)	M CHF	17'264		
Gross value added (industry itself)	M CHF	6'227		

Figure 4.12 displays the shares of supply chain stages in total impact as well as the share of the industry in the global impact for each footprint (and value added/gross production value for comparison reasons). It thus shows how much of the total environmental impact induced by the chemical industry stems from the industry itself, how much is caused in the supply chain and how relevant each indicator for the Swiss chemical industry is.

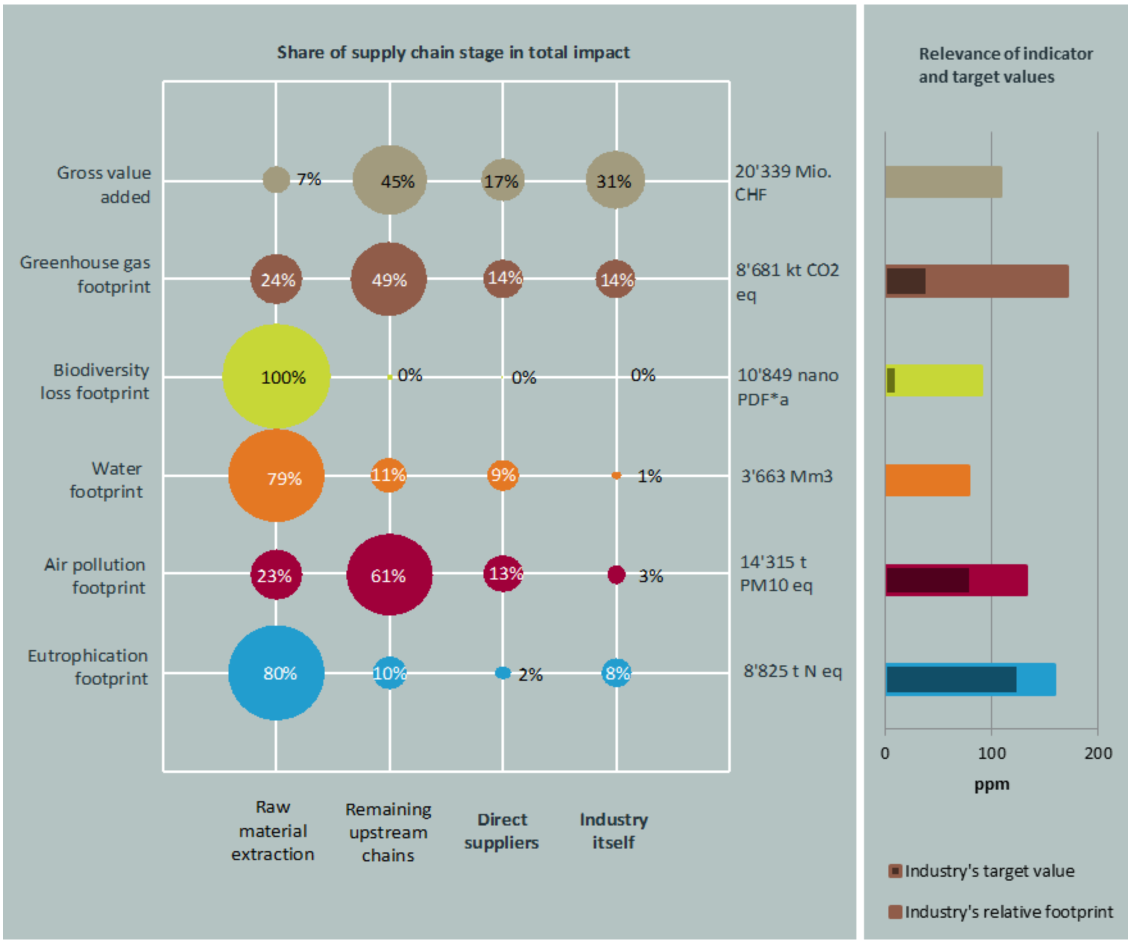

Figure 4.12: Environmental footprints caused by the Swiss industry 'Production of chemical products' by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

The results show a differentiated picture of the distribution of environmental impacts along the supply chain of the chemical industry. In most cases the chemical industry, generating 31 % of total value added, is responsible for a minor share of environmental impacts, whereas the major share occurs in its supply chain. The chemical industry contributes 14 % to the greenhouse gas footprint and 8 % to the eutrophication footprint. Its shares are negligible for the other footprints. Compared to the industry itself and other suppliers, raw material extraction dominates the results for the biodiversity, the water and the eutrophication footprint, whereas it plays a minor role for the greenhouse gas and the air pollution footprint with shares between 23 % and 24 %. The major share of the greenhouse gas and the air pollution footprints occurs in the upstream parts of the supply chain between raw material extraction and the direct suppliers.

The comparison of shares in value added and environmental footprints reveals that raw material extraction is especially resource and emission intensive, especially with regard to the biodiversity, water and eutrophication footprints. Regarding the greenhouse gas and the air emission footprint, the emission shares roughly mirror the value added shares of direct and intermediate suppliers, thus pointing to an average emission intensity in the supply chain. The chemical industry itself displays a below average emission intensity.

Most relevant for the chemical industry is the greenhouse gas footprint (see Figure 4.12; share of the respective footprint in the global footprints compared to the share of the gross production value of the chemical industry in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.3.4.

4.3.3.2 Focus on greenhouse gas footprint

The focus footprint chosen for the Swiss chemical industry is the greenhouse gas footprint, since it is one of the highest ranking footprints for this industry. As seen in Table 4.5 the global amount of greenhouse gas emissions induced by the chemical industry in Switzerland adds up to 8’681 kt CO_2 eq.

Figure 4.13 highlights which industries (aggregated over all countries) emit the greenhouse gases along the supply chain of the Swiss chemical industry. The largest emitter is the chemical industry itself with a share of 27 %, partly in its role as focal industry and partly in its role as direct supplier (from abroad). ‘Mining and quarrying’, supplying the chemical industry with inorganic raw materials and ‘electricity from fossil fuels’ follow with shares between 16 % and 18 %. The shares of other industries are significantly lower. Here basic metal production, public heat generation and other non-metallic minerals can be mentioned. Industries outside the top ten hold a share of almost 20 %.

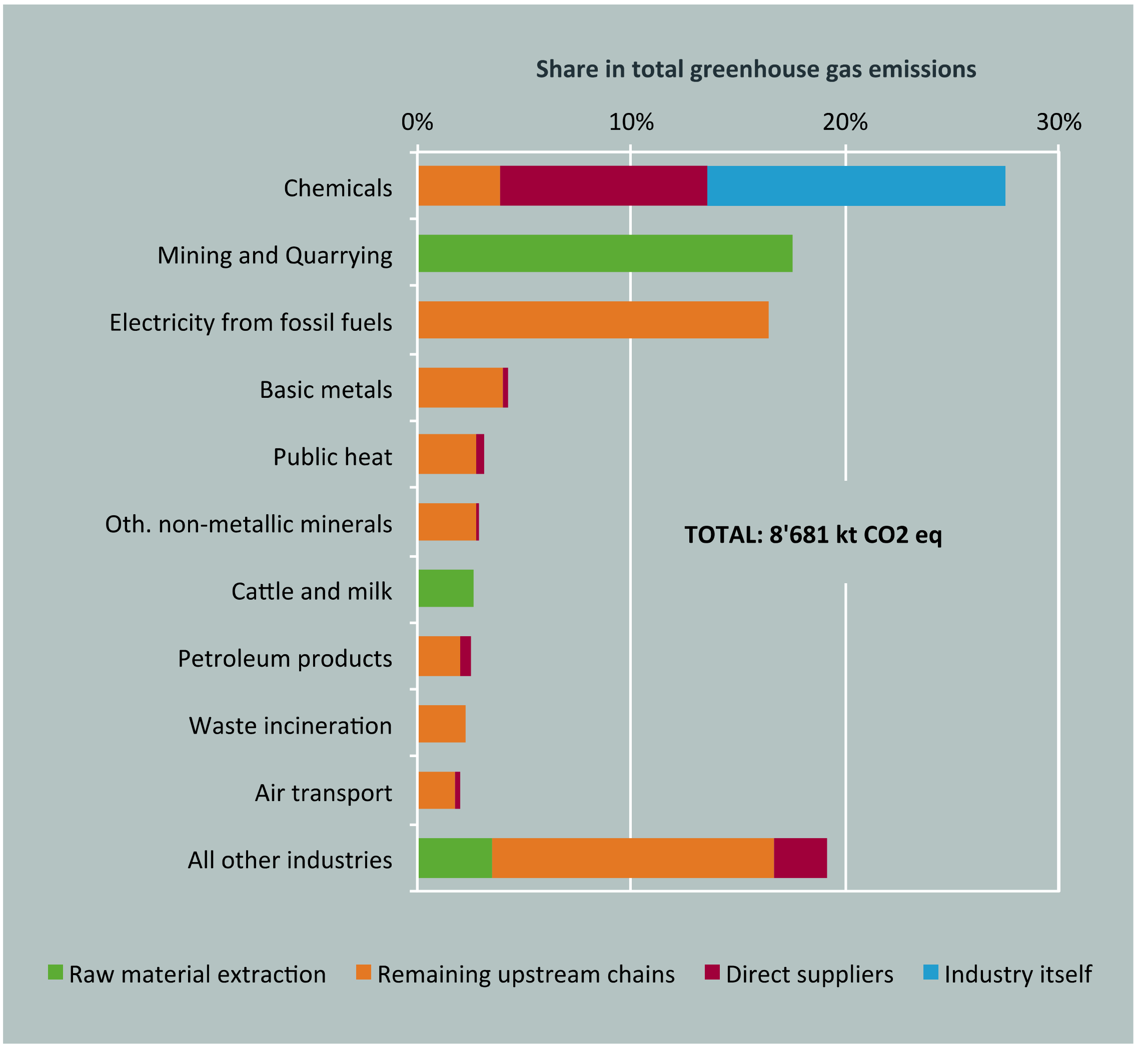

Figure 4.13: Greenhouse gas footprint caused by the industry ‘Production of chemical products’ by supply chain stage and supplying industries (Source: Calculations Rütter Soceco)

Figure 4.14 illustrates how the responsible companies are distributed across supply chain stages and countries. The diagram shows that 22 % of the footprint are due to emissions in Switzerland (14 % by the industry itself and the rest in the other supply chain stages).

Thus 78 % of the emissions take place abroad. The country differentiation of greenhouse gas emissions reveals China, Germany and the US to be the largest foreign polluters. In comparison to the value added distribution across countries (cf. Figure 4.11) China, Russia and India are ranked much higher when measuring in greenhouse gas emissions. This is due to the (in average) higher greenhouse gas emission intensities in those countries when compared to western countries such as Germany or the US. With regard to supply chain stages, the remaining upstream chains between raw material extraction and direct suppliers to the chemical industry are particularly important. Direct suppliers with significant greenhouse gas emissions are mainly located in Europe and the US, whereas raw material extraction is mainly located outside Europe.

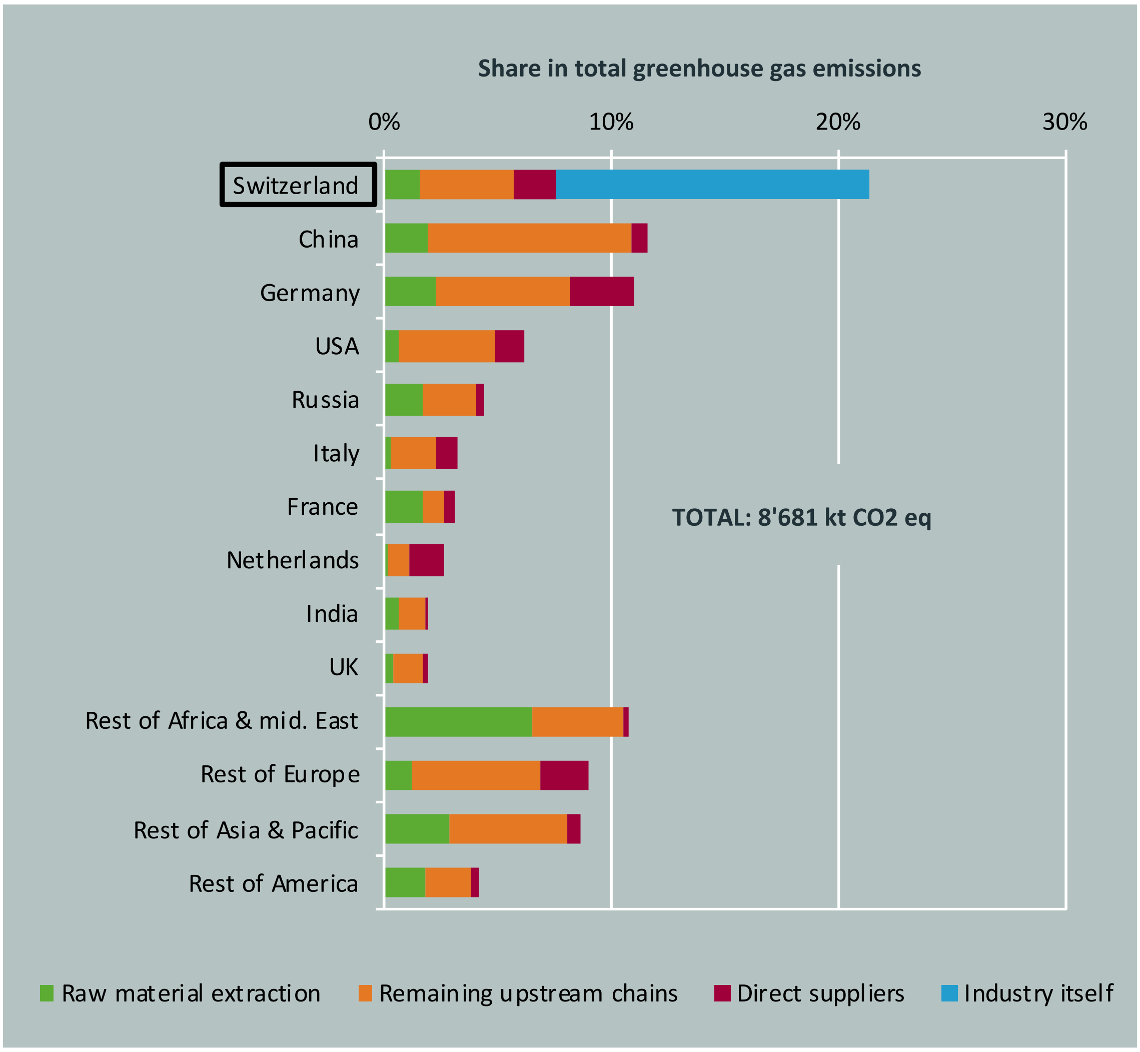

Figure 4.14: Greenhouse gas footprint caused by the Swiss industry 'Production of chemical products', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

In a different perspective the greenhouse gas footprint is allocated to the direct suppliers in the sense that each supplying industry is allocated its total footprint. This allows companies to identify which of their suppliers they should access with which priority in order to optimise the environmental performance of their supply chain. The analysis presented in Figure 4.15 allocates the greenhouse gas emissions caused by the Swiss chemical industry within the supply chain to domestic and foreign direct suppliers. The direct emissions of the chemical industry itself are shown for reasons of comparison.

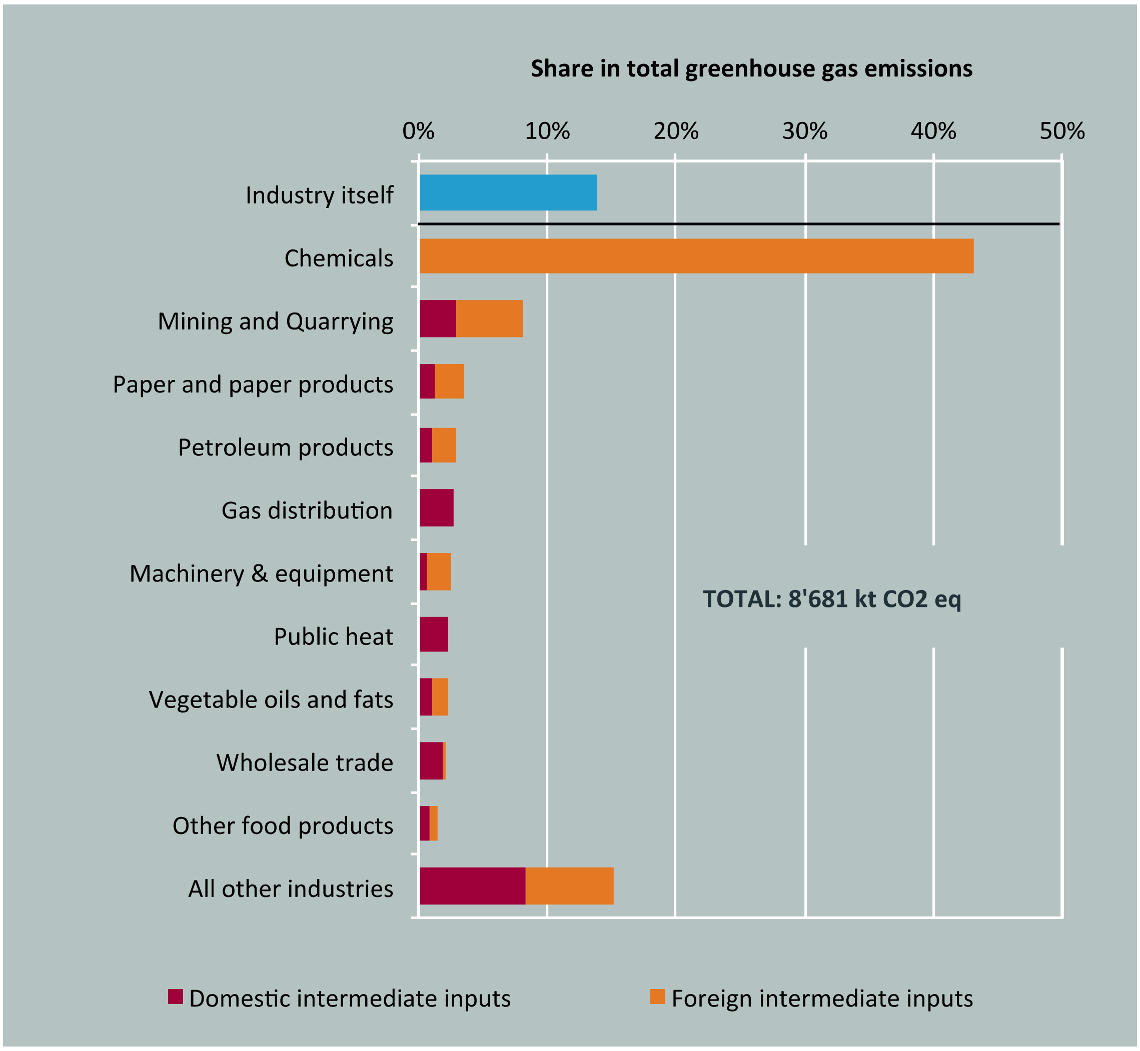

Figure 4.15: Greenhouse gas footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry 'Production of chemical products' (Source: Calculations Rütter Soceco)

Over 40 % of the greenhouse gas emissions caused by the Swiss chemical industry within the supply chain are linked to intersectoral purchases of intermediate inputs from the chemical industry itself. Other important direct suppliers are 'mining and quarrying', paper and paper products supplying the chemical industry with raw and packaging materials, refineries supplying energy and raw materials for organic chemicals. Other suppliers are related to energy consumption, machinery and the food industry supplying products such as oils and fats, starch and sugar as inputs to the chemical industry.

4.3.3.3 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

Regarding the air emission footprint, less than 10% of total emissions occur in Switzerland. Foreign emissions are spread across a large variety of countries with China, Germany and the USA responsible for the largest shares. The chemical industry, basic metal manufacturing and electricity generation from fossil fuels each cause roughly 15% of the total footprint, with the rest being distributed across a large number of industries. Biodiversity loss is mainly related to vegetal products used as raw materials in the chemical industry (e.g. oils, sugar and starches). Cattle farming induced by animal raw materials and by food supply to persons employed in the supply chain and forestry induced by the use of wood in buildings and other investment goods also play a role. Switzerland accounts for only 8 % of the total footprint. Tropical countries with a larger biomass loss potential (e.g. Brazil, Indonesia and the rest of Asia) have larger shares than for the other footprints. Approximately 50 % of the footprint occur outside the top ten countries. Thus the impact is spread across a variety of countries. The picture looks similar for the AWARE water footprint. Agriculture dominates, but chemicals account for 10% of the water footprint. With regard to country distribution, the water footprint is less concentrated than the other footprints, i.e. it spreads across a larger number of countries. Countries with extensive irrigation and/or high water scarcity (e.g. China, US, India, Italy and Spain) have the largest shares in the footprint (between 4 % and 15 %). In these countries even a low economic involvement in the supply chains can lead to large water footprints due to their large water footprint multipliers. The share of Switzerland is negligible with 2 %.

4.3.3.4 Environmental footprint according to the ecological scarcity method

The total environmental footprint according to the method of ecological scarcity (Frischknecht & Büsser Knöpfel 2013) of the industry ‘Production of chemical products’ is 13’587 billion eco-points. Nearly three quarters of it are caused by imported goods (Figure 4.16). The industry itself generates 15 % of its total footprint, with the main contributors being emissions of fossil CO_2 and nickel. Another 8 % and 5 %, respectively, stem from the remaining suppliers and direct suppliers in Switzerland.

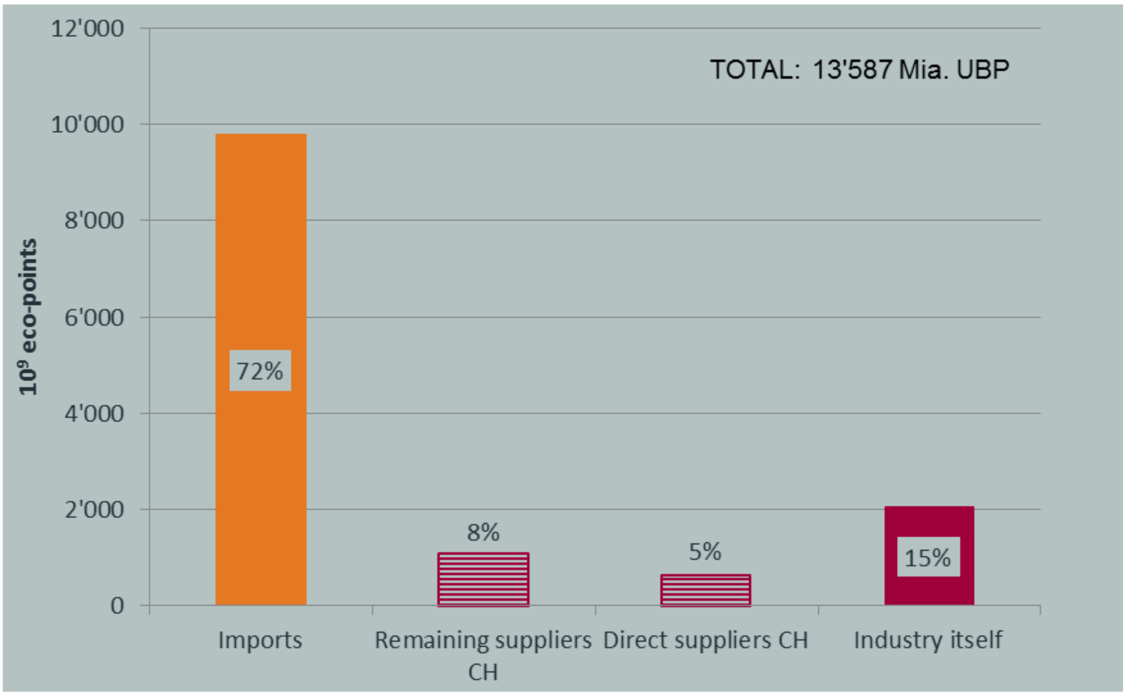

Figure 4.16: Environmental footprint in eco-points caused by the industry ‘Production of chemical products’ by supply chain stages and imports (Source: Calculations treeze)

Figure 4.17 shows the ten most important contributing direct suppliers to the total environmental impacts of the Swiss chemical industry. The ten largest contributors explain just about half of the total environmental footprint of the production of chemical products. Seven of them are imported precursor products. The three largest contributors are the import of other chemicals (20 %), organic chemicals (7 %) and ’Mining and quarrying’ (6 %).

The footprint of the imported chemical products is determined by the raw material and energy requirements in their production. The most important contributors are different organic chemicals and agricultural raw materials (e.g. for starch production). The ‘Mining and quarrying’ industry provides for example lime based chemical additives, chemical raw materials and chemical active ingredients. About 60 % of the environmental footprint of this industry occurs within the country and stems mainly from its gravel resource requirements, from CO_2-emissions and gypsum requirements. The rest is due to its electricity use as well as from construction and disposal services. The environmental footprint of the electricity used (industry ‘Electricity distribution’) is caused by the production of Swiss and foreign nuclear power as well as imported electricity from coal power plants. Further impacts stem from other imported products (vegetable oils and fats, petroleum products, inorganic chemicals) as well as from oils and fats produced in Switzerland. For those as well as for the imported vegetable fats and oils, the main impacts occur during the cultivation of the oleaginous crops.

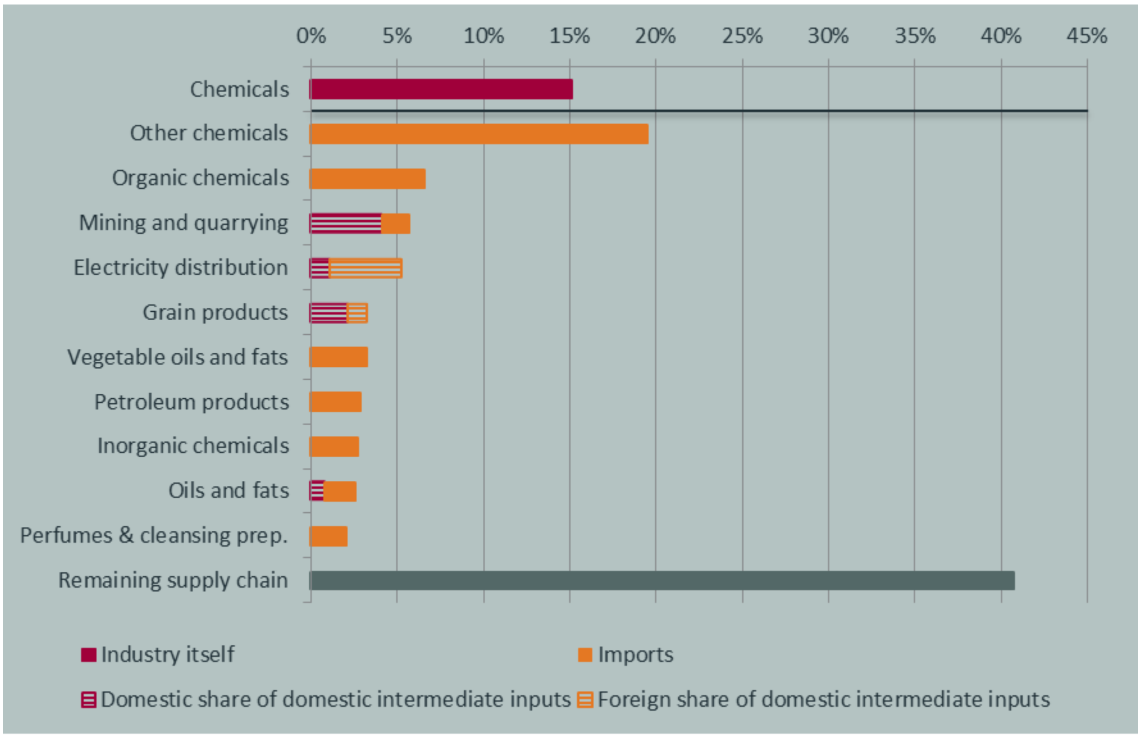

Figure 4.17: Environmental footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry ‘Production of chemical products’. Remaining supply chain = all other direct suppliers (Source: Calculations treeze)

4.3.3.5 Conclusion

Over 70 % of the greenhouse gas and the environmental footprint of the Swiss chemical industry are related to emissions occurring abroad. This is due to high purchases from the foreign chemical industry, which is the most important contributor to the greenhouse gas emissions and the total environmental impact of the Swiss chemical industry. Other important direct suppliers for both the greenhouse gas and the environmental footprint of the Swiss chemical industry are ‘mining and quarrying’ (delivering inorganic raw materials for the chemical industry), ‘petroleum products’ and ‘vegetable oils and fats’.

For the greenhouse gas emissions, also ‘paper and paper products’ belong to the ten most important direct contributors, as well as heat supply (‘gas distribution’; ‘public heat’), ‘machinery & equipment’, ‘wholesale trade’ and ‘other food products’. On the other hand, the electricity use, ‘fertilizers’ and ‘grain products’ are only among the ten most important direct suppliers for the total environmental footprint.

For both the greenhouse gas and the total environmental footprint the industry itself causes about one seventh of the total emissions over the whole supply chain.

4.3.4 Comparison with the planetary boundaries

Figure 4.18 shows the share of the environmental footprints of the Swiss industry 'Production of chemical products' in the respective global environmental footprints as well as the relative reduction needs. The Swiss chemical industry contributes most to the greenhouse gas footprint. The second largest contribution is to the eutrophication footprint, followed by the contributions to the air pollution and biodiversity loss footprints. For the latter, the industry's share in the global environmental impact is below its share in global gross production value.

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, the greenhouse gas footprint is identified as priority field of action for the Swiss chemical industry. In second place comes the biodiversity footprint.

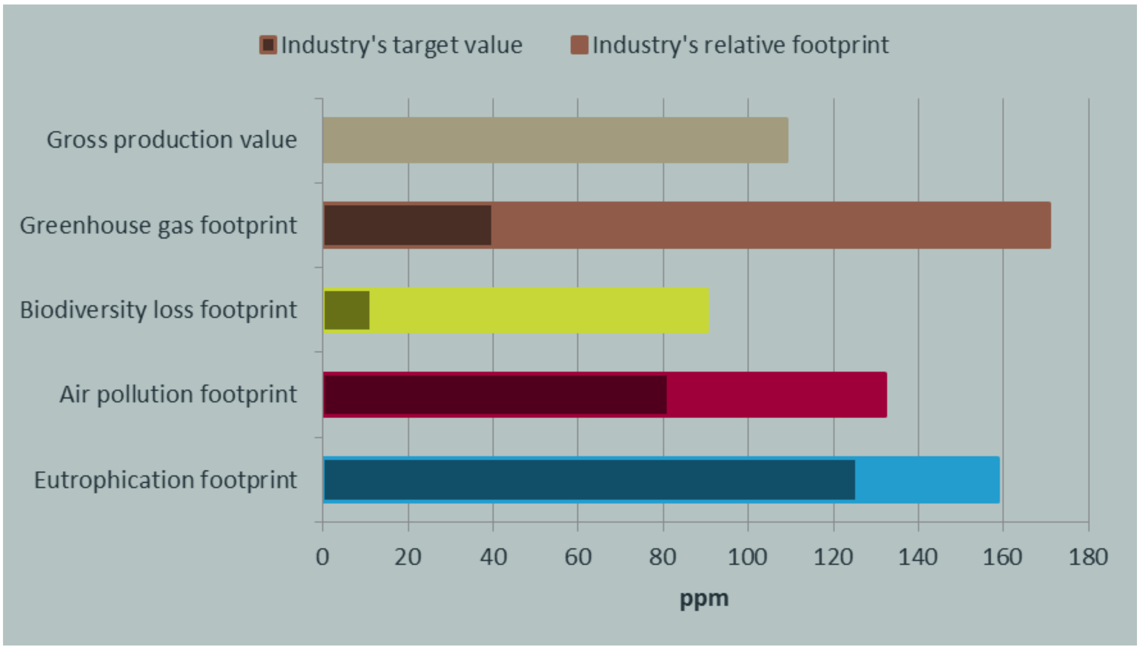

Figure 4.18: Share of environmental footprints caused by the Swiss industry 'Production of chemical products' in global environmental footprints and respective planetary boundaries (Source: Calculations treeze)

Table 4.6 shows the water footprint of the Swiss chemical industry, differentiated by country, and the share of renewable water supply used in the respective country. 12 % of the water footprint of the Swiss chemical industry occurs in India, where 37 % of the renewable water supply is already used. The tolerable amount of sustainably usable water is also exceeded in Italy and Spain, where 7 % and 4 %, respectively, of the water footprint of the Swiss chemical industry stem from. In China, where 15 % of the water footprint of the Swiss chemical industry takes place, the sustainably useable share of 20 % of the renewable water supply is almost reached. Therefore India, China, Italy and Spain are the countries with a need for action regarding the water footprint of the Swiss chemical industry. Another 9 % of the water footprint of the Swiss chemical industry stems from the United States, where in a national average already 16 % of the renewable water supply are used. As especially in large countries, regional differences in water availability can be high, imports from this country should also be monitored for their impact on the water footprint.

Table 4.6: Water footprint of the Swiss chemical industry differentiated after country and share of renewable water supply used in the respective countries

Country	Share of renewable water supply used	Water footprint of chemical industry [Mm^3]	Share of total water footprint of the chemical industry
China	20%	536	15%
India	37%	446	12%
United States	16%	336	9%
Italy	24%	247	7%
Spain	29%	149	4%
Switzerland	5%	61	2%
Turkey	17%	30	1%
France	15%	20	1%
Greece	13%	20	1%
Australia	5%	19	1%
Remaining countries and unspecified regions		1799	49%

4.3.5 Measures for reducing environmental impacts

4.3.5.1 Focal areas for measures

For the chemical industry, most of the environmental impacts are related to imported products. But also the emissions from the industry itself are not negligible. Therefore, effective measures for reducing the environmental impacts of the chemical industry should focus on those two areas:

- For the imported goods a sustainable supply chain management is crucial. Therefore, different possibilities exist (see e.g. Jungmichel et al. 2017):
    - Integration into purchasing: environmental issues are included in framework agreements or a supplier code. Specific ecological requirements can be taken into account in purchasing criteria and specifications. Com-

pliance can be checked by presenting certificates or by audits of suppliers.

- Cooperation with suppliers: knowledge transfer and capacity building among suppliers worldwide (e.g. on the subject of energy efficiency). Environmental topics can be anchored in regular target discussions with suppliers or joint projects can be implemented to identify suitable solutions for improvements. The exchange also allows better coordination of processes with the supplier. Furthermore, own experiences, e.g. from energy efficiency measures in the context of the use of environmental management systems, can be passed on to suppliers in order to initiate improvements there. The qualification can take place either through own training programs or with the help of existing knowledge platforms.
- Supply Chain Structure: targeted development of transparent supply chains that meet high ecological standards. This measure covers the entire supply chain. One possibility is direct procurement from raw material producers. This creates greater transparency regarding the origin of materials and existing local environmental standards, which in turn enables the implementation of targeted measures to improve the environmental performance of the raw material producer. In order to avoid that eventual higher purchase prices become an obstacle to the procurement of products from sustainable sources, it makes sense to build up sustainable supply chains step by step and at the same time to sensitize customers to these products.
- Product structure (use of more sustainable product components): This area of action also covers the entire value chain. Product design changes can be an important lever for reducing environmental impacts in the supply chain. This concerns above all the replacement of critical raw materials by more environmentally friendly alternatives, e.g. the use of recycled material. Changes to product design can also help to avoid or at least reduce the scope of problematic processes from an environmental perspective. This field of measures has a high innovation potential both for the procuring company and the (pre-)suppliers. The prerequisites are that sustainable alternatives for product components are available and that companies are able to achieve more sustainable product designs through their research and development activities.

- For the direct emissions from industry itself, especially the reduction of fossil CO_2- and nickel emissions are central. Besides, also the emissions of halogenated hydrocarbons could play a certain role:
  - CO_2-emissions: Enhancement of the energy efficiency of buildings and production facilities, replacement of fossil fuels by fuels or electricity from renewable sources, waste heat recovery

  - Nickel-emissions to water: Use best available technique (BAT) for production and waste water treatment
  - Halogenated hydrocarbons: use of alternative refrigerants (see e.g. https://www.responsible-care.ch/unser-ziel-ist-es-bei-roche-alle-klimaschaedigenden-kaeltemittel-zu-ersetzen/)
- Beside the above mentioned measures, also measures addressing the ‘Mining and quarrying’ industry, ‘paper and paper products’ are important. For both industries, their impact is mainly related to the energy supply and the induced CO_2-emissions. Reducing these impacts requires the same measures as for the CO_2-emissions of the chemical industry itself: a sustainable energy supply from renewable sources as well as the enhancement of the energy efficiency of buildings and production facilities.

4.3.5.2 Monitoring parameters

The development of the environmental impacts of the chemical industry could be monitored with the following indicators:

- Amount of CO_2, nickel and halogenated hydrocarbons emitted per t of product
- Amount of purchased inputs per CHF revenue
- Share of known players in the supply chain
- Share of purchased inputs sustainably produced (according to agreements with producer, certification schemes, collaboration with producer etc.)
- Amount of electricity used per t of product and share of renewable electricity
- Amount of fossil fuels used per t of product

4.3.5.3 Instruments and guidelines

The following instruments help in finding and implementing appropriate measures to reduce the environmental impacts in the production of chemical products:

- Existing initiatives of the chemical industry:
  - Responsible Care‘-Program (RC): voluntary initiative of the globally active chemical industry with the aim of continuously improving performance in the areas of safety, health and environmental protection. Further information: https://www.responsible-care.ch/
  - Chemie³ - Nachhaltigkeitsinitiative der deutschen Chemie: Joint sustainability initiative of VCI, IG BCE and BAVC with the aim of anchoring the principle of sustainability as a guiding principle in the chemical industry. Inter alia with a guide to sustainable supply chain management especially designed for small and medium-sized companies in the chemical industry (https://www.chemiehoch3.de/de/home/die-

initiative/news/nachhaltigkeit-in-der-lieferkette-chemie3-leitfaden-bietet-orientierung.html)
Further information: https://www.chemiehoch3.de/de/home.html
    - Portal of the International Councils of Chemical Associations (ICCA): https://www.icca-chem.org/energy-climate/
- Sustainable supply chain management: Environmental management systems:
    - Initiative "Together for Sustainability": https://tfs-initiative.com/
    - Environmental management scheme of the European Union EMAS: www.emas.de
    - ISO 14001 ff. (https://www.iso.org/iso-14001-environmental-management.html) and ISO 50001 (https://www.iso.org/iso-50001-energy-management.html)
- Energy reduction measures
    - Guidelines Chemicals Sector of Carbon Trust: https://www.carbontrust.com/resources/guides/sector-based-advice/chemicals/
- Guidelines to industry-specific best available technique standards:
    - European Commission Best Available Techniques (BAT) and Best Available Techniques Reference Documents (BREF) Guides: http://eippcb.jrc.ec.europa.eu/reference/
    - Environmental, health and safety guidelines of the World Bank: https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/sustainability-at-ifc/policies-standards/ehs-guidelines

4.4 Production of machinery

4.4.1 Introduction

The industry 'Production of machinery'[21] includes the manufacture of general and special purpose machinery, e.g. metal forming machinery and machine-tools or agricultural and forestry machinery. The Swiss machinery industry employed 72'367 fulltime equivalents (FTE) in 2015. This corresponds to 2 % of the entire Swiss workforce. Absolute employment as well as the employment share of machinery has declined between 2011 and 2015 (see Table 4.7).

---

[21] Code 28 according to NOGA 2008, code 29 according to NOGA 2002

Table 4.7: Employment in the machinery industry (Source: FSO – STATENT)

Year	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	78'053	2.0%		
2015	72'367	1.8%	-1.9%	1.0%

4.4.2 Economic impact

The total value added induced by the Swiss machinery industry amounts to 40’084 Mio. CHF[22]. Figure 4.19 shows how it is distributed across the different supply chain stages. The industry itself generates 31 % of the induced value added. While the direct suppliers (24 %) and the supply chain stages ‘remaining upstream chains’ (42 %) are also accountable for substantial value added shares, the fraction of value added imputable to raw material extracting industries (3 %) is almost negligible.

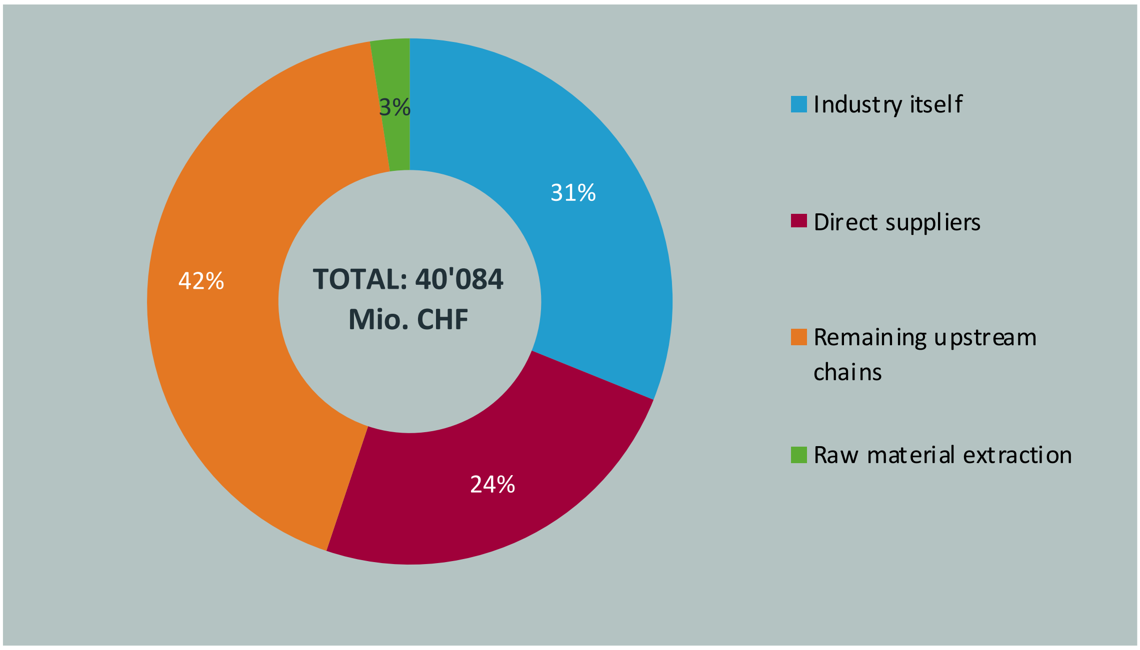

Figure 4.19: Total gross value added induced by the Swiss industry ‘Production of machinery’, differentiated by supply chain stages (Source: Calculations Rütter Soceco)

In order to understand where - in geographical terms – the value added induced by the Swiss machinery industry is generated, Figure 4.20 shows the shares of induced value added differentiated by countries and supply chain stages.

[22] These and the following economic data refer to the year 2008.

The upper section of the figure displays the share of value added generated by the industry itself (31 %) as well as the shares generated within domestic (33 %) and foreign (36 %) parts of the supply chain. Thus almost two thirds of the value added is created in Switzerland while the rest is generated abroad.

Within the Swiss supply chain, the shares of value added generated by direct suppliers and industries in the remaining upstream chains are of similar size, whereas in the foreign supply chains the share of the direct suppliers is substantially lower. With regard to the raw material extraction industries, value added is almost completely induced in foreign countries. The results show that the direct suppliers of Swiss machinery are mainly located in Switzerland. These also include suppliers of services. Direct suppliers of materials, parts and components are largely based in foreign countries.

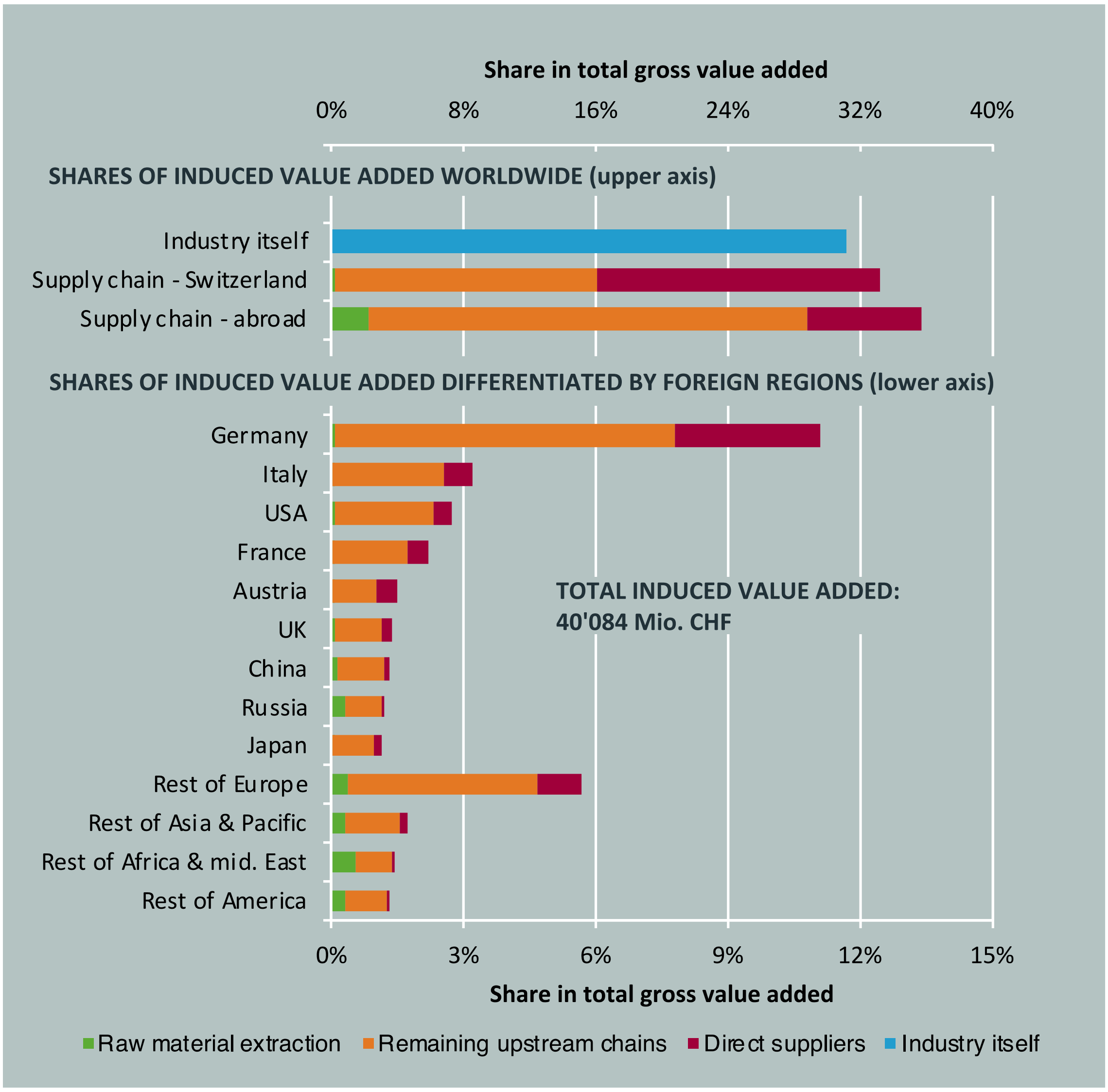

Figure 4.20: Total gross value added induced by the Swiss industry ‘Production of machinery’, differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

The lower part of Figure 4.20 displays the share of foreign countries in the total value added generated by Swiss machinery (lower scale). Among the top nine countries Germany has by far the largest share in total induced valued added (11 %). Italy, the US, France and Austria follow with shares between 1 % and 3 %. China and Russia are the most important emerging countries in the value chain of Swiss machinery, though with a small share in value added. Countries outside the top nine account for more than 10 % of value added.

In terms of supply chain stages, intermediate suppliers between raw material extraction and direct suppliers have the largest relevance. Raw material suppliers are mainly located outside Europe.

4.4.3 Environmental impacts

4.4.3.1 Overview

Table 4.8 contains an overview of the total environmental footprints caused by the Swiss machinery industry. On the one hand the footprints are reported in absolute terms, on the other hand as intensities in relation to gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

Table 4.8: Environmental footprints caused by the Swiss industry ‘Production of machinery’ (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Per M CHF gross output	Per M CHF gross value added
Greenhouse gas footprint	kt CO_2 eq	10'031	0.27	0.80
Biodiversity footprint	nano PDF*a	5'602	0.15	0.45
Water footprint	Mm3	2'348	0.06	0.19
Air pollution footprint	t PM10 eq	23'090	0.63	1.85
Eutrophication footprint	t N eq	4'859	0.13	0.39
Environmental footprint	G-eco Pt.	13'853	0.37	1.11
Gross output (industry itself)	M CHF	36'942		
Gross value added (industry itself)	M CHF	12'462		

Figure 4.21 displays the share of supply chain stages in total impact as well as the share of the industry in the global impact for each footprint apart from the environmental

footprint (and value added/gross production value for comparison reasons). It thus shows how much of the total environmental impact induced by Swiss machinery industry stems from the industry itself, how much is caused in the supply chain and how relevant each indicator for the Swiss machinery industry is.

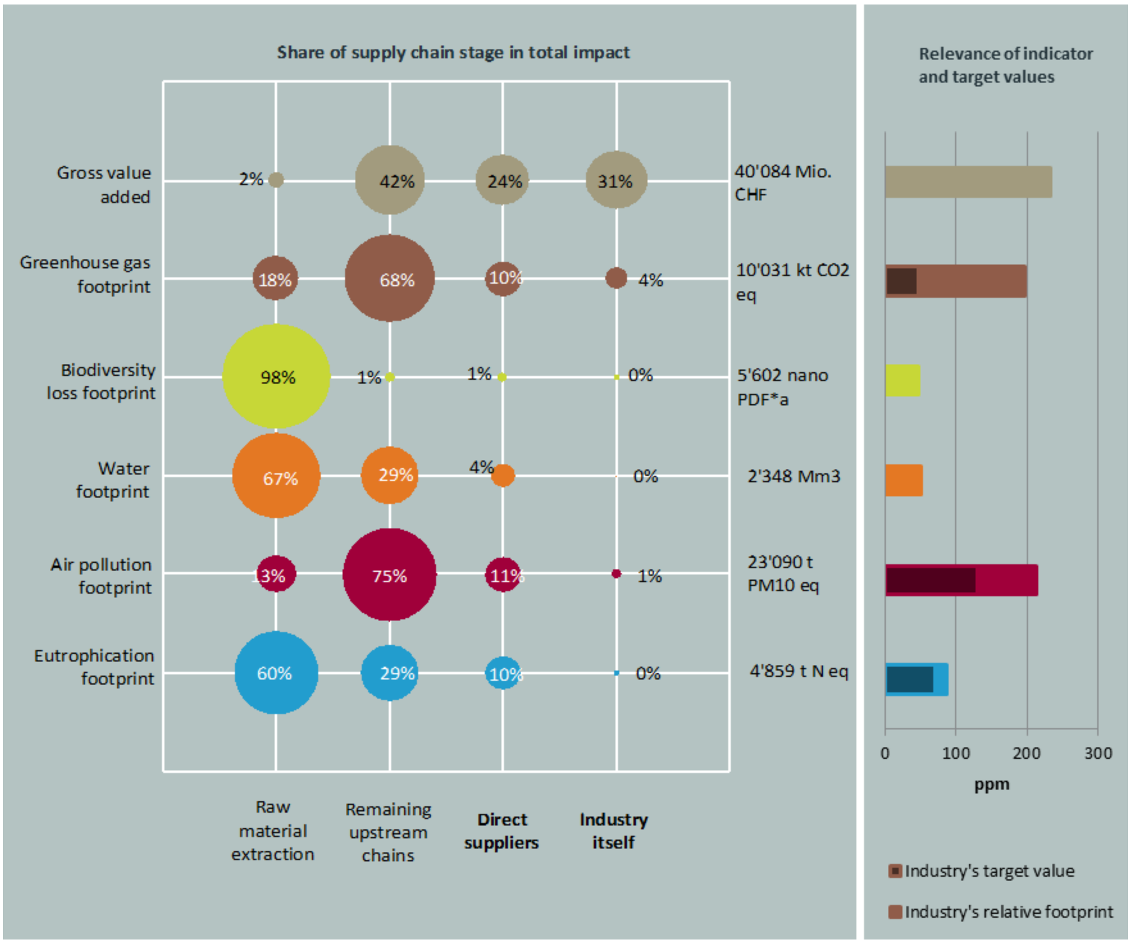

Figure 4.21: Environmental footprints caused by the Swiss industry 'Production of machinery' by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

The machinery industry, contributing 31 % of total value added, only has a negligible share in its own environmental footprints. Its share is largest for the greenhouse gas footprint with only 4 %. Thus between 96 % and 100 % of the impacts occur in the supply chain industries. The share of direct suppliers is also smaller than their value added share, but still relevant with approximately 10 % respectively for the greenhouse gas, the air pollution and the eutrophication footprints. For the greenhouse gas and the air pollution footprints, the remaining upstream chains between raw material extraction and direct suppliers have the largest shares (68 % resp. 75 %). They include basic material production, e.g. steel or aluminium production, but also less used materials such as plastics, rubber or glass. With regard to the biodiversity footprint (98 %), the water footprint

(67 %) and the eutrophication footprint (60 %) most of the impact stem from raw material extraction. Remaining upstream chains are also important.

Most relevant for the machinery industry are the air pollution and the greenhouse gas footprints (see Figure 4.21; share of the respective footprints in the global footprints compared to the share of the gross production value of the machinery industry in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.4.4.

4.4.3.2 Focus on air pollution footprint

The focus footprint chosen for the machinery industry is the air emission footprint, since this is the highest ranking footprint (cf. Table 3.2). As seen in Table 4.8 the global amount of air emissions induced by Swiss machinery adds up to 23’090 t PM_{10} eq. Figure 4.22 displays which industries (aggregated over all countries) emit the air pollutants which are caused by Swiss machinery. The largest emitter is the basic metals industry which is accountable for almost 40 % of the global air emissions induced. ‘Electricity from fossil fuels’ follows on the second place (15 %). Other important supply chain industries in terms of air emissions are ‘mining and quarrying’ of mineral resources and energy carriers, water transport, petroleum products and other non-metallic minerals. The industries not present in the top ten account for less than 20 % of the air emissions footprint.

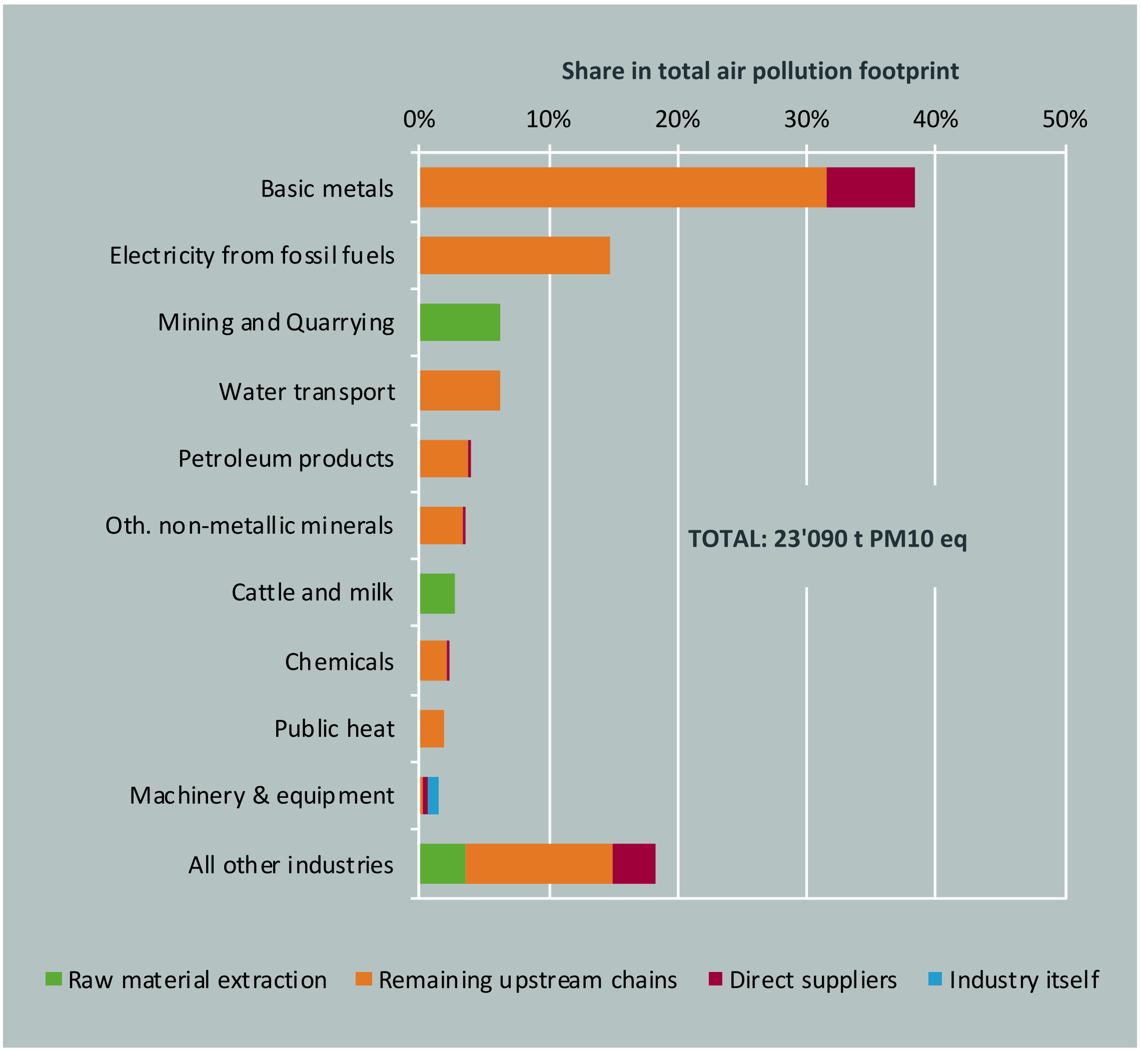

Figure 4.22: Air pollution footprint caused by the industry 'Production of machinery' by supply chain stage and industry (Source: Calculations Rütter Soceco)

Figure 4.23 illustrates how the responsible companies are distributed across supply chain stages and countries. The diagram shows that only 5 % of the footprint are due to emissions in Switzerland with the industry itself contributing only 1 %. 95 % of the emissions occur abroad.

The country differentiation of greenhouse gas emissions reveals China (with 20 % of the total emissions), Germany (10 %) and Russia (6 %) to be the largest foreign polluters in the context of the supply chains of the Swiss machinery industry. Other important emitters are South Africa, Brazil, the USA and India. The emission share of these emerging countries (almost 40 % of total emissions) is significantly larger than their share in induced value added (under 5 %). This illustrates the impact of the larger emission intensities (per unit of value added) in these countries when compared to the more developed countries.

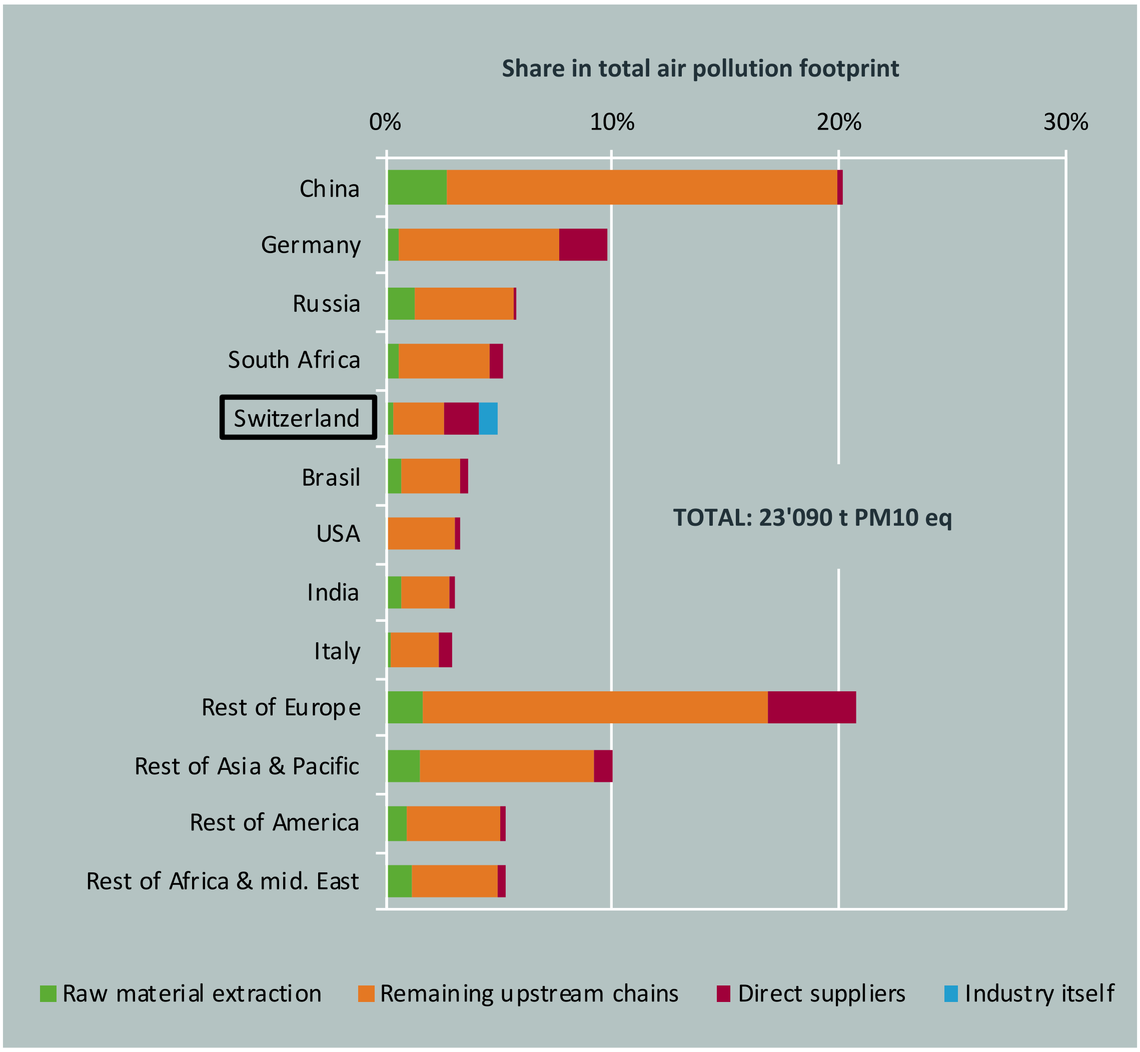

Figure 4.23: Air pollution footprint caused by the Swiss industry ‘Production of machinery’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

From a practical point of view it is useful to understand which direct inputs purchased by the Swiss machinery industry are responsible (to what extent) for the total air emissions caused within the supply chain. This allows the companies to identify, which of their suppliers they should access with which priority in order to optimise the environmental performance of their supply chain. The analysis presented in Figure 4.24 allocates the air emissions caused by Swiss machinery within the supply chain to domestic and foreign direct suppliers. For reasons of comparison the share of machinery (‘industry itself’) is also included.

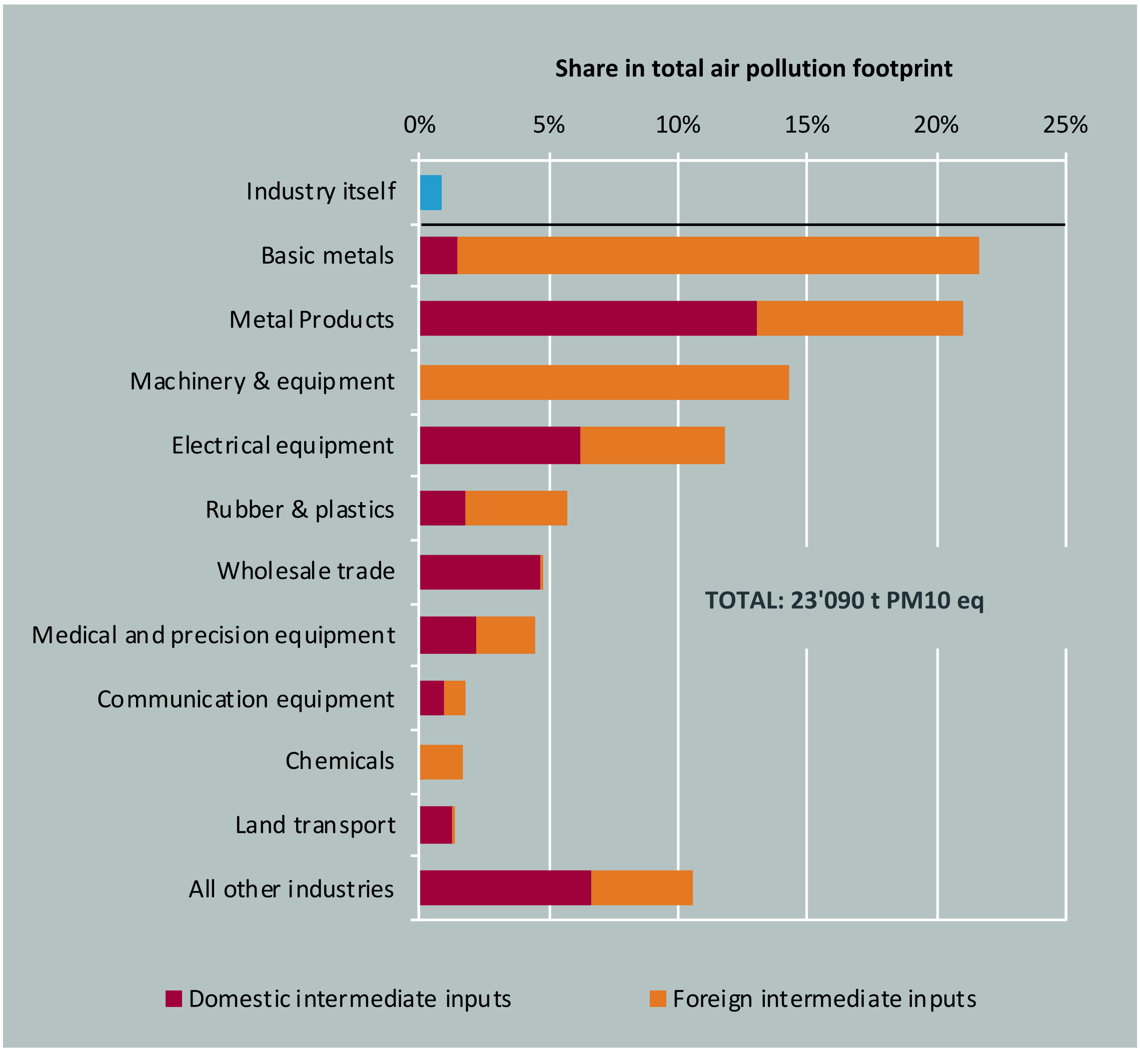

Figure 4.24: Air pollution footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry 'Production of machinery' (Source: Calculations Rütter Soceco)

The most important direct suppliers are the basic metals and the metal products industries with shares of more than 20 % respectively of the air emission footprint caused by the Swiss machinery industry. Basic metals mainly stem from foreign suppliers, whereas domestic suppliers have a larger relevance with regard to metal products. Also important are technology and component suppliers from within the machinery industry (14 %), the electrical equipment (12 %) and precision equipment (4 %) industries. Other important suppliers come from rubber and plastics processing supplying parts for machinery and from the trade and transport industries. Suppliers from outside the top ten account for over 10 % of the total footprint.

4.4.3.3 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

For the biodiversity, the water and the eutrophication footprint raw material supply and especially agriculture are predominant. This reflects that agriculture generally dominates these midpoint indicators, even if it is not an important input for the machinery industry. Forestry plays a role as supplier of wood for investment goods, packaging etc. Furthermore, a noteworthy share of the water footprint can be attributed to the basic metals industry, an important share of the eutrophication footprint on the other hand is caused by disposal activities.

With regard to the country distribution it is worth mentioning that Switzerland and China together are equally responsible for almost 40 % of the eutrophication footprint. China is also dominating the water footprint followed by India, Italy and the USA. The biodiversity footprint is spread among many countries.

For the greenhouse gas footprint, the responsible industries are mainly electricity generation from fossil fuels, mining and quarrying of energy carriers and minerals and the basic metals industry. The production of machinery itself also enters the top five industries. With regard to the responsible countries of the supply chain, China, Germany and Switzerland dominate.

4.4.3.4 Environmental footprint according to the ecological scarcity method

The total environmental footprint of the industry 'Production of machinery' is 13'853 billion eco-points. Nearly 90 % of it are caused by imported goods (Figure 4.25). The remaining Swiss suppliers cause 5 %, the direct Swiss suppliers 4 % and the industry itself only 2 % of its total environmental footprint. The footprint of the industry itself is mainly caused by the emissions of fossil CO_2, followed by other emissions such as NMVOC, nitrogen oxides, and benzene.

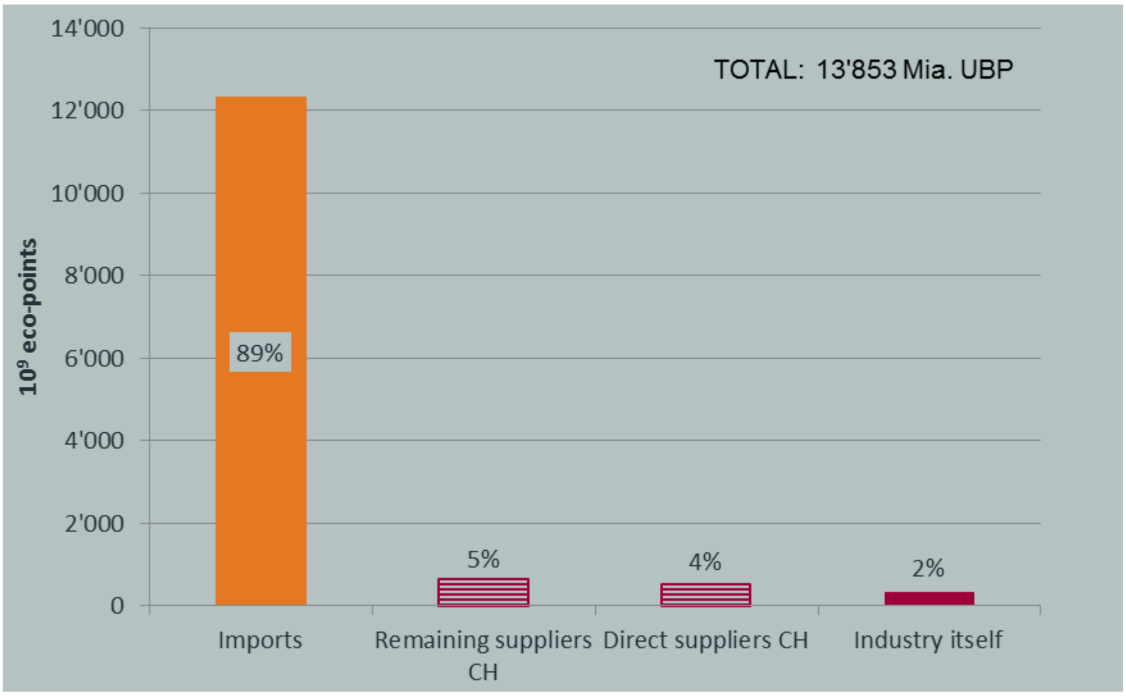

Figure 4.25: Environmental footprint in eco-points caused by the industry ‘Production of machinery’ by supply chain stages and imports (Source: Calculations treeze)

Figure 4.26 shows the ten most important contributing direct suppliers to the total environmental impact of the industry ‘Production of machinery’. The ten most important contributors explain nearly 70 % of the total environmental footprint. With almost 15 % the most important contributor are the Swiss ‘Metal products’. Their environmental footprint occurs mainly abroad and is due to the import of iron and steel as well as non-ferrous metals. The direct imports of manufactures of metals, iron and steel and non-ferrous metals each contribute about 10 % to the total environmental footprint of the industry ‘Production of machinery’. The environmental footprint of all these contributors is mainly due to the production of the respective metals.

With 7 % the fifth most important direct supplier is the Swiss ‘Computer and electrical industry’. Here again, important contributors are the import of iron and steel, import of non-ferrous metals, the metal products and the import of manufactures of metals. Additionally, also the import of electrical machinery contributes to the environmental footprint of the ‘office and electrical equipment’. Furthermore, 5 % of the total environmental footprint of the industry ‘Production of machinery’ is related to the import of electrical machinery.

The wholesale and retail trade contributes 4 % to the total environmental footprint of the industry ‘Production of machinery’. Its environmental footprint is caused by its electricity need, infrastructure (‘Construction’ and ‘Renting and other business services’), by the ‘Disposal services’ and imported petroleum products. Further rather minor contributions stem from imported industrial machinery and equipment, from the electricity use and the Swiss industry ‘Rubber and plastic products’.

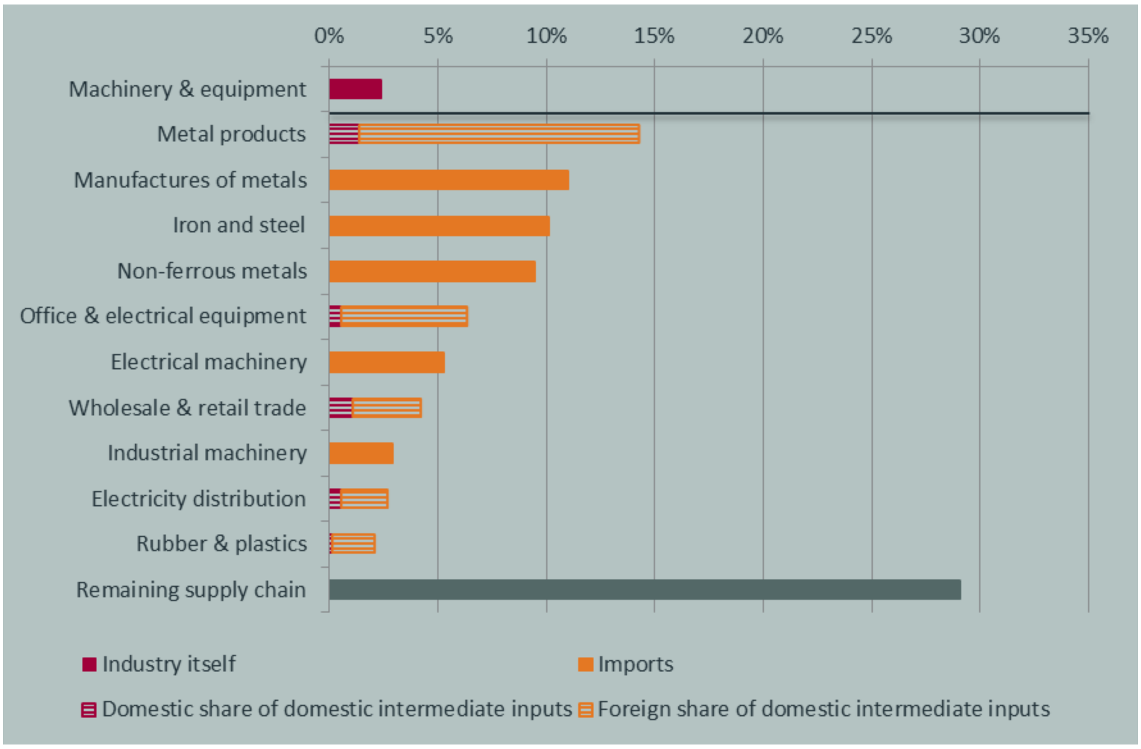

Figure 4.26: Environmental footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry ‘Production of machinery’. Remaining supply chain = all other direct suppliers (Source: Calculations treeze)

4.4.3.5 Conclusion

For air pollution and the total environmental footprint, 95 % and nearly 90 % of the emissions, respectively, occur abroad. The most important contributing direct suppliers are very similar for both indicators. Metal production causes the highest impacts, either directly via the purchase of metals or indirectly via the purchase of metal products. The second most important contribution stems from purchased components like different kind of machinery, electrical equipment and precision equipment. Other important suppliers are rubber and plastic products, the trade industry and in the case of the air pollution footprint the transport industries. The impacts of the machinery industry itself are negligible for all indicators analysed.

The results of this study can be compared to a similar study of the Swiss MEM[23] industry (Droz & Hellweg 2018). The main results with regard to the environmental relevance of the foreign part of the supply chain and the contribution of specific industries and countries to the environmental footprints of Swiss machinery are comparable. Differences of results can be explained by

[23] MEM: metals, machinery, electrical engineering, precision instruments and vehicle manufacturing

- the different system boundaries: while this study analyses the Swiss machinery industry, Droz & Hellweg analyse the MEM industry, of which machinery is a part.
- the different method for calculating the economic variables: Droz & Hellweg estimate the turnover of the MEM industry from exports and estimated shares of exports in turnover, while this study uses data on gross output and gross value added from official Swiss statistics. Both studies calculate specific environmental intensities as the environmental footprint divided by turnover resp. output. Yet the use of different variables (turnover vs. output) and different data sources make a comparison of results difficult.
- the different database used for calculating the environmental footprints: Droz & Hellweg use the multiregional EE-IOT Exiobase v3.3. This study uses a combination of the Swiss EE-IOT 2008 and Exiobase v3.4, since the Swiss economic data in Exiobase v3.3 were found to be distorted in the sense that economic data (output and value added) deviate from official Swiss statistics. Therefore the Swiss EE-IOT and data from Swiss trade statistics were used to analyse Swiss value chains and imports. Exiobase is only used to analyse value chains in foreign countries.

4.4.4 Comparison with the planetary boundaries

Figure 4.27 shows the share of the environmental footprints of the Swiss industry ‘Production of machinery’ in the respective global environmental footprints as well as the relative reduction needs. Of the environmental impacts analysed, the Swiss machinery industry contributes most to the air pollution and the greenhouse gas footprints. The contributions to the eutrophication and the biodiversity loss footprints are smaller. For all indicators analysed, the industry’s shares in the global environmental impacts is lower than its share in global gross production value.

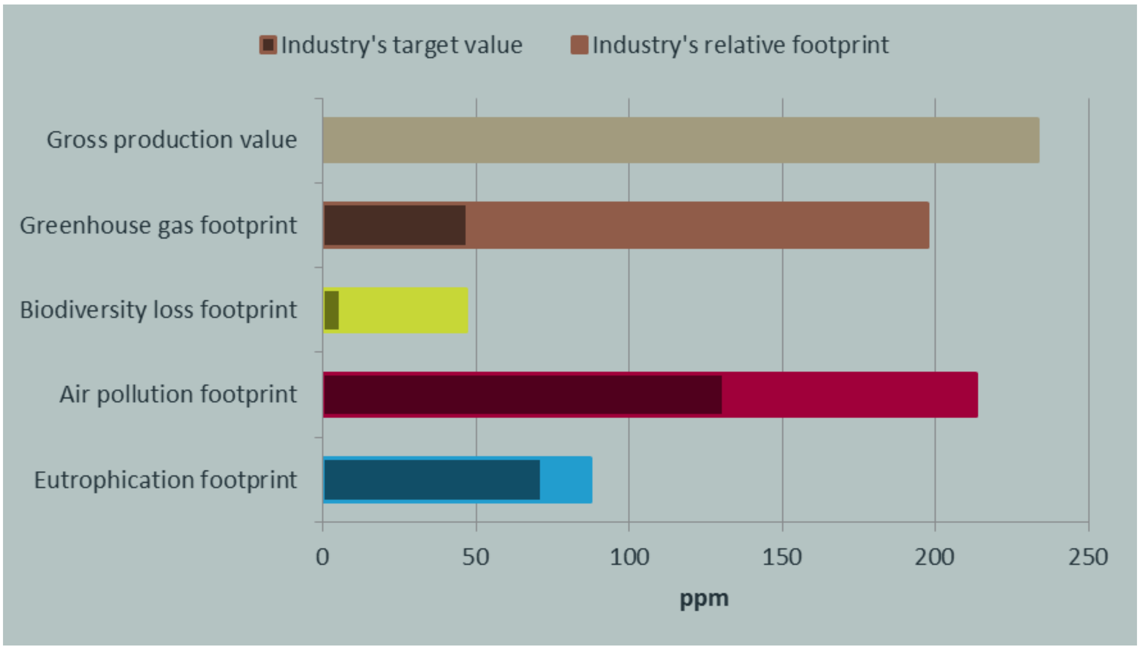

Figure 4.27: Share of environmental footprints caused by the Swiss industry ‘Production of machinery’ in global environmental footprints and respective planetary boundaries (Source: Calculations treeze)

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, for the Swiss machinery industry the greenhouse gas footprint is identified as priority field of action, followed by the air pollution footprint.

Table 4.9 shows the water footprint of the Swiss industry ‘Production of machinery’, differentiated after country, and the share of renewable water supply used in the respective country. Half of the water footprint of the Swiss industry ‘Production of machinery’ occurs in countries where the tolerable amount of sustainably usable water of 20 % is exceeded or almost reached (China, India, Italy, USA, Spain, Turkey, South Africa and Bulgaria). Nearly one third of the water footprint of the Swiss industry ‘Production of machinery’ stems from China, where 19.5 % of the renewable water supply is used. This is in line with the high importance of China for the air pollution footprint. The other countries contribute less to the water footprint of the Swiss industry ‘Production of machinery’, but the amount of sustainably useable water is exceeded by 5 % to 17 %. In all these countries, there is a need for action regarding the water footprint of the Swiss machinery industry.

Table 4.9: Water footprint of industry 'Production of machinery' differentiated after country and share of renewable water supply used in the respective countries

Country	Share of renewable water supply used	Water footprint industry 'Production of machinery' [Mm^3]	Share of total water footprint of the industry 'Production of machinery'
China	20%	719	31%
India	37%	215	9%
Italy	24%	132	6%
United States	16%	110	5%
Spain	29%	57	2%
Turkey	17%	36	2%
South Africa	25%	34	1%
Australia	5%	28	1%
Bulgaria	29%	20	1%
Switzerland	5%	18	1%
Remaining countries and unspecified regions		980	42%

4.4.5 Measures for reducing environmental impacts

4.4.5.1 Focal areas for measures

For the 'Production of machinery' industry, most of the environmental impacts are related to imported products. Metal production causes the most important contribution. Effective measures for reducing the environmental impacts through the production of machinery therefore focus on the use and production of purchased goods, especially metals.

The environmental impacts of the purchased metals and metal products can be reduced by enhancing the material efficiency, i.e. using less material input for the same amount of products. This can be achieved by implementing ecodesign into the development of new and enhancements of existing products. Another possibility is the use of recycled instead of primary metals.

An important step for reducing the environmental impacts of the supply chain is the implementation of a sustainable supply chain management. Different possibilities exist for this purpose (see Subsection 4.3.5.1).

4.4.5.2 Monitoring parameters

The development of the environmental impacts of the ‘Production of machinery’ industry could be monitored with the following indicators:

- Amount of metals (e.g. iron and steel) used per CHF revenue
- Share of secondary material (recycled metals) in total metal input
- Share of known players in the supply chain
- Share of purchased inputs sustainably produced (according to agreements with producer, certification schemes, collaboration with producer etc.)

4.4.5.3 Instruments and guidelines

The following instruments help in finding and implementing appropriate measures to reduce the environmental impacts in the production of machinery:

- Increasing material and energy efficiency:
  - Reffnet: www.reffnet.ch
- Sustainability in the mechanical engineering industry:
  - Blue competence sustainability initiative: http://www.bluecompetence.net/home
- Sustainable supply chain management: Environmental management systems:
  - Environmental management scheme of the European Union EMAS: www.emas.de
  - ISO 14001 ff. (https://www.iso.org/iso-14001-environmental-management.html) and ISO 50001 (https://www.iso.org/iso-50001-energy-management.html)
- Metal production
  - Guidelines from the International Council on Mining and Metals (ICMM): http://www.icmm.com/en-gb
  - Standards of the Aluminium Stewardship Initiative (ASI): https://aluminium-stewardship.org/

4.5 Real estate services and construction

In this chapter the cluster of real estate services and construction is presented. Both industries are important in shaping the supply chains of buildings and infrastructure construction in Switzerland. We first present the supply chain of real estate services, that also includes the construction industry as an important supplier, and then additionally zoom in briefly on the supply chain of the construction industry.

4.5.1 Introduction

The real estate services industry includes commercial real estate services as well as private households as real estate owners[24]. Commercial real estate services consist of

- buying and selling of own real estate,
- renting and operating of own or leased real estate,
- real estate activities on a fee or contract basis.

Private households as real estate owners form a separate industry in the Swiss national accounts. It comprises the own use of dwellings owned by private households and rental income by private households.

The construction industry includes the following activities:

- development of buildings projects,
- construction of residential and non-residential buildings,
- civil engineering,
- specialized construction activities (e.g. installation, roofing, painting).

The relationship between the real estate services and the construction industry is depicted in Figure 4.28. The construction is an important supplier for the real estate services industry. Apart from the real estate services industry there are other owners of real estate and of infrastructure (e.g. roads, wastewater management, power lines). The construction industry also supplies services to these entities. Thus the real estate services industry has suppliers other than the construction industry. And the construction industry supplies services to clients from outside the real estate services industry, including owners of infrastructure.

In the following, real estate services and real estate industry are used as synonyms.

[24] Real estate services: NOGA 68 according to NOGA 2008, NOGA 70 according to NOGA 2002; private households as real estate owners: NOGA 98 according to NOGA 2008, NOGA 97 according to NOGA 2002

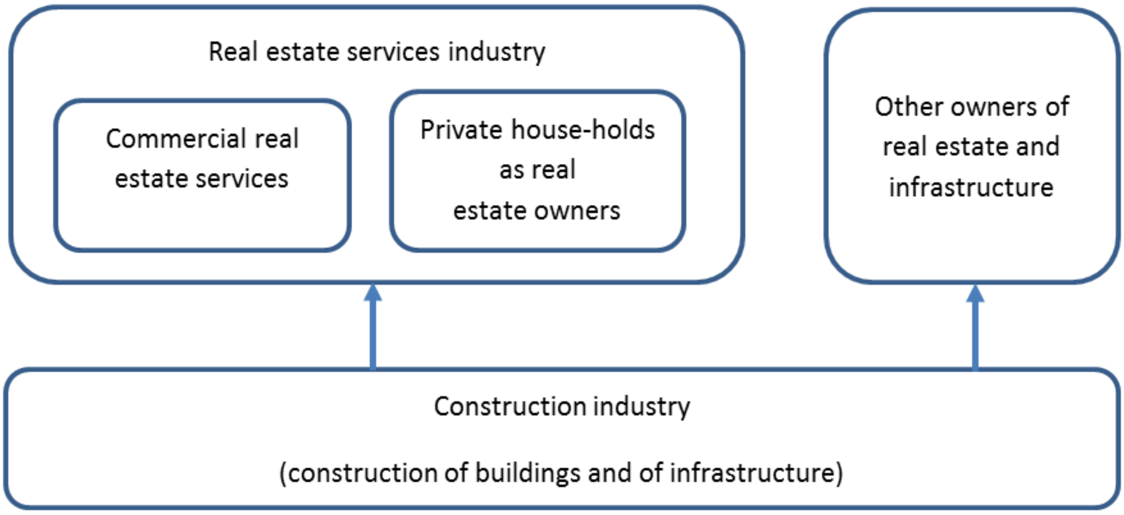

Figure 4.28: Relationship between the construction and the real estate services industry

The industry 'commercial real estate services' is a small industry with regard to employment, but shows an above average growth rate. It employed almost 45'000 persons (FTE) in 2015 and grew annually on average by 2.4 % between 2011 and 2015. Private households as real estate owners do not have any employees, but are important with regard to gross value added, since depreciation of their real estate significantly contributes to value added in the national accounts.

The Swiss construction industry is one of the larger Swiss industries. It employed almost 326'000 persons (FTE) in 2015. This corresponds to 8.1 % of the entire Swiss workforce. On average, employment has grown by 0.9 % per year between 2011 and 2015 (see Table 4.10).

Table 4.10: Employment in real estate services and the construction industry (Source: FSO – STATENT)

Year	Real estate services industry			Construction industry			
	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	40'820	1.1%		314'438	8.2%		
2015	44'795	1.1%	2.4%	325'576	8.1%	0.9%	1.0%

4.5.2 Economic impact of the real estate services industry

The total value added induced by the Swiss real estate industry amounts to 89’171 Mio. CHF[25]. Figure 4.29 shows how it is distributed across the different supply chain stages[26]. The largest share is generated by the industry itself (56 %), which is due to the large value added of private households as real estate owners. The supply chain stages ‘direct suppliers’ (20 %, e.g. construction industry) and ‘remaining upstream chains’ (23 %, e.g. cement and tile manufacturers) are also accountable for substantial value added shares. The fraction of value added imputable to raw material extracting industries (1 %) is almost negligible.

[25] These and the following economic data refer to the year 2008.

[26] The use phase, that is relevant for environmental impacts, corresponds to a consumption activity and thus does not generate value added.

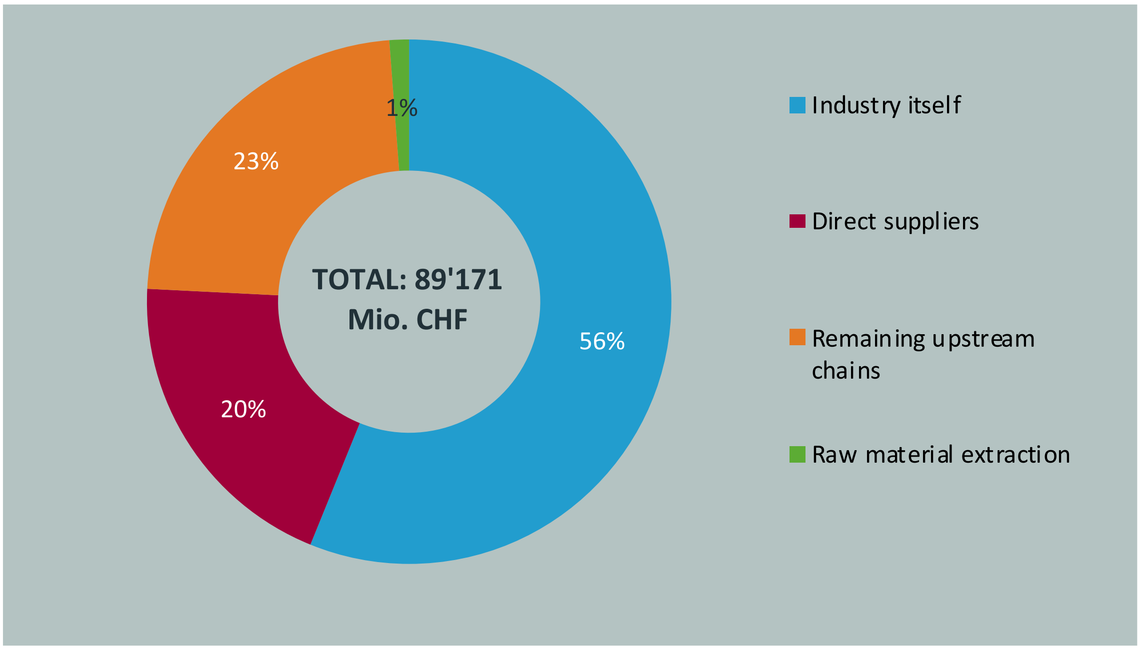

Figure 4.29: Total gross value added induced by the Swiss industry ‘Real estate services’, differentiated by supply chain stages (Source: Calculations Rütter Soceco)

In order to understand where - in geographical terms – the value added induced by the Swiss real estate industry is generated, Figure 4.30 shows the shares of induced value added differentiated by countries and supply chain stages.

The upper section of the figure displays the share of value added generated by the industry itself (56 %) as well as the shares generated within domestic (32 %) and foreign (12 %) parts of the supply chain. Thus almost 90 % of the value added generated within the supply chains is created in Switzerland while the rest is created abroad.

Within the Swiss supply chains, the shares of value added generated by direct suppliers is larger than that of the remaining upstream chains, whereas in the foreign supply chains the share of the direct suppliers is substantially lower. Thus a major share of direct suppliers appears to be located in Switzerland.

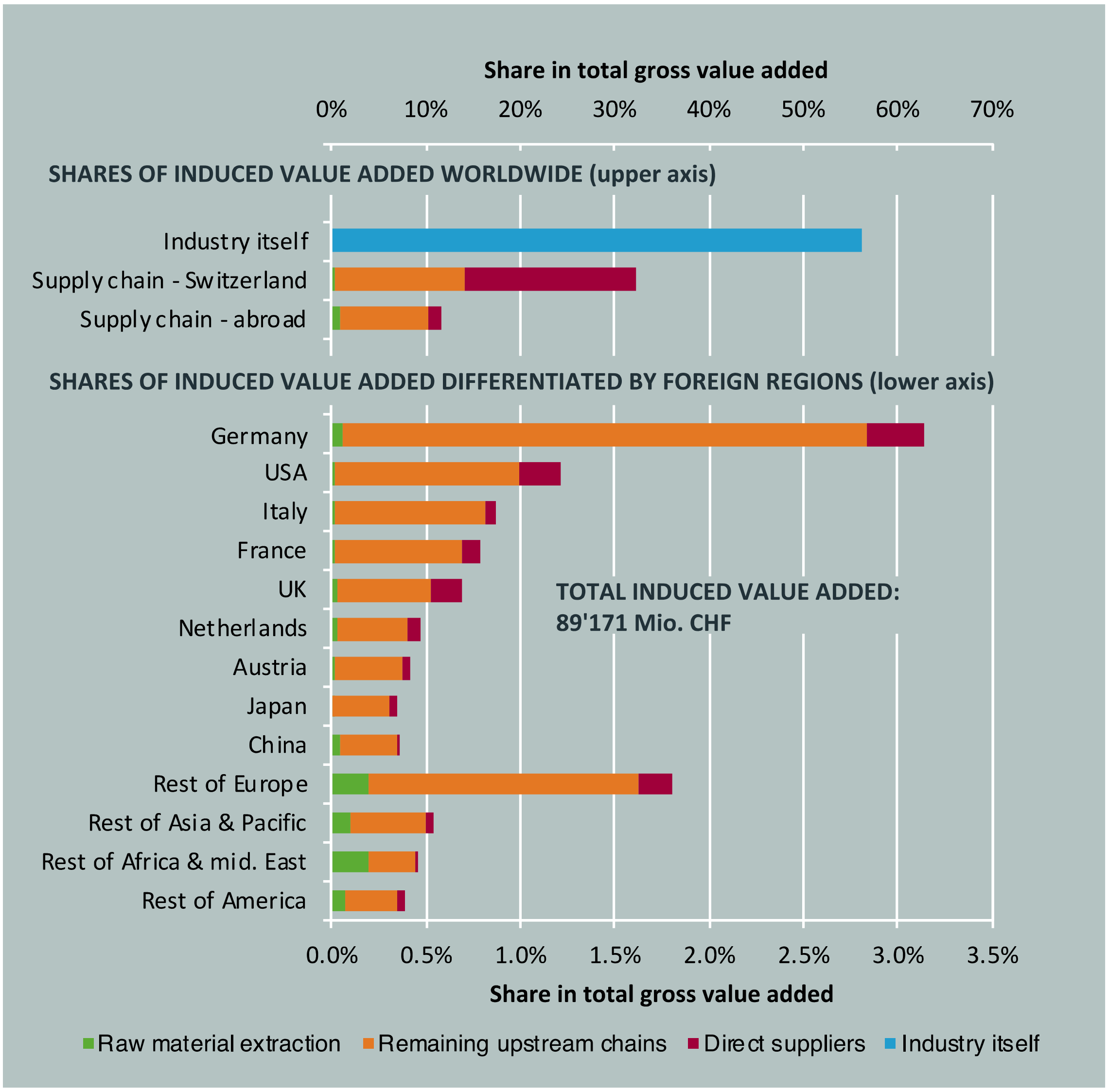

Figure 4.30: Total gross value added induced by the Swiss industry 'Real estate services, differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

The lower part of Figure 4.30 displays the share of foreign countries in the total value added generated by the real estate industry. Germany has the largest share with 3 % of the total valued added, followed by the US, Italy, France and the UK. The countries outside the top ten account for approximately 3 % of total value added. In terms of supply chain stages, value added in foreign countries is mainly generated by intermediate suppliers situated between direct suppliers and raw material extraction.

4.5.3 Environmental impacts of the real estate services industry

4.5.3.1 Overview

Table 4.11 contains an overview of the total environmental footprints caused by the Swiss real estate industry, including the use phase (i.e. environmental impacts caused by heating of buildings). On the one hand the footprints are reported in absolute terms, on the other hand as intensities in relation to gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

Table 4.11: Environmental footprints caused by the Swiss industry 'Real estate services' (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Of which in the use phase	Of which in production	Per M CHF gross output (only production)	Per M CHF gross value added (only production)
Greenhouse gas footprint	kt CO_2 eq	24'286	16'569	7'716	0.11	0.15
Biodiversity footprint	nano PDF*a	6'631	879	5'753	0.08	0.11
Water footprint	Mm^3	3'707	1'884	1'823	0.03	0.04
Air pollution footprint	t PM_{10} eq	28'254	13'756	14'499	0.20	0.29
Eutrophication footprint	t N eq	7'173	925	6'249	0.09	0.12
Environmental footprint	G-eco Pt.	26'605	16'820	9'785	0.14	0.20
Gross output (industry itself)	M CHF	70'412				
Gross value added (industry itself)	M CHF	50'064				

Aiming to understand the supply chain stages in which the different environmental impacts take place, Figure 4.31 displays the share of supply chain stages in total impact as well as the share of the industry in the global impact for all footprints apart from the environmental footprint (and value added/gross production value for comparison reasons). It thus shows how much of the total environmental impact induced by the real estate industry stems from the industry itself, how much is caused in the supply chain and how relevant each indicator for the Swiss real estate industry is.

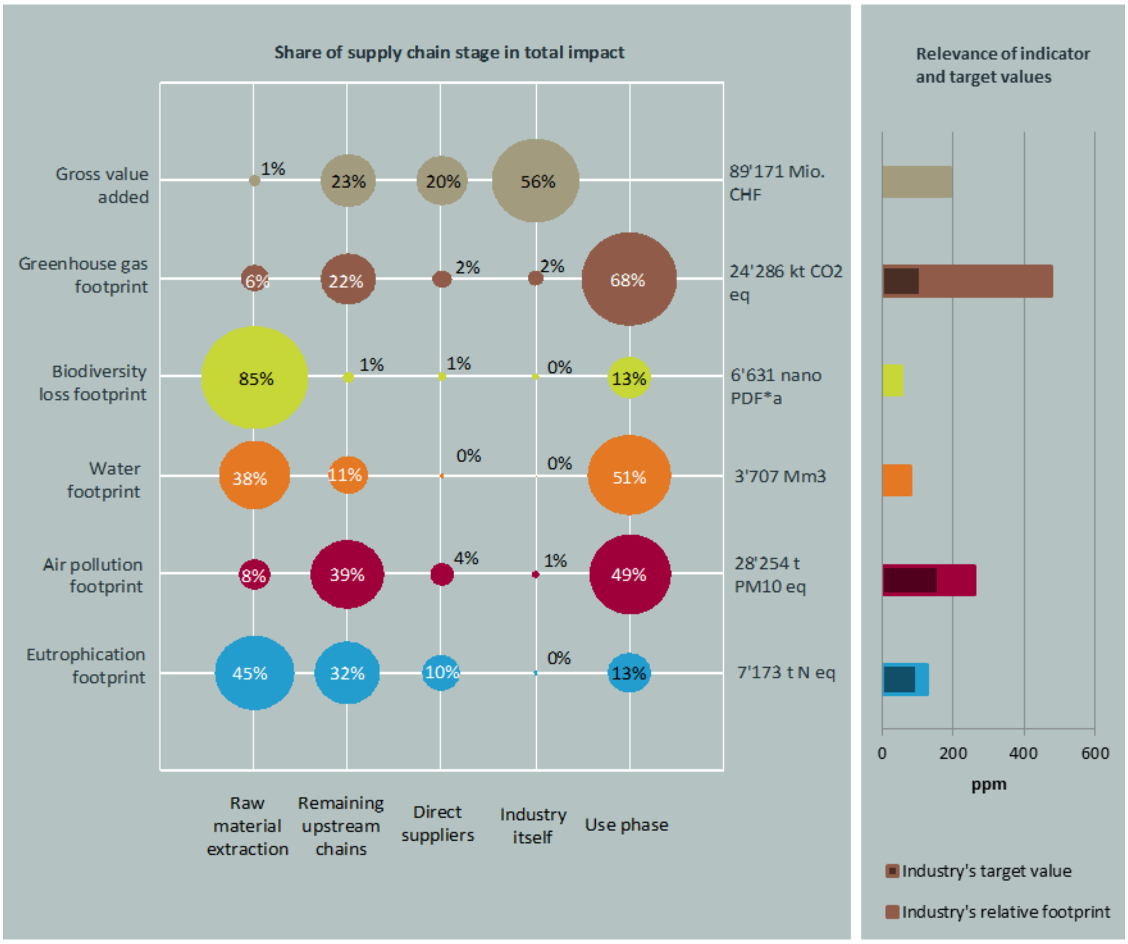

Figure 4.31: Environmental footprints caused by the Swiss industry ‘Real estate services’ by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

This figure shows that the use phase accounts for large shares of the various footprints. It is most important for the greenhouse gas footprint (with a share of 68 %), for the water footprint (51 %) and the air pollution footprint (49 %), including e.g. the environmental impacts of households’ energy use for heating and cooling, other electricity use and water use. The use phase is less relevant for the biodiversity and the eutrophication footprint. The real estate industry itself and its direct suppliers (e.g. construction) generate much of the value added but only small shares of the environmental footprints. The remaining upstream chains (e.g. cement and tile industries) have significant shares in the greenhouse gas (22 %), the air pollution (39 %) and the eutrophication footprints (32 %). Finally raw material extraction as usual dominates the biodiversity footprint (85 %), but is also quite relevant for the eutrophication (45 %) and the water (38 %) footprint.

The real estate services have a large greenhouse gas footprint (see Figure 4.31; share of the respective footprint in the global footprints compared to the share of the gross production value of the real estate services in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.5.4.

4.5.3.2 Focus on greenhouse gas emissions

The focus footprint chosen for the Swiss real estate industry is the greenhouse gas footprint. As seen in Table 4.11 the global amount of greenhouse gas emissions induced by the real estate industry in Switzerland adds up to 24’286 kt CO_2 eq, of which 7’716 kt CO_2 eq are caused in the supply chain of the real estate industry. The use phase accounts for 68 % of the total greenhouse gas footprint, mainly due to space heating and to a lesser extent to warm water, electricity and water use.

Regarding the supply chain, Figure 4.32 displays in the lower part, which industries of the supply chain (aggregated over all countries) emit the greenhouse gases. The largest emitter is the industry ‘electricity from fossil fuels’ which is accountable for 5 % of the greenhouse gas footprint. ‘Mining and quarrying’ follows on the second place (4 %). In general a large fraction of greenhouse gas emissions stems from basic industries like other non-metallic minerals or basic metals. Real estate services and construction are responsible for almost 2 % of the emissions respectively. Transport, petroleum products and chemicals follow among the top ten. Industries outside the top ten account for more than 8 % of the greenhouse gas footprint.

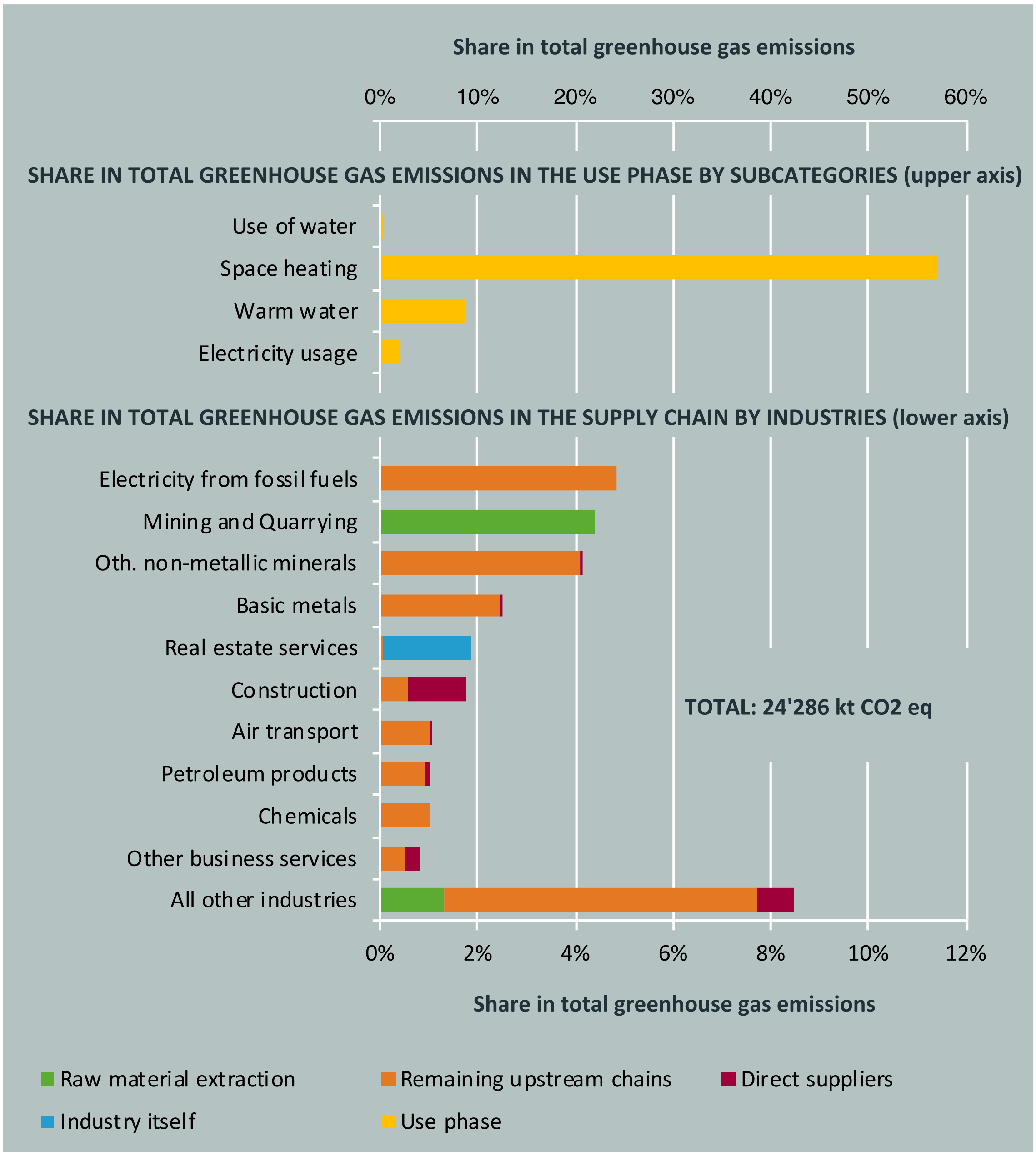

Figure 4.32: Greenhouse gas footprint caused by the industry ‘Real estate services’ by supply chain stage and supplying industries (Source: Calculations Rütter Soceco)

Figure 4.33 illustrates how the responsible companies are distributed across supply chain stages and countries. The lower part of the diagram shows that more than three quarters of the footprint are due to emissions in Switzerland (68 % during the use phase and more than 8 % by the industry itself and by Swiss supply chain industries) while the remaining emissions take place abroad.

The country differentiation of greenhouse gas emissions reveals China and Germany to be the largest foreign polluters in the real estate industry’s supply chain, followed by

Russia, the US and Italy. Countries outside the top ten account for 9 % of the footprint. Emissions abroad are mainly caused by remaining upstream chains and to a lesser extent by raw material extraction.

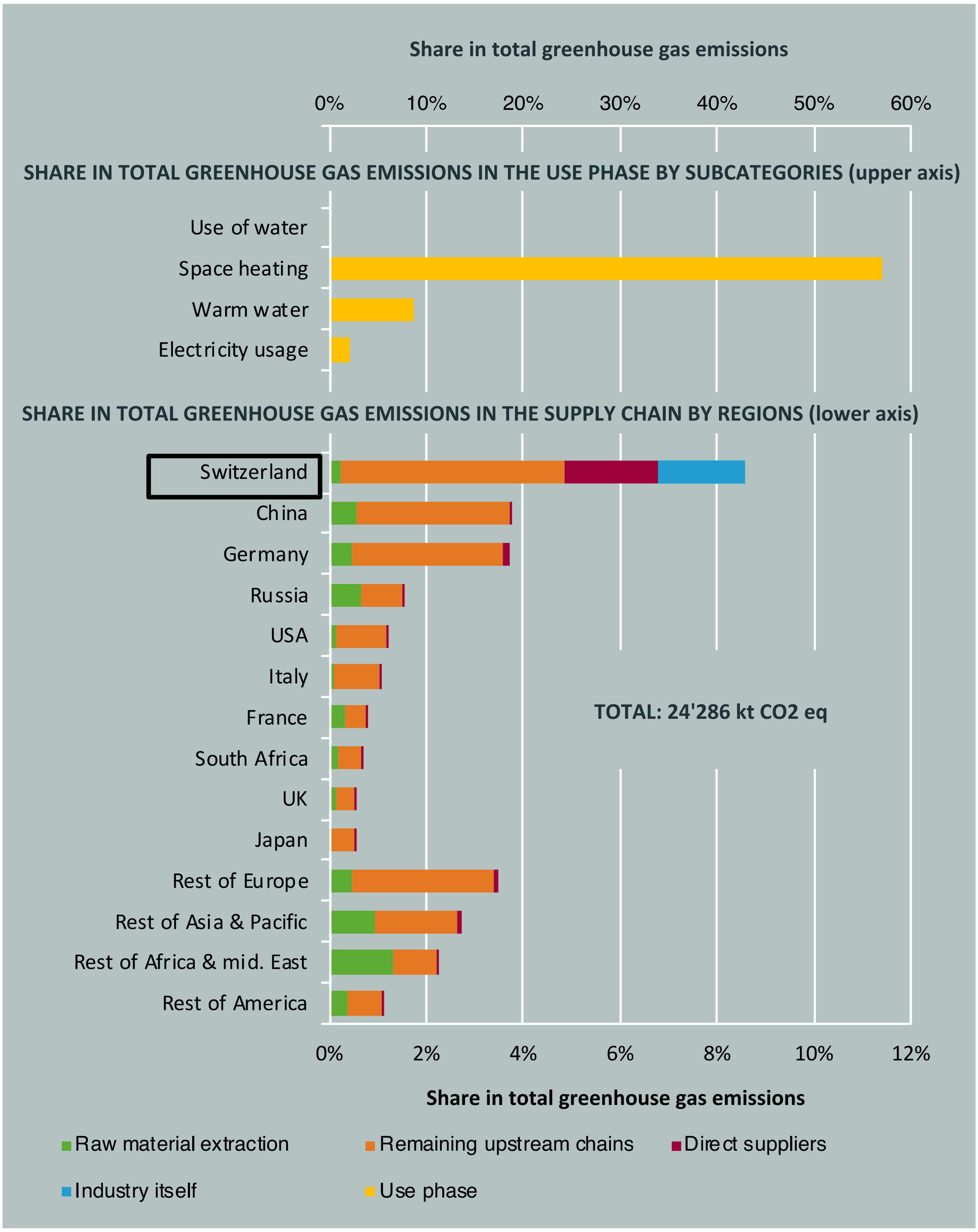

Figure 4.33: Greenhouse gas footprint caused by the Swiss industry ‘Real estate services', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

From a practical point of view it is useful to understand which direct intermediate inputs purchased by the Swiss real estate industry are responsible (to what extent) for the total greenhouse gas emissions caused by the industry within the supply chains. This allows the companies to identify, which of their suppliers they should access with which priority in order to optimise the environmental performance of their supply chain. The analysis presented in the lower part of Figure 4.34 allocates the greenhouse gas emissions caused by the Swiss real estate industry within the supply chain to domestic and foreign direct suppliers. Thus each direct supplying industry is presented with its own greenhouse gas footprint, including all emissions along its own supply chain. The emissions of the industry itself are shown for comparison reasons.

The results show that construction as a direct supplier to the real estate industry is responsible for almost 18% of the greenhouse gas footprint[27]. Surprisingly financial services and other business services are also relevant with shares between 3 % and 4 %. Here the main contributors are energy use and the use of investment goods, that are environmentally intensive. The impact of other suppliers is rather small. Therefore in order to optimise its total induced environmental impacts, real estate service providers need to focus on the use phase, i.e. energy consumption of buildings, and the energy and materials used for the construction of buildings.

[27] This includes the greenhouse gas emissions of the construction industry's supply chain.

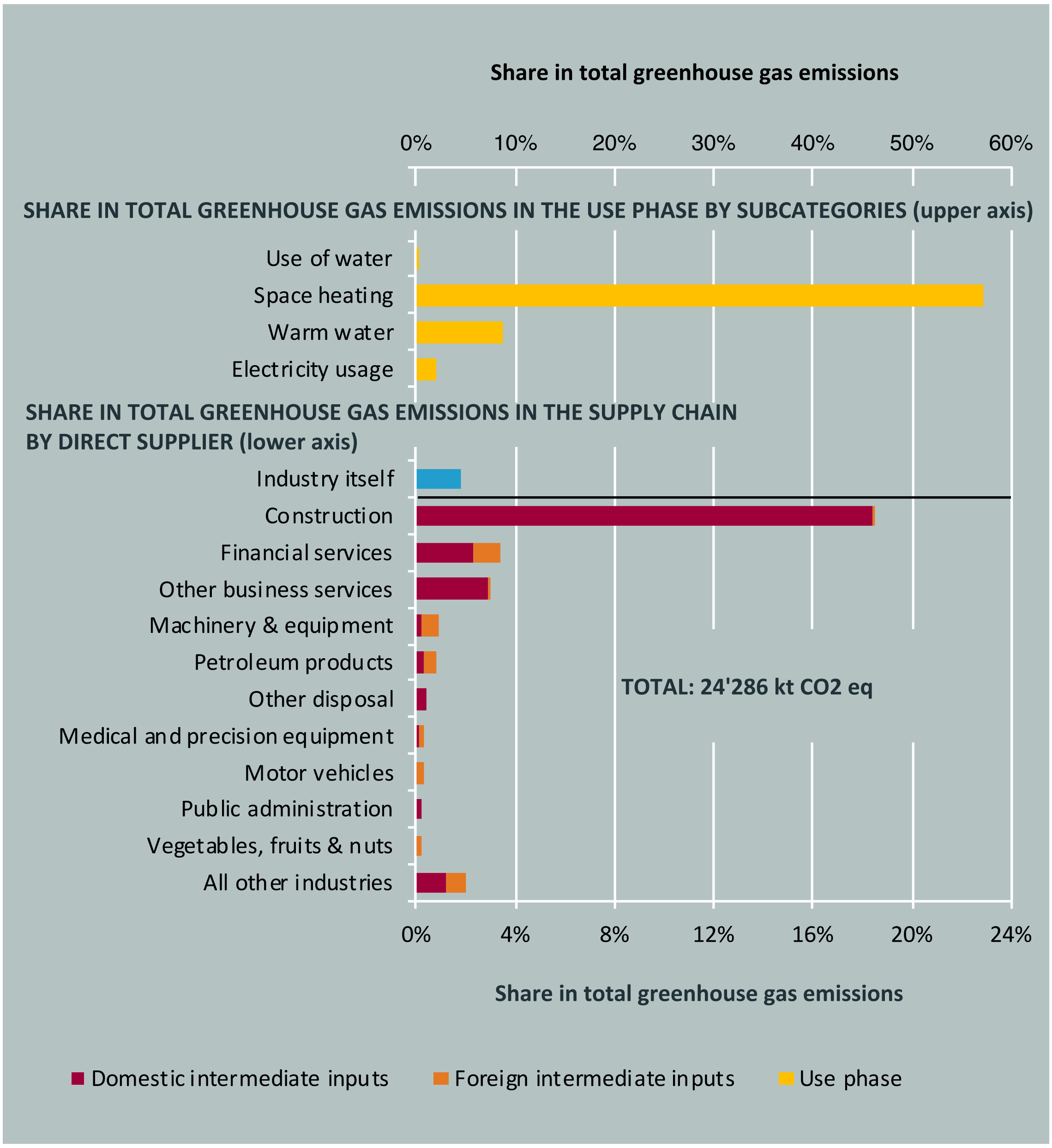

Figure 4.34: Greenhouse gas footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry 'Real estate services' (Source: Calculations Rütter Soceco)

4.5.3.3 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

For the biodiversity, the water and the eutrophication footprint raw material supply and particularly agriculture are predominant. However, for both the biodiversity as well as the eutrophication footprint, the largest shares are caused by other industries: Forestry in the case of the biodiversity footprint and disposal activities in the case of the eutrophication footprint.

The air pollution footprint on the other hand, is mainly caused in Basic metals, electricity generation from fossil fuels, other non-metallic minerals. A non-neglectable share is also to be attributed to the construction industry which is the main direct supplier for real-estate services.

With regard to the country distribution it catches the eye that Switzerland is predominant in all the environmental footprints with exception of the water footprint, which is dominated by China followed by India. However, Switzerland still enters the top ten countries also for the water footprint.

In addition to Switzerland important shares of the different footprint are caused by the following countries: Indonesia and Brazil for the biodiversity footprint, China and Germany for the air pollution and the eutrophication footprint.

For all the environmental footprints more the 25 % are directly connected with the most important direct supplier of the real estate industry: Construction.

4.5.3.4 Environmental footprint according to the ecological scarcity method

The total environmental footprint of the industry ‘Real estate services’ is 26’605 billion eco-points (UBP), of which only 9’785 billion eco-points (37 %) are caused by the supply chain (see Figure 4.35). The annual environmental impacts caused by the energy demand during the use of residential buildings amount to 16’820 billion eco-points and exceeds that of the total industry with its supply chain by about 50 %. With nearly 80 % the biggest contribution to the environmental footprint of the use phase stems from space heating.

Within the supply chain, more than 70 % of its environmental footprint are caused by imported goods. Of this, 44% is due to imports into the ‘Construction’ industry. The foreign share of the environmental impacts is mainly due to imports of energy carriers (electricity and fossil fuels) and metals. The remaining Swiss suppliers cause 18 %, the direct Swiss suppliers 8 % and the industry itself only 2 % of the total environmental footprint of the real estate services. The ‘Construction’ industry thereby accounts for 72 % of the other suppliers and 50 % of the direct suppliers. In total, the ‘Construction’ industry contributes 61 % to the environmental footprint of the industry ‘Real estate services’.

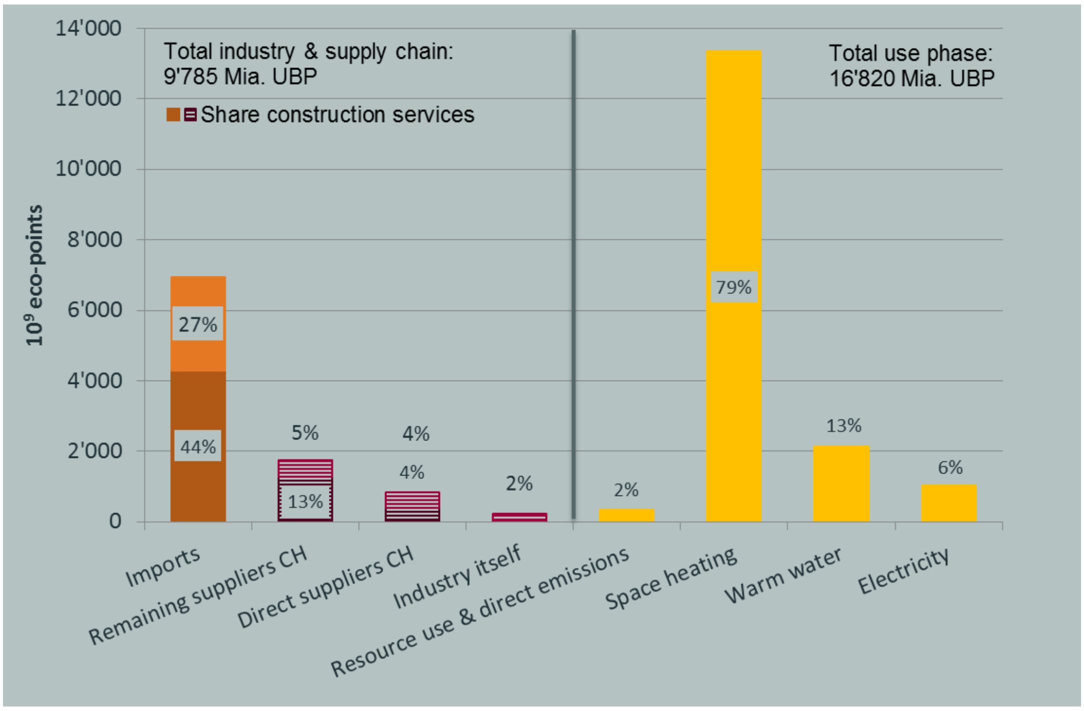

Figure 4.35: Environmental footprint in eco-points (UBP) caused by the industry 'Real estate services' and the contribution of the 'Construction' industry by supply chain stages and imports (Source: Calculations treeze)

The biggest contribution to the environmental footprint (in UBP) of the industry 'Real estate services', including the direct suppliers of the 'Construction' industry, comes from the Swiss industry 'Other business services'. It contributes 10 % to the total environmental footprint (Figure 4.36). The biggest contributor the environmental impacts of the industry 'Other business services' are the disposal services, publishing and printing products used (paper production, especially energy consumption), the electricity use of this industry, the impacts of membership organizations (construction and disposal services, electricity) as well as the direct emissions of the 'Construction' industry (mainly CO_2 and nitrous oxide).

Nearly 9 % of the environmental footprint stem from the disposal services directly supplied to the real estate services (i.e. disposal of wastes generated during building and maintenance of the buildings). 60 % of the environmental footprint of this industry is due to direct emissions, above all nutrient releases (nitrogen, phosphorus) and heavy metal emissions into water bodies, carbon stored in landfills and dioxin emissions into air.

A bit more than 7 % from the total environmental footprint come from the 'Other non-metallic mineral products'. This industry is a supplier to the construction industry and comprises e.g. cement production. The biggest contributors to its environmental footprint are its direct emissions (above all CO_2-emissions and release of other air pollutants such as heavy metals, nitrogen oxides and particulates) and its energy needs (electricity, petroleum products).

The 'Financial services' contribute another 7 % to the total environmental footprint of the 'Real estate services'. Main contributors here are 'Construction', 'Renting and other business services' as well as the electricity use.

The 'Metal products' and the direct emissions of the 'Construction' industry itself contribute each about 4 % to the total environmental footprint of the 'Real estate services'. The environmental footprint of the 'Metal products' occurs mainly abroad and is due to the import of iron and steel as well as non-ferrous metals. The most important direct emissions from the construction industry are carbon dioxide, nitrogen oxides, particulates, chlorofluorocarbons and non-methane volatile organic compounds (NMVOC).

Other more minor contributions stem from the 'Manufactures of metals', 'Wood and wood products', 'Petroleum and petroleum products' as well as 'Computer and electrical equipment'.

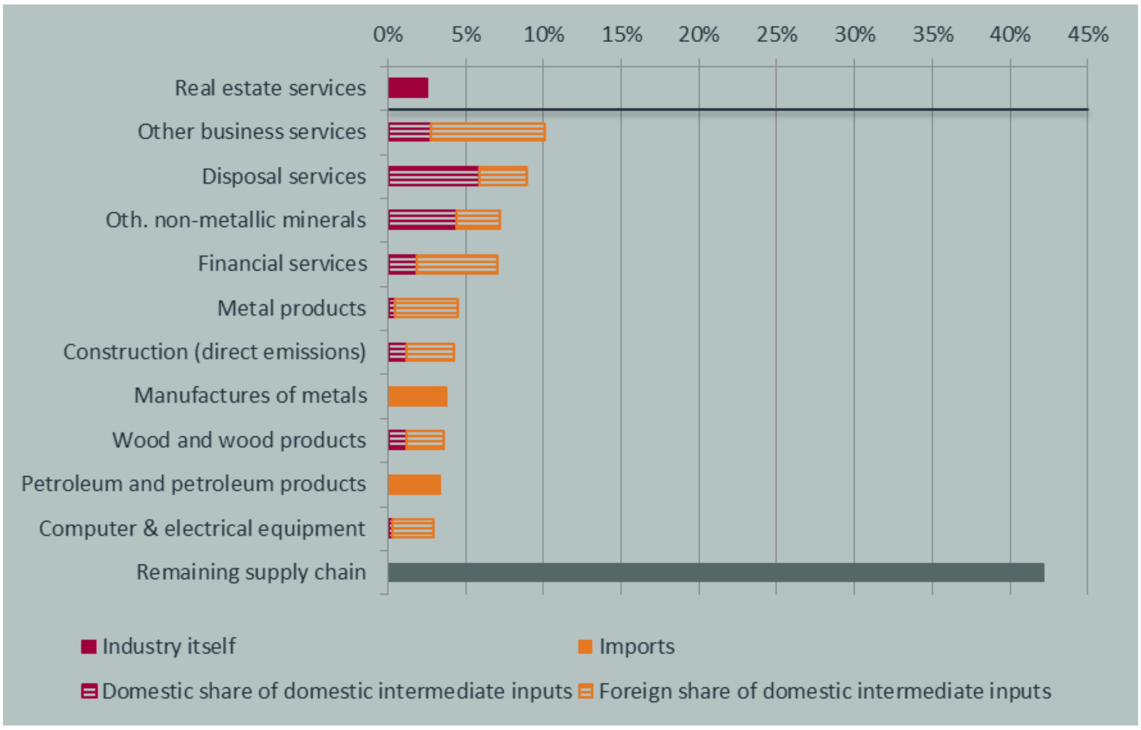

Figure 4.36: Environmental footprint caused by the direct suppliers of intermediate goods and services for the Swiss industries 'Construction' and 'Real estate services'. Remaining supply chain = all other direct suppliers (Source: Calculations treeze)

4.5.3.5 Spotlight on the environmental impacts of the construction industry

The construction industry is one of the main suppliers to the real estate services industry and an important contributor to the supply chain environmental impacts of that industry. But the construction industry is also active in other areas. It constructs buildings for customers outside the real estate services industry (e.g. companies owning their own real estate) and it constructs civil engineering structures. In the following we briefly summarise the environmental impacts of the construction industry and its supply chain.

Table 4.12 gives an overview of the environmental footprints of the Swiss construction industry. The comparison with the results for the Swiss real estate industry (Table 4.11, column 'production') show that the construction industry's footprints are larger, even though the value added induced by Swiss construction is significantly lower. The greenhouse gas, biodiversity, water, air pollution and total environmental footprints of the construction industry are almost double as large as those of the real estate services industry (without the use phase). The eutrophication footprint is 50 % larger. The table also displays that the environmental intensities per unit of output or value added are significantly higher. These results show that the construction industry is the environmentally most relevant supplier to the real estate services industry, but also a relevant industry in its own right.

Table 4.12: Environmental footprints caused by the Swiss construction industry (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Per M CHF gross output	Per M CHF gross value added
Greenhouse gas footprint	kt CO_2 eq	14'853	0.25	0.55
Biodiversity footprint	nano PDF*a	11'079	0.18	0.41
Water footprint	Mm3	3'372	0.06	0.12
Air pollution footprint	t PM10 eq	29'638	0.49	1.09
Eutrophication footprint	t N eq	9'361	0.15	0.35
Environmental footprint	G-eco Pt.	20'280	0.34	0.75
Gross output (industry itself)	M CHF	60'409		
Gross value added (industry itself)	M CHF	27'115		

4.5.3.6 Conclusion

The lion's share of the environmental impacts of the real estate services industry is generated during the use of the buildings. This is mainly due to the consumption of fossil heating fuels and the electricity requirements for lighting and climate control systems.

Within the supply chain, the 'construction' industry is the biggest contributor the greenhouse gas and the total environmental footprint of the Swiss industry 'real estate services'. For both indicators, the construction industry accounts for about 60 % of the impacts. Besides 'construction', also 'other business services' as well as 'financial services' make a substantial contribution to the greenhouse gas and the total environmental footprint of the Swiss 'real estate services' industry, with 'financial services' being more important for the greenhouse gas footprint and ‘other business services’ for the total environmental footprint.

Via ‘construction’, various building materials such as non-metallic minerals, metal and wood products as well as petroleum products contribute to the environmental impacts of ‘real estate services’. Besides, also disposal plays a role for the total environmental footprint and to a minor extent also for the greenhouse gas footprint of this.

For both indicators only more than a quarter of the emissions are generated in Switzerland.

4.5.4 Comparison with the planetary boundaries

Figure 4.37 shows the share of the environmental footprints including the use phase (in parts per million, ppm) of the Swiss industry ‘Real estate services’ in the respective global environmental footprints as well as the relative reduction needs (for the definition of the reduction needs, see chapter 2.5). Of the environmental impacts analysed, the Swiss real estate services contribute most to the greenhouse gas footprint. The second largest contribution is to the air pollution footprint. For those two indicators, the industry’s shares in the global environmental impacts exceed its share in global gross production value. For the eutrophication and the biodiversity loss footprints, the industry’s shares in the global footprints are lower than its share in global gross production value.

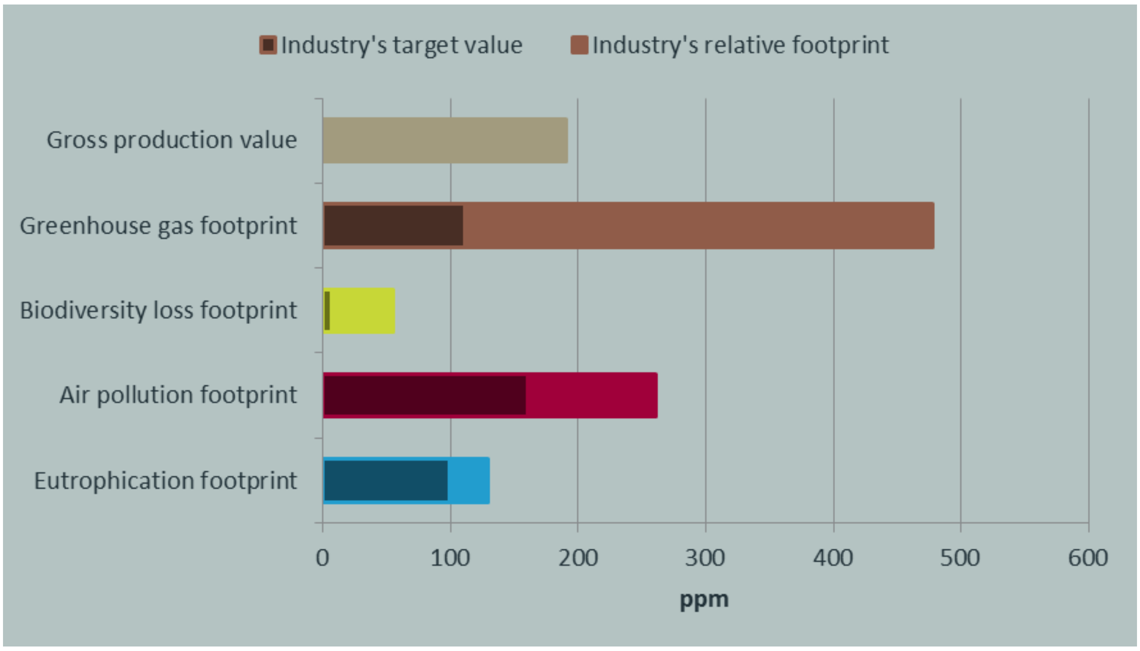

Figure 4.37: Share of environmental footprints caused by the Swiss industry ‘Real estate services’ in global environmental footprints and respective planetary boundaries (Source: Calculations treeze).

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, the greenhouse gas footprint is the priority field of action for the Swiss industry ‘Real estate services’, followed by the air pollution footprint.

Table 4.13 shows the water footprint of the industry ‘Real estate services’, differentiated after country, and the share of renewable water supply used in the respective country (see chapter 2.5.3). 23 % of the water footprint of the industry ‘Real estate services’ occurs in China, where nearly 20 % of the renewable water supply is already used. In India, where 8 % of the water footprint of the industry ‘Real estate services’ takes place, 37 % of the renewable water supply is used. Also in Italy, Spain and South Africa, where a smaller part of the water footprint of the Swiss industry ‘Real estate services’ occurs, more than the sustainably usable share (20 %, see chapter 2.5.3) of the renewable water supply is used. Aiming at reducing the water footprint of the Swiss industry ‘Real estate services’, these are the countries where an emphasis should be put on.

Depending on the region from which an imported product stems, water consumption can also be problematic in a country where the country-wide average for sustainable use is not exceeded. This could be the case for the USA and Turkey, for example, where the sustainably usable share is almost reached. These countries should therefore also be taken into account when developing measures to reduce the water footprint.

Table 4.13: Water footprint of the Swiss industry ‘Real estate services’ differentiated after country and share of renewable water supply used in the respective countries

Country	Share of renewable water supply used	Water footprint of ‘Real estate services’ [Mm^3]	Share of total water footprint of the industry ‘Real estate services’
China	20%	426	23%
India	37%	152	8%
United States	16%	101	6%
Italy	24%	81	4%
Spain	29%	42	2%
Turkey	17%	30	2%
Switzerland	5%	22	1%
Greece	13%	19	1%
Australia	5%	14	1%
South Africa	25%	12	1%
Remaining countries and unspecified regions		923	51%

4.5.5 Measures for reducing environmental impacts

4.5.5.1 Focal areas for measures

Use phase (13-68 % of footprints)

As the energy use during use phase contributes most to the annual greenhouse gas, air pollution and environmental footprint of the real estate services, the improvement of the energy efficiency of the buildings is a central field of action. The industry has a great influence in this respect; especially on the main contributor space heating. Through better isolation less energy is needed. The remaining energy demand should be covered by renewable energy sources (e.g. solar power, geothermal energy, etc.). Frischknecht et al. (2018), for example, have shown that changes in living habits can reduce the greenhouse gas footprint per person by up to almost 10%.

Also for the water footprint, the use phase is the most important contributor. Here it is important to install household appliances that save as much water as possible.

Supply chain (32-77 % of footprints)

Within the supply chain, the construction industry is the most important contributor to the environmental footprint of the industry 'real estate services'. Cement production is a crucial area to be addressed. This includes above all the energy consumption and the associated emissions of this industry. Also the direct emissions of the construction services themselves are not negligible and are mostly due to the use of fossil fuels.

Another important focal area are the disposal services. Release of nutrients and other pollutants to the environment have to be further minimized. This is best done by avoiding waste generation (durable materials, reuse, recycling). If wastes are generated, they have to be properly treated and the release of harmful substances has to be minimized.

Also for the materials and products used in construction (especially metal products, rubber and plastics, wood and wood products as well as machinery and electrical industry), it is important to minimize their environmental footprint. This can be achieved by implementing a sustainable supply chain management (consideration of ecological criteria in procurement, e.g. by including environmental issues in framework agreements or a supplier code, anchoring of environmental topics in regular target discussions with suppliers or implementation of joint projects to identify suitable solutions for improvements). Another possibility is the use of recycled materials whenever possible.

4.5.5.2 Monitoring parameters

- Heating requirements per square metre of building area
- Electricity needs per square metre of building area
- Amount of fossil energy used for heating and cooling of buildings
- Amount of recycled materials used in the construction industry

- Amount of fossil fuels used in the construction industry
- Amount of correctly treaded disposal resp. amount of recycled disposal
- Share of buildings built considering ecological criteria (according to agreements with producer, certification schemes, collaboration with producers etc.)
- Proportion of total energy reference area accounted for by certified, ecologically exemplary building area . The area of buildings meeting the Minergie standards® is already surveyed[28]. This indicator is planned be further developed in the near future by accounting separatly for the advanced sustainability label SNBS.

4.5.5.3 Instruments and guidelines

- Sustainable Construction:
  - Netzwerk nachhaltiges Bauen Schweiz: https://www.nnbs.ch/
  - https://www.kbob.admin.ch/kbob/de/home/publikationen/nachhaltiges-bauen.html
  - http://www.brenet.ch/
- Life cycle assessment data in the construction industry:
  - KBOB-list: https://www.kbob.admin.ch/kbob/de/home/publikationen/nachhaltiges-bauen/oekobilanzdaten_baubereich.html
  - Environmental product declarations: http://www.environdec.com/
- Sustainability standards and labels for buildings:
  - Standard nachhaltiges Bauen Schweiz (SNBS): www.snbs.ch
  - Breeam: http://www.breeam.com/
  - German Sustainable Building Council (DGNB): http://www.dgnb.de/en/
  - LEED Green Building Rating System: https://new.usgbc.org/leed
  - Minergie-Eco: https://www.minergie.ch/de/zertifizieren/eco/
  - Overview of existing labels: http://www.ecolabelindex.com/ecolabels/?st=category,buildings / Land-karte Standards und Labels (see www.nnbs.ch or info@nnbs.ch for or-ders)
- Energy labels for buildings:

[28] wirtschaft-und-konsum--daten--indikatoren-und-karten/wirtschaft-und-konsum--indikatoren/indikator-wirtschaft-und-konsum.pt.html

  - Overview of existing building standards in Switzerland: https://www.energiestiftung.ch/energieeffizienz-gebaeudestandards.html
  - Minergie: https://www.minergie.ch/
  - Passivhaus: http://www.passiv.de/
- Swiss Competence Center for Energy Research on Future Energy Efficient Buildings & Districts (SCCER FEEB&D): http://www.sccer-feebd.ch/
- Information on energy efficiency and renewable energies: https://www.energie-cluster.ch/

4.6 Health and social work

4.6.1 Introduction

The industry 'Human health, veterinary and social work'[29] includes the following activities according to the respective NOGA definition:

- activities of hospitals,
- activities of medical and dental practices,
- other human health activities (midwifes, physiotherapists, chiropractic etc.),
- veterinary activities,
- social work activities with accommodation (orphanages, children's boarding hoes and hostels, homes for the aged etc.),
- social work activities without accommodation (e.g. crèches and day nurseries, day homes for the handicapped, charity care institutions and other social work activities).

The Swiss health, veterinary and social work industry (subsequently referred to as health and social work industry) is large in terms of workforce. In 2015 the industry employed 492'004 people (FTE) of which approximately 60 % in the health- and 40 % in the social work area. This corresponds to 12 % of the entire Swiss workforce. Apart from being one of the largest Swiss industries, the health and social work industry is growing well above average. Employment increased between 2011 and 2015 by 3.7 % per year on average, while the entire Swiss workforce grew by 1 % per year (see Table 4.14).

[29] Code 85 according to NOGA 2002, Code 86-88 according to NOGA 2008; in NOGA 2008 veterinary activities are excluded

Table 4.14: Employment in the health and social work industry (Source: FSO – STATENT).

Year	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	425'992	11.1%		
2015	492'004	12.3%	3.7%	1.0%

4.6.2 Economic impact

The total value added induced by the Swiss health and social work industry amounts to 60’485 Mio. CHF[30]. Figure 4.38 shows how it is distributed across the different supply chain stages. The largest share is generated by the health and social work industry itself (56 %). While the ‘direct suppliers’ (e.g. suppliers of pharmaceuticals or medical technology; 16 %) and the supply chain stages ‘remaining upstream chains’ (26 %) are also accountable for substantial value added shares, the relevance of raw material extracting industries (2 %) is almost negligible.

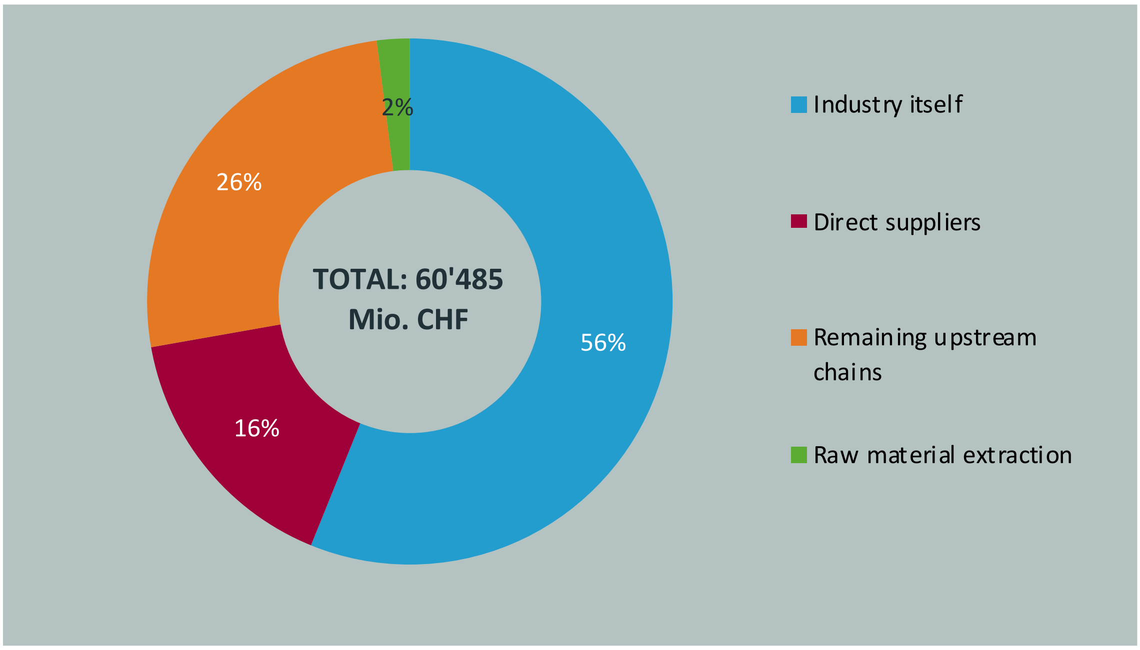

Figure 4.38: Total gross value added induced by the Swiss industry ‘Health and social work’, differentiated by supply chain stages (Source: Calculations Rütter Soceco)

[30] These and the following economic data refer to the year 2008.

In order to understand where - in geographical terms – the value added induced by the Swiss health and social work industry is generated, Figure 4.39 shows the shares of induced value added differentiated by countries and supply chain stages.

The upper section of the figure displays the share of value added generated by the industry itself (56 %) as well as the shares generated within domestic (27 %) and foreign (17 %) supply chains. Slightly more than half of the value added generated within the supply chains is created in Switzerland while the rest is created abroad.

Within the Swiss supply chains, the shares of value added generated by direct suppliers and industries in the remaining upstream chains are of similar size, whereas in the foreign supply chains the share of the direct suppliers is substantially lower. The share of value added in raw material extraction industries is mainly induced abroad.

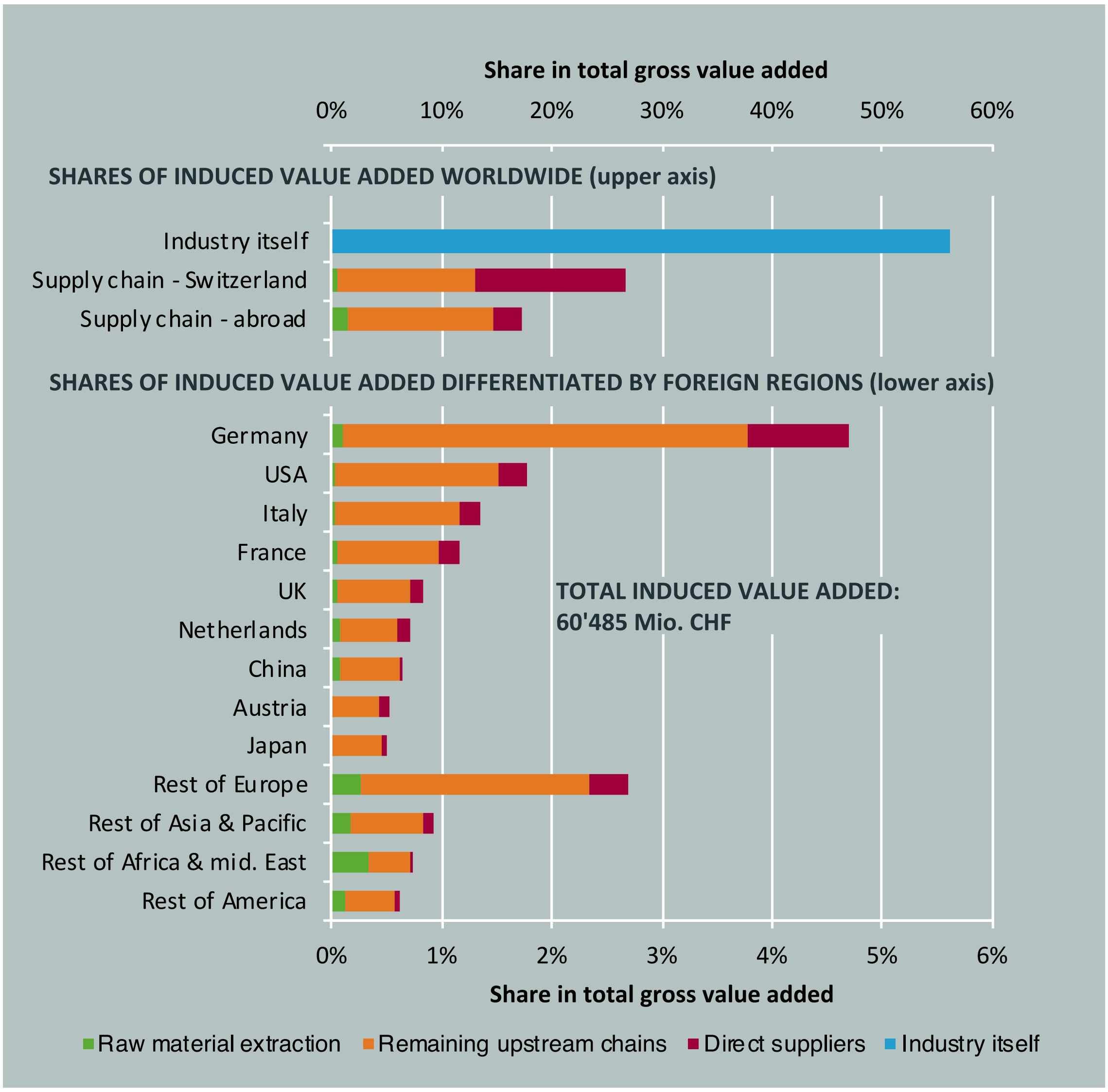

Figure 4.39: Total gross value added induced by the Swiss industry 'Health and social work', differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

The lower part of Figure 4.39 displays the share of foreign countries in the total value added generated by the health and social work industry (lower scale). Germany takes the largest share with 4.5 %, followed by the US and various European countries with shares between 0.5 % and 2 %. China and Japan are the only non-European countries among the top ten. Countries outside the top ten hold a share of 5 % in total value added. In terms of supply chain stages, intermediate suppliers between raw material extraction and direct suppliers dominate the foreign parts of the supply chain. Value added from raw material extraction is located outside Switzerland and for a large share also outside Europe.

4.6.3 Environmental impacts

4.6.3.1 Overview

Table 4.15 contains an overview of the total environmental footprints caused by the Swiss health and social work industry. On the one hand the footprints are reported in absolute terms, on the other hand as intensities in relation to gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

Table 4.15: Environmental footprints caused by the Swiss industry 'Health and social work' (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Per M CHF gross output	Per M CHF gross value added
Greenhouse gas footprint	kt CO_2 eq	8'290	0.16	0.24
Biodiversity footprint	nano PDF*a	9'302	0.17	0.27
Water footprint	Mm^3	3'229	0.06	0.10
Air pollution footprint	t PM_{10} eq	15'345	0.29	0.45
Eutrophication footprint	t N eq	12'119	0.23	0.36
Environmental footprint	G-eco Pt.	12'887	0.24	0.38
Gross output (industry itself)	M CHF	53'414		
Gross value added (industry itself)	M CHF	33'959		

Aiming to understand the supply chain stages in which the different environmental impacts take place, Figure 4.40 displays the share of supply chain stages in total impact as well as the share of the industry in the global impact for each footprint apart from the total environmental footprint (and value added/gross production value for comparison reasons).

It has to be borne in mind that only the production of the medicaments used in hospitals and other medical practices, but not the production of the medicaments used in private households is included in this industry. The impacts of the use of medicaments (e.g. release to the environment through waste water streams) are not considered.

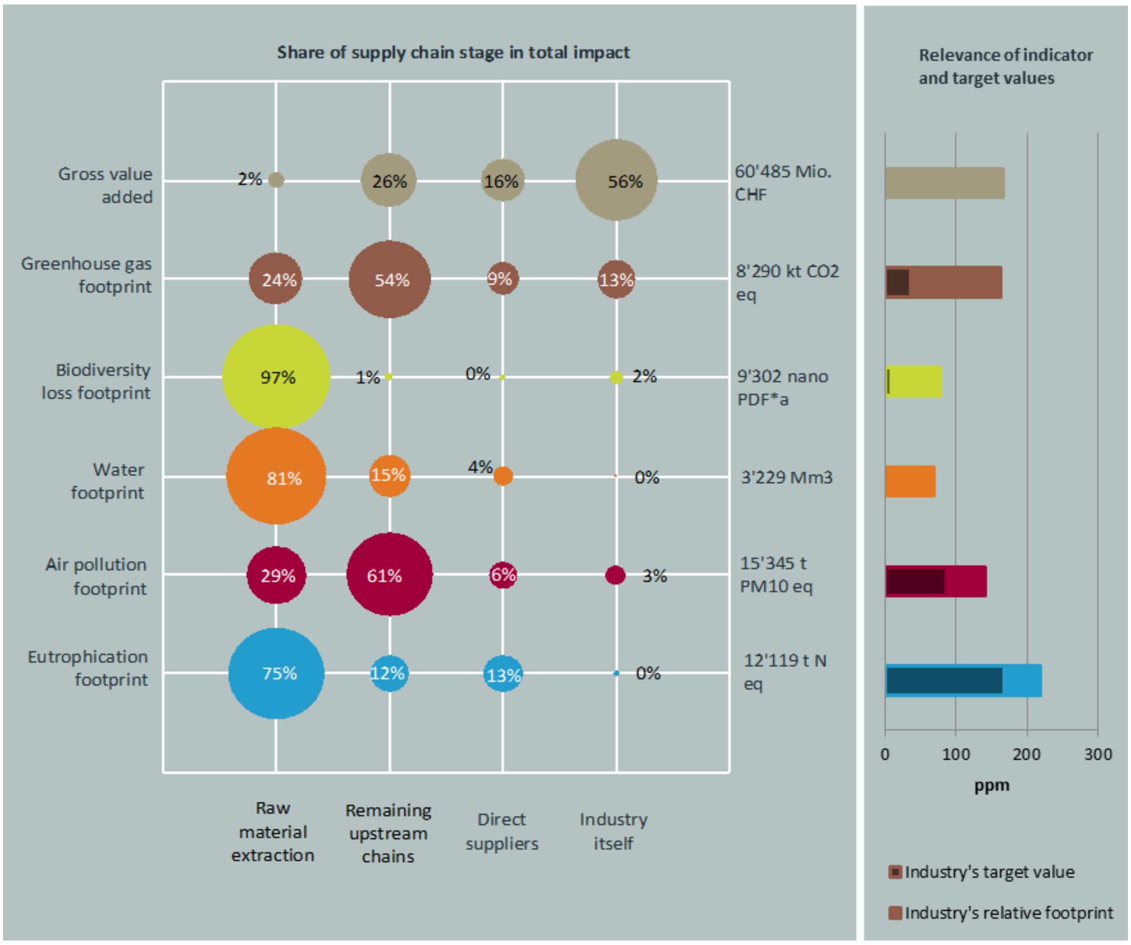

Figure 4.40: Environmental footprints caused by the Swiss industry ‘Human health and social work’ by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

This figure shows that for the biodiversity footprint (97 %), the water footprint (81 %) and the eutrophication footprints (75 %) most of the impact stem from raw material extraction while the other stages are of substantially less significance. For the greenhouse gas footprint as well as for the air pollution footprint on the other hand, the largest pollution shares are caused by industries between raw material extraction and direct suppliers, termed remaining upstream chains (55 % resp. 61 %).

The only footprint for which also the industry itself causes a significant share of the impact is the greenhouse gas footprint (13 %). For all the other footprints the emissions of the Swiss health and social work industry itself are of negligible size.

In terms of supply chain stages at which they take place an interesting insight arises from the divergence between the environmental footprints and value added: while the largest fraction of value added is created in the Swiss health and social work industry itself, this stage is almost of negligible size for most of the environmental pollutions. On the other hand, most of the environmental pollutions take place in early stages of the supply chain such as raw material extraction and remaining upstream chains. The share of value added created in these stages by contrast is of significantly lower magnitude.

Most relevant for the health industry is the eutrophication footprint (see Figure 4.40; share of the respective footprint in the global footprints compared to the share of the gross production value of the health industry in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.6.4.

4.6.3.2 Focus on greenhouse gas emissions

The focus footprint chosen for the Swiss health and social work industry is the greenhouse gas footprint, since this is the industry's highest ranking footprint (cf. Table 3.2). As seen in Figure 4.20 the global amount of greenhouse gas emissions induced by the health and social work industry in Switzerland adds up to 8'290 kt CO_2 eq.

Figure 4.41 highlights which industries (aggregated over all countries) emit the greenhouse gases which are caused by the Swiss health and social work industry. The largest emitter is the industry 'electricity from fossil fuels' which is accountable for 14 % of the global greenhouse gas emissions induced by the Swiss health and social work industry. Next follow 'mining and quarrying' (13 %) and the health and social work industry itself (12 %) with similar emission shares. Other important supply chain industries in terms of greenhouse gas emissions are 'cattle and milk' due to in-house catering services for patients in hospitals and elderly home inhabitants, basic metals and non-metallic minerals used for construction activities as well as the chemical industry, that supplies pharmaceuticals to the Swiss health and social work industry. Industries not mentioned in the top ten still have a share of almost 30 % of the greenhouse gas footprint.

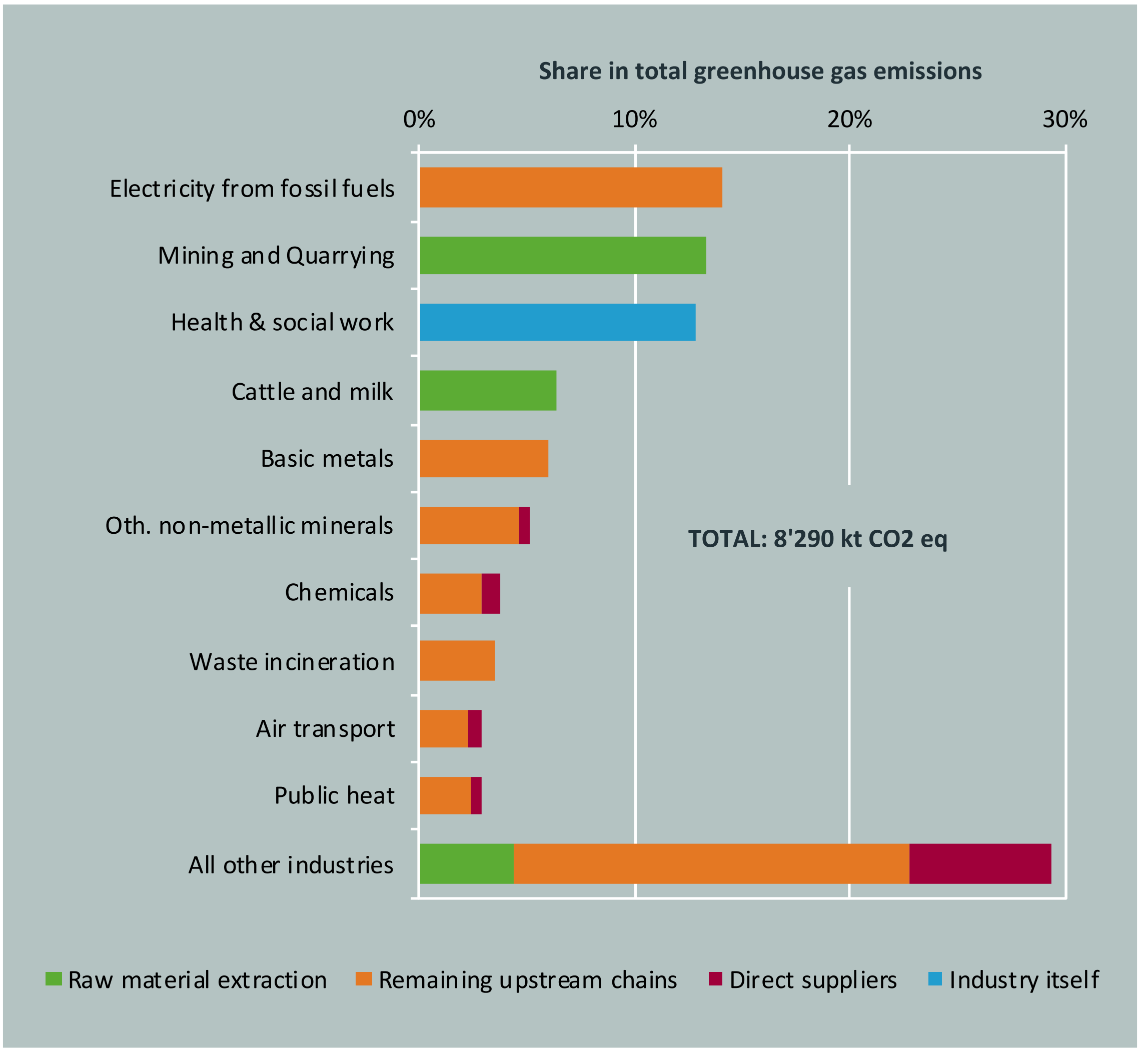

Figure 4.41: Greenhouse gas footprint caused by the industry 'Health and social work' by supply chain stage and supplying industries (Source: Calculations Rütter Soceco)

Figure 4.42 illustrates how the responsible companies are distributed across supply chain stages and countries. The diagram shows that 32 % of the footprint are due to emissions in Switzerland (13 % by the industry itself and 19 % by Swiss supply chain industries) while the remaining emissions take place abroad.

The country differentiation of greenhouse gas emissions reveals China, Germany, Russia and the US to be the largest foreign polluters in the context of the supply chains of the Swiss health and social work industry. In comparison to the value added distribution across countries (see Figure 4.42) China and Russia are ranked much higher when measuring in greenhouse gas emissions. This is due to the (in average) higher greenhouse gas emission intensities in those countries when compared to western countries such as Germany or the US. In the foreign countries most of the emissions stem from intermediate and raw material suppliers.

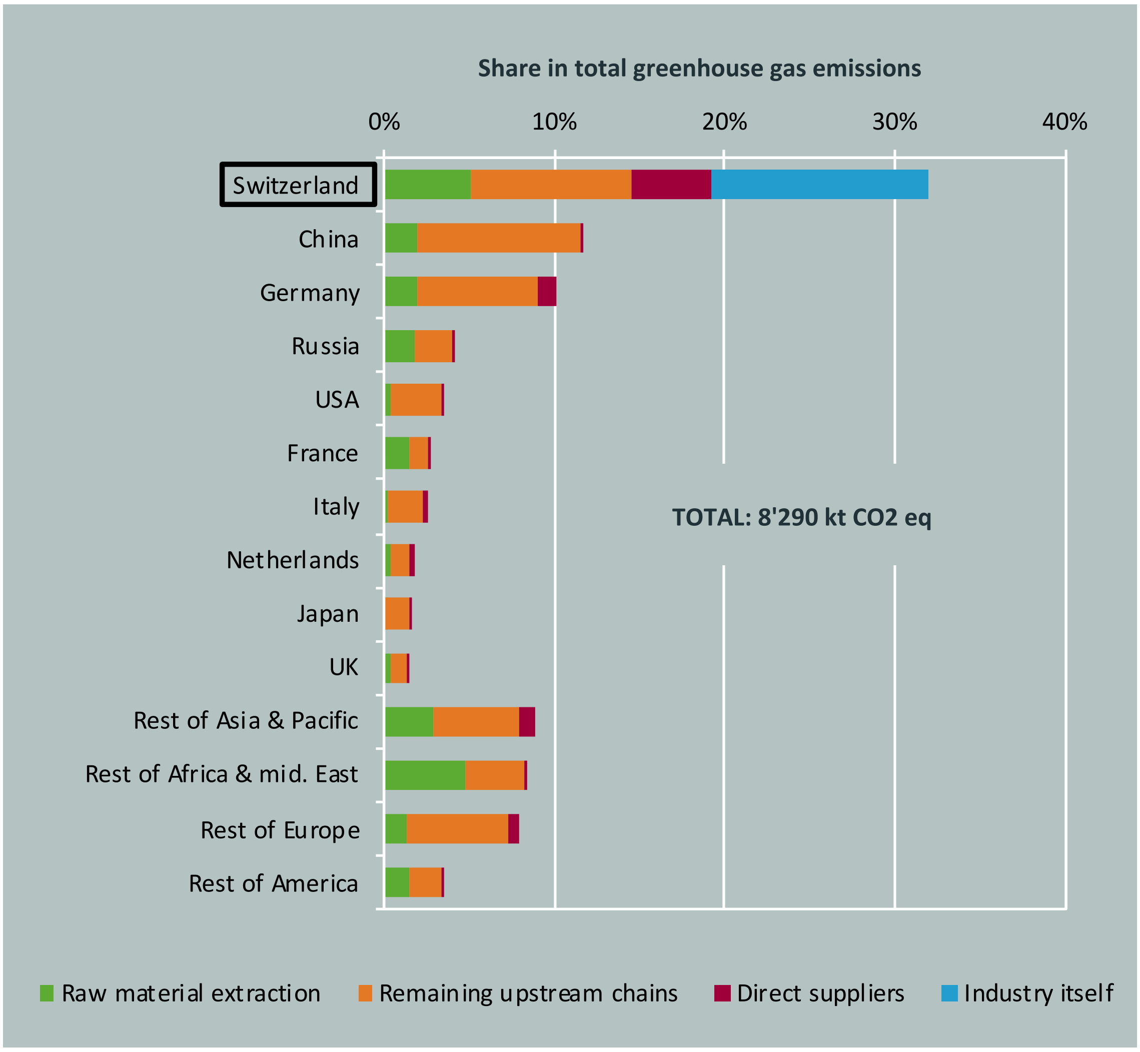

Figure 4.42: Greenhouse gas footprint caused by the Swiss industry 'Health and social work', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

From a practical point of view it is useful to understand which direct intermediate inputs purchased by the Swiss health and social work industry are responsible (at what extent) for the total greenhouse gas emissions caused by the industry within the supply chains. This allows the companies to identify, which of their suppliers they should access with which priority in order to optimise the environmental performance of their supply chain. The analysis presented in Figure 4.43 allocates the greenhouse gas emissions caused by the Swiss health and social work industry within the supply chain to domestic and foreign direct suppliers. For reasons of comparison the share of health and social work ('industry itself') is also included.

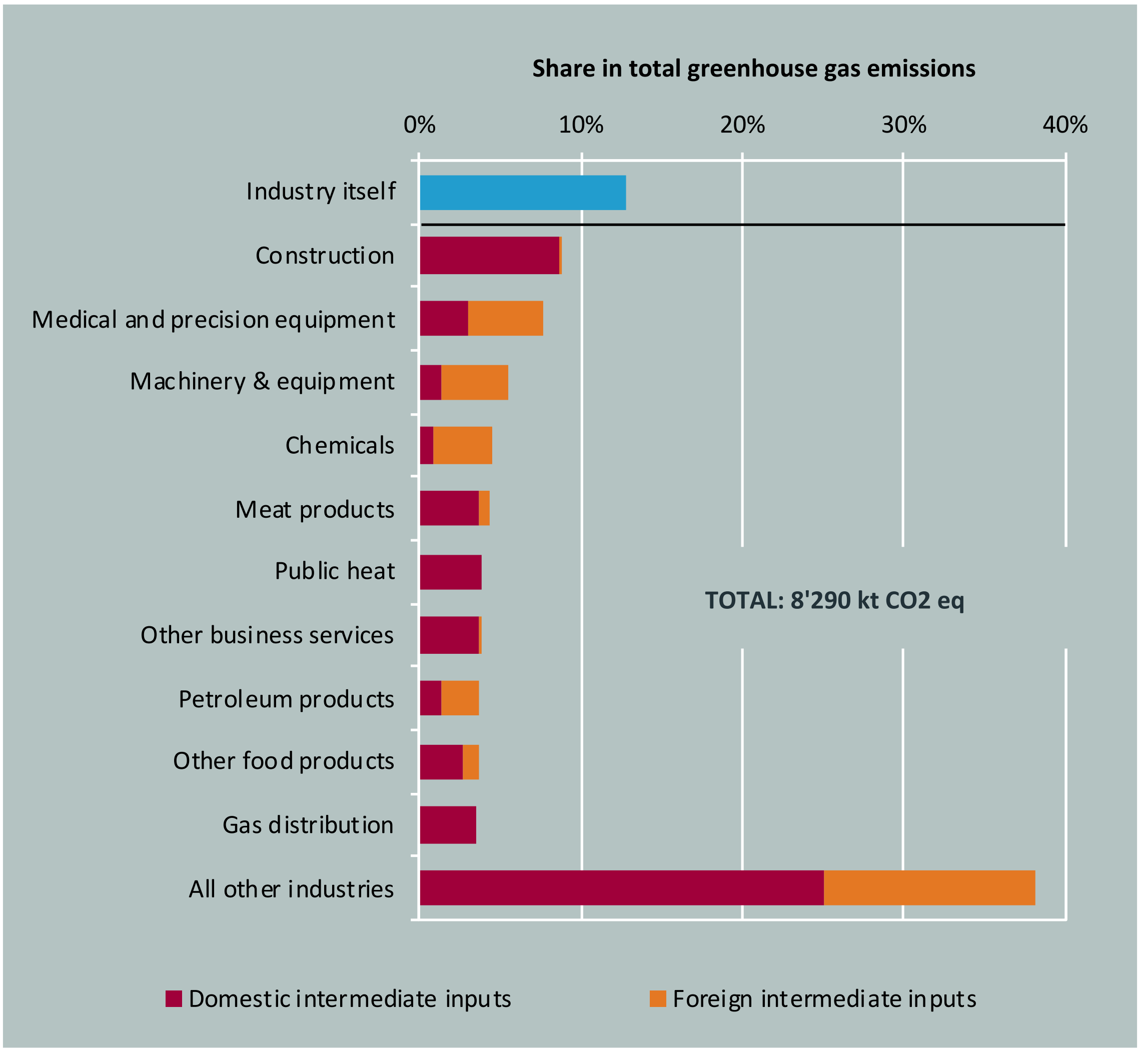

Figure 4.43: Greenhouse gas footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry 'Health and social work' (Source: Calculations Rütter Soceco)

The results show that many suppliers with small shares each are relevant and that the health and social work industry is a capital intensive business. Some of the most important direct suppliers are linked to investment expenditures of the health and social work industry, i.e. construction with a share of 8 % of the total greenhouse gas footprint and 'machinery and equipment' with a share of 5 %. Medical and precision equipment and chemicals supplying pharmaceuticals refer to medical suppliers. Meat and other food products account for almost 10 % of the greenhouse gas footprint. Energy carriers (public heat, petroleum products and gas) are also relevant. Other direct suppliers that are not in the top ten, are responsible for almost 40 % of the total footprint.

4.6.3.3 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

For the biodiversity, the water and the eutrophication footprint raw material supply and particularly agriculture are predominant. However, for these footprints other industries are also responsible for important fractions of the respective footprints: e.g. forestry for the biodiversity footprint, chemicals and basic metals for the water footprint and disposal activities for the eutrophication footprint.

The air pollution footprint is mainly caused in the basic metals industry, electricity generation from fossil fuels, water transport, but also in agriculture due to food supply to persons employed in the global supply chains.

The look to the country distribution of the footprints reveals that Switzerland is ranked first in the biodiversity, the air pollution and the eutrophication footprint. In addition to Switzerland important shares are caused by Indonesia and Brazil for the biodiversity footprint, China and Germany for the air pollution and the eutrophication footprint. The water footprint takes place mostly in China, India, USA, Italy and Spain, whereas Switzerland is ranked sixth with a substantially lower share than those countries.

4.6.3.4 Environmental footprint according to the ecological scarcity method

The total environmental footprint of the industry 'Health and social work' according to the method of ecological scarcity (Frischknecht & Büsser Knöpfel 2013) is 12'894 billion eco-points. 70 % of it are caused by imported goods (Figure 4.44). The industry itself generates only 5 % of its total footprint, with fossil CO_2-emissions being the main contributor. Another 5 % stem from domestic direct suppliers and 20 % are caused by the remaining suppliers in Switzerland.

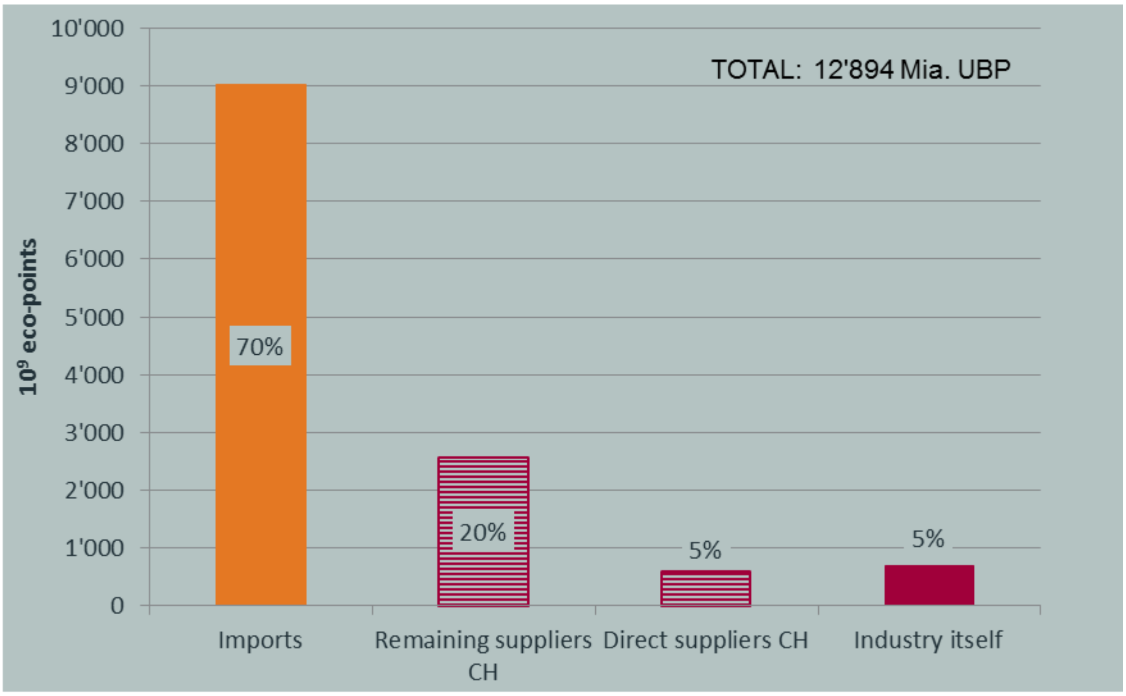

Figure 4.44: Environmental footprint in eco-points caused by the industry 'Health and social work' by supply chain stages and imports (Source: Calculations treeze)

The ten most important contributors explain just about half of the total environmental footprint of the health industry. 11 % of it is caused by the 'Electricity distribution' (Figure 4.45). These impacts mainly stem from the electricity from Swiss and foreign nuclear power plants and imported electricity from coal power plants. 7 % is related to 'Construction' (see chapter 4.5.3). The next important contributing industry is the 'Disposal services', followed by 'Meat products', 'Dairy products' and 'Coffee, tea, cocoa, spices etc.'. The last three industries deliver the food consumed in hospitals and homes for the elderly. In total, the food consumed in hospitals and other health and social work facilities causes 30 % of the total environmental footprint of this industry.

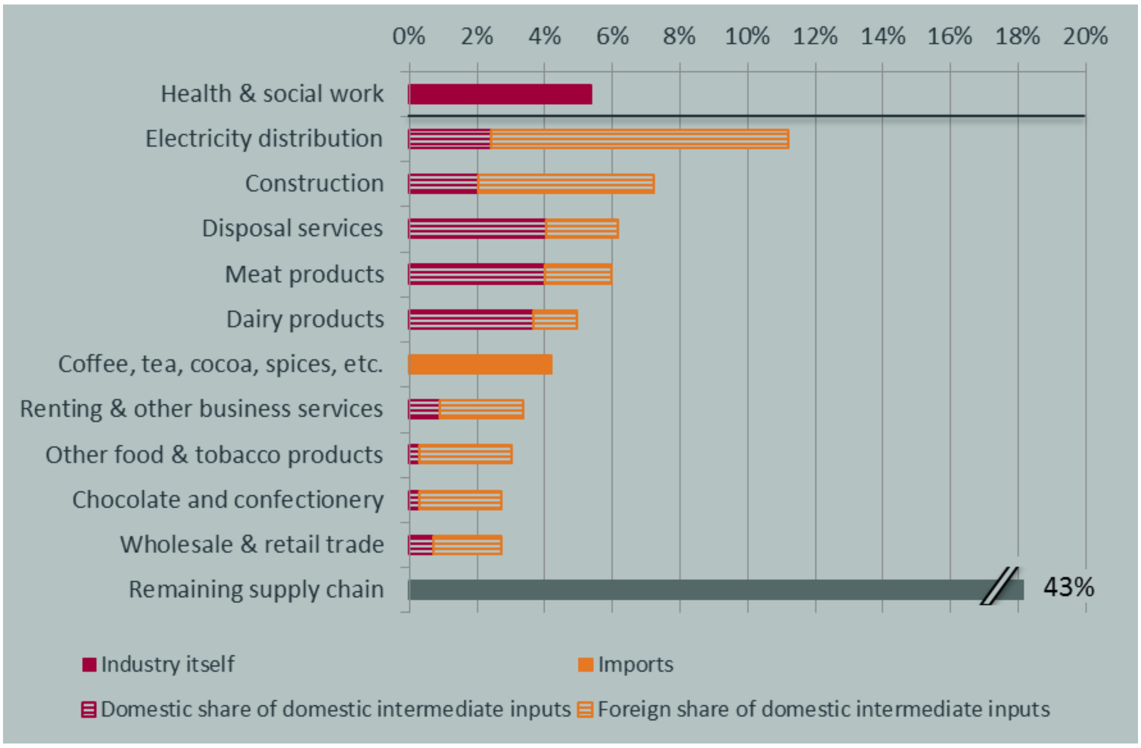

Figure 4.45: Environmental footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry 'Health and social work'. Remaining supply chain = all other direct suppliers (Source: Calculations treeze)

4.6.3.5 Conclusion

The supply chain of the 'Health and social work' industry is highly diversified and the emissions are distributed to a large number of supplying industries. For the total environmental footprint, the electricity used is the most important contributor, followed by 'construction' and 'disposal services'. The remaining of the ten most important direct suppliers are almost all linked to the food consumed in the health industry, with meat, dairy products and coffee/cocoa being the foods with the highest contribution.

Due to the low greenhouse gas emissions of the Swiss electricity mix, the 'electricity distribution' is not among the ten most important contributors for the greenhouse gas footprint. Here, 'construction' is most important, followed by 'medical and precision instruments', 'machinery & equipment' and 'chemicals'. Also here food products show up, namely 'meat products' and 'other food products'. Besides, heat supply is an important contributor to the greenhouse gas footprint of the health industry ('public heat', 'petroleum products', 'gas distribution').

For both indicators, nearly one third of the emissions occur in Switzerland and two thirds abroad.

The differences in the results of the greenhouse gas and the total environmental footprint are mainly due to the additional environmental categories included in the ecological scarcity method. Especially food products are more relevant because of their impacts in the areas of water use and biodiversity loss. Furthermore, the contribution of the disposal services and the electricity distribution is larger, as not only greenhouse gas emissions are considered.

Not included in this study are the impacts of the release of medicaments to the environment through waste water streams. For a few selected substances (e.g. for the chemically very stable iodinated X-ray contrast media), healthcare facilities are the main sources (Bundesrat 2017). Measures to reduce micropollutants at source can be found in the report of the Federal Council in fulfilment of the postulate 12.3090 Hêche of 7 March 2012 (Bundesrat 2017).

4.6.4 Comparison with the planetary boundaries

Figure 4.46 shows the share of the environmental footprints of the Swiss industry 'Health and social work' in the respective global environmental footprints as well as the relative reduction needs. Of the environmental impacts analysed, the Swiss health and social work industry contributes most to the eutrophication footprint. The second largest contribution is to the greenhouse gas footprint, followed by the contribution to the air pollution footprint. For the eutrophication footprint, the industry's share in the global environmental impact exceeds its share in global gross production value.

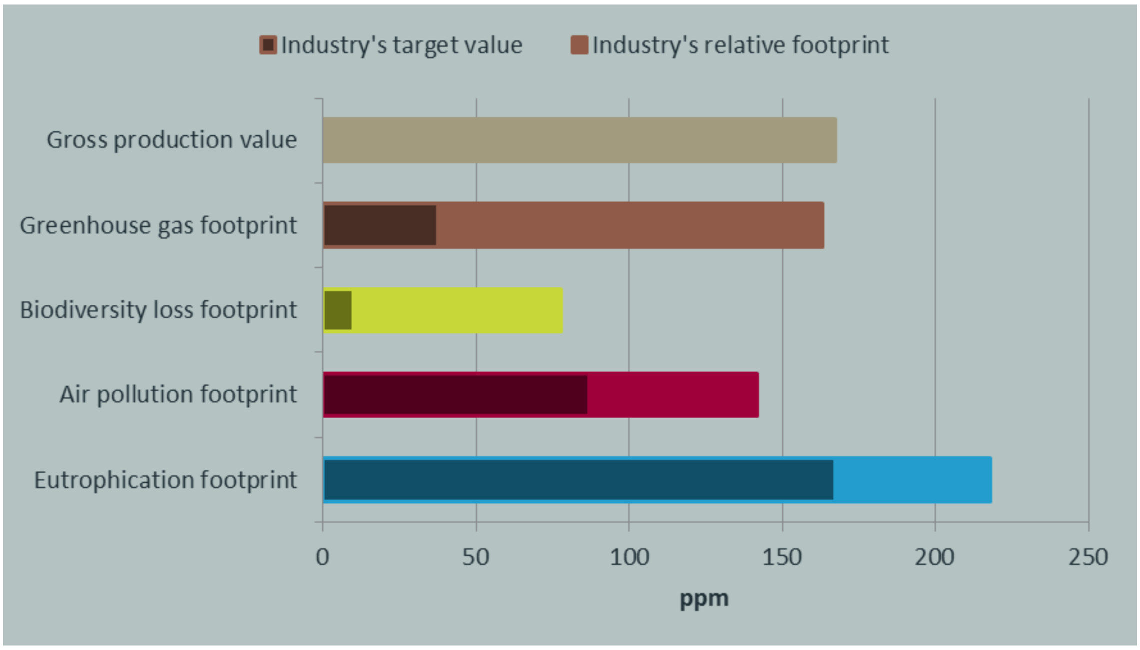

Figure 4.46: Share of environmental footprints caused by the Swiss industry 'Health and social work' in global environmental footprints and respective planetary boundaries (Source: Calculations treeze)

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, the greenhouse gas footprint is identified as priority field of action for the Swiss health and social work industry. In the second row is the biodiversity footprint, followed by the air pollution and eutrophication footprints.

Table 4.16 shows the water footprint of the industry 'Health and social work', differentiated after country and the share of renewable water supply used in the respective country. Countries with a high water stress and at the same time a water consumption of more than 20 % of the renewable water supply are India, Italy and Spain. In China, where the Swiss health industry also has a high water footprint, the sustainably usable share of 20 % of the renewable water supply is almost reached. The third most important country in terms of water footprint is the USA, where already 16 % of the renewable water supply are used. Also in Turkey and Mexico, where smaller part of the water footprint of the Swiss health industry occur, more than three thirds of the sustainably usable amount of water are used. These countries should be addressed specifically when developing measures for reducing the water footprint of the health industry.

Table 4.16: Water footprint of industry 'Health and social work' differentiated after country and share of renewable water supply used in the respective countries

Land	Share of renewable water supply used	Water footprint industry 'Health and social work' [Mm^3]	Share of total water footprint of the industry 'Health and social work'
China	20%	712	22%
India	37%	318	10%
United States	16%	234	7%
Italy	24%	177	5%
Spain	29%	136	4%
Switzerland	5%	58	2%
Turkey	17%	44	1%
Greece	13%	33	1%
Australia	5%	22	1%
Mexico	17%	21	1%
Remaining countries and unspecified regions		1475	46%

4.6.5 Measures for reducing environmental impacts

4.6.5.1 Focal areas for measures

Effective measures to reduce the environmental impacts in the health industry should tackle the most important contributors over the whole supply chain. As for the health and social work industry, most of the impacts occur in the upstream chain, measures are focused on that area:

- One of the biggest contributors to the greenhouse gas footprint are the medical instruments. The use of reusable instruments instead of disposable ones should be systematically evaluated.
- Catering is another focal area. Recommended measures are promoting attractive vegetarian menus, reducing the meat portions, reducing or even avoiding flown-in products and preference for seasonal offers. Foodwaste can be avoided by economically graduated portions or "modular" menus (allow for starters and desserts to be booked individually).

A resource-saving infrastructure and environmental protection within the industry is also important and can help to lower the impacts of the supply chain:

- The environmental impacts of construction can be reduced by applying environmental criteria on new buildings and refurbishments.
- Increasing energy efficiency, purchase of energy efficient equipment (introduce the energy consumption as a standard evaluation criterion in purchase decisions for equipment) and the use of electricity and heat from renewable sources help lower the environmental impacts of the energy industry.
- Avoidance of waste lowers not only the contribution from the disposal services, but may at the same time lead to lower consumption and therefore may have an effect on the whole supply chain.

4.6.5.2 Monitoring parameters

The development of the environmental impacts of the health industry could be monitored with the following indicators:

- Purchase / waste quantity of one way medical instruments
- Purchase quantity of meat / dairy products / coffee & cocoa
- Amount of foodwaste
- Electricity consumption and amount of fossil fuels consumed

These indicators should be monitored both in absolute and relative terms. We propose to use number of patient days to establish the relative indicators.

4.6.5.3 Instruments and guidelines

The following instruments help in finding and implementing appropriate measures to reduce the environmental impacts in the health industry:

- Ökologiekommission des VZK Verbands Zürcher Krankenhäuser: Through its cooperation with "H+ Die Spitäler der Schweiz", the VZK's Ecology Commission is the Swiss-wide contact for all ecological and waste disposal issues affecting the health industry. The Commission's objective is to provide ecological advice to hospitals, clinics and care institutions. Further information: https://www.hplus.ch/de/ueber-uns/fachkommissionen/

- Green+Check (Siemens Healthineers): Structured methodology that provides health care facilities of all sizes with strategic support for sustainable development. Further information: https://www.healthcare.siemens.ch/infrastructure-it/green-hospitals/do-the-green-check or www.siemens.ch/spital

- Green Hospitals: Environmental Impact Assessment, Resource Efficiency and Hands-On Applications:
Funded by the Swiss National Science Foundation (SNSF) as part of the National Research Programme "Sustainable Economy: Resource Efficiency and Hands-On Applications" (NRP 73), this project is investigating relevant hospital processes from an environmental point of view, the efficiency of hospitals from an economic and ecological point of view, and how processes in hospitals can be designed to conserve resources. Together with partner hospitals, concrete implementation proposals are worked out and tested. The project started in September 2017 and will finish in August 2021. First publications are expected in the year 2019[31]. Further information: www.greenhospital.ch

- Minergie-P and Minergie-A requirements for hospitals
Minergie-Eco show case hospital Solothurn

- Single use medical devices: See e.g. "Merkblatt Entsorgung Einweginstrumente" (http://www.hplus.ch/de/dienstleistungen/branchenloesungen/oekologie/entsorgung/) or article at https://www.environmentalleader.com/2016/05/how-reprocessing-medical-devices-can-save-millions-while-diverting-waste/

- Sustainability in procurement: Fact sheets and information on diverse product categories as e.g. nutrition under http://oeffentlichebeschaffung.kompass-nachhaltigkeit.ch/

---

[31] Personal communication M. Stucki, ZHAW, 12.2.2018

- Foodwaste in hospitals: ZHAW-study at http://www.heimeundspitaeler.ch/archiv-redaktion/2015/ausgabe-2/30-prozent-food-waste
  or study of Williams et al. (2011): Plate waste in hospitals and strategies for change

- united against waste: case studies: hospital of Lucerne, old people's homes Binningen (http://www.united-against-waste.ch/fallstudien/)

- BULETTI M. 2004: Entsorgung von medizinischen Abfällen. Vollzug Umwelt. undesamt für Umwelt, Wald und Landschaft, Bern. 72 S. (https://www.bafu.admin.ch/bafu/de/home/themen/abfall/publikationen-studien/publikationen/entsorgung-von-medizinischen-abfaellen.html)

4.7 Food trade

4.7.1 Introduction

The food trade industry is defined in this study as trade of food for household consumption. Starting point for the calculations are the household expenditures for food, beverages and tobacco according to the Swiss IOT. The economic and environmental footprints include retail and wholesale trade of food and food production and their respective supply chains.

As an industry, food trade includes the following activities:

- Wholesale of food, beverages and tobacco,
- Retail sale of food in non-specialised stores, e.g. supermarkets,
- Retail sale of food and beverages in specialised stores and on markets.

The Swiss food trade industry employed around 100'000 persons[32] (FTE) in 2015, corresponding to 2.5 % of the entire Swiss workforce. Since 2011 employment has decreased by on average 0.4 % per year, while the entire Swiss workforce has grown (cf. Table 4.17).

[32] This figure includes employment in non-specialised stores that is related to non-food products, since it is not possible to separate employment for food and non-food products.

Table 4.17: Employment in the food trade industry (Source: FSO – STATENT)

Year	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	100'750	2.6%		
2015	99'224	2.5%	-0.4%	1.0%

4.7.2 Economic impact

The total value added induced by the Swiss food trade industry amounts to 36'965 Mio. CHF[33]. Figure 4.47 shows how it is distributed across the different supply chain stages. The industry itself generates 27 % of the induced value added, whereas the fraction of value added imputable to direct suppliers industries (19 %) are smaller. The largest share however, is generated by industries classified as "remaining upstream chains", which are accountable for 41 % of the induced value added. A considerably high share of 13 % is due to the raw material extracting industries in the supply chain.

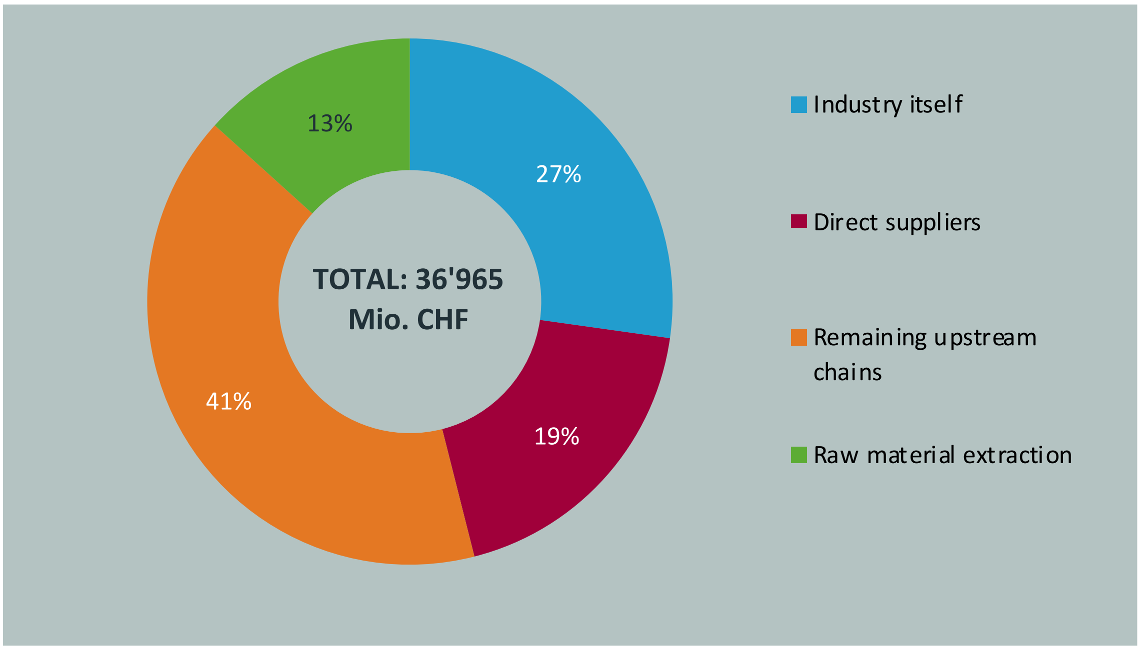

Figure 4.47: Total gross value added induced by the Swiss industry 'Food trade', differentiated by supply chain stages (Source: Calculations Rütter Soceco)

[33] These and the following economic data refer to the year 2008.

In order to understand where - in geographical terms – the value added induced by the Swiss food trade industry is generated, Figure 4.48 shows the shares of induced value added differentiated by countries and supply chain stages.

The upper section of the figure displays the share of value added generated by the industry itself (27 %) as well as the shares generated within domestic (35 %) and foreign (37 %) supply chains. More than half of the value added generated within the supply chains is created in Switzerland while the rest is created abroad.

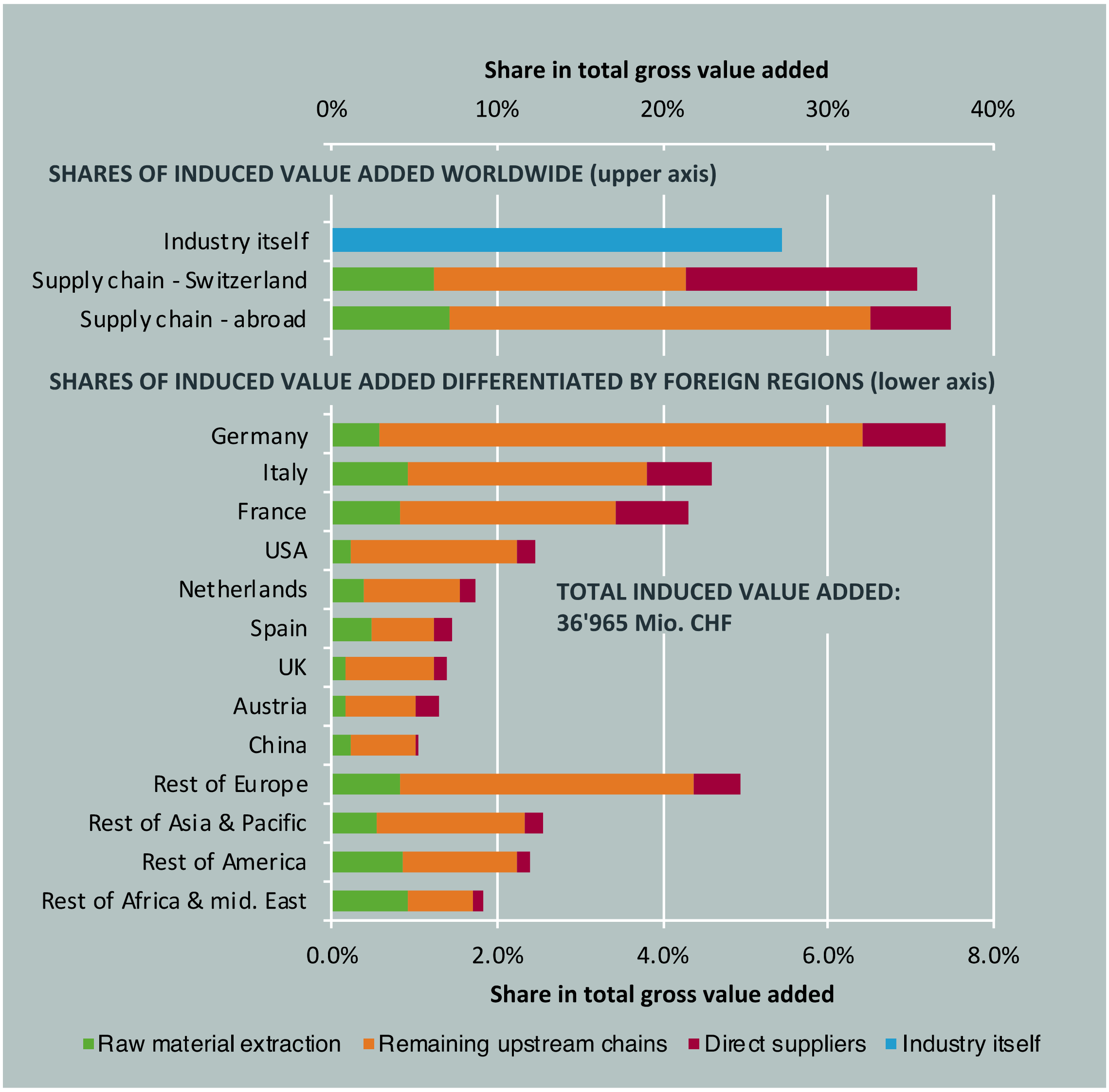

Figure 4.48: Total gross value added induced by the Swiss industry ‘Food Trade’, differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

Within the Swiss supply chains, the shares of value added generated by direct suppliers and industries in the remaining upstream chains are of similar size, whereas in the foreign supply chains the share of the direct suppliers is substantially lower. In addition, the share of value added induced in raw material extraction industries in foreign supply chains is slightly larger than in Swiss supply chains.

Turning the attention to the lower part of Figure 4.48 one can see that Germany (7 % of the total valued added caused abroad) and the Italy (5 %) are those foreign countries in which the Swiss food trade industry induces the largest amounts of value added “creation”. In terms of supply chain stages, it’s noticeable that the largest portions of value added in raw material extraction industries are generated in Africa and the Middle East, the rest of America and Asia as well as in some of the European countries such as Italy and France or the rest of Europe.

4.7.3 Environmental impacts

4.7.3.1 Overview

Table 4.18 contains an overview of the total environmental footprints caused by the Swiss food trade industry, e.g. the total environmental impacts of food sold by retail trade to households from cradle to retail trade company gate for each of the footprint indicators. On the one hand the footprints are reported in absolute terms, on the other hand as intensities in relation to gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

Table 4.18: Environmental footprints caused by the Swiss industry ‘Food trade’ (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Per M CHF gross output	Per M CHF gross value added
Greenhouse gas footprint	kt CO_2 eq	15'681	0.99	1.56
Biodiversity footprint	nano PDF*a	76'519	4.83	7.60
Water footprint	Mm^3	25'587	1.62	2.54
Air pollution footprint	t PM_{10} eq	48'734	3.08	4.84
Eutrophication footprint	t N eq	76'578	4.83	7.61
Environmental footprint	G-eco Pt.	50'469	3.19	5.01
Gross output (industry itself)	M CHF	15'842		
Gross value added (industry itself)	M CHF	10'066		

Aiming to understand the supply chain stages in which the different environmental impacts take place, Figure 4.49 displays the share of the supply chain stages in total impact as well as the share of the industry in the global impact for all footprints apart from the total environmental footprint (and value added/gross production value for comparison reasons). It thus shows how much of the total environmental impact induced by the food trade industry stems from the industry itself, how much is caused in the supply chain and how relevant each indicator for the Swiss food trade industry is.

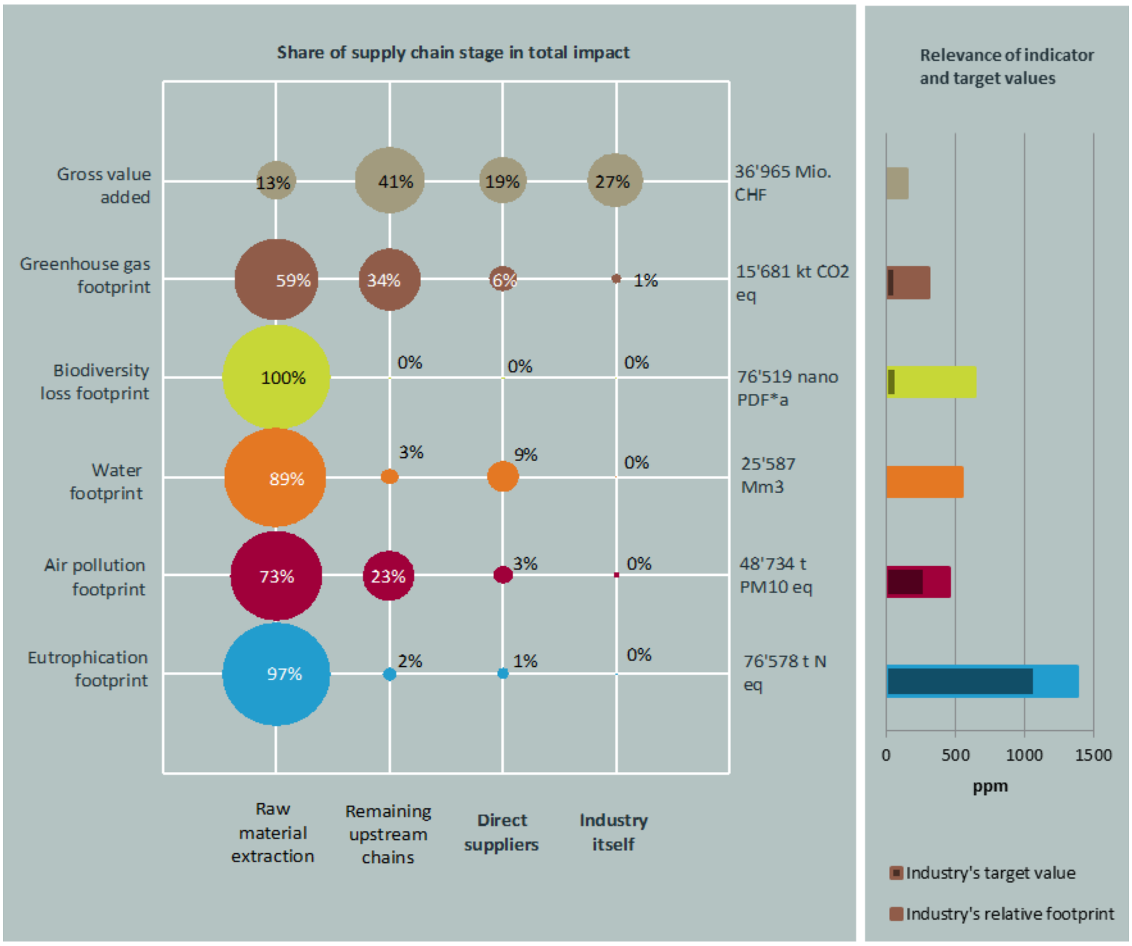

Figure 4.49: Environmental footprints caused by the Swiss industry ‘Food trade’ by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

This figure shows that raw material production is responsible for most of the induced impact in the cases of the biodiversity footprint (100 %), the water footprint (89 %) and the eutrophication footprint (97 %), while the other stages are of substantially less significance. Raw material suppliers also have major shares in the greenhouse gas and the air pollution footprint, but here the remaining upstream chains are also important with shares of 23 % and 34 %. The impact of food trade itself and of its direct suppliers are negligible. It should be noted that direct suppliers from agriculture are recorded in the category ‘raw material extraction’, not in the category ‘direct suppliers’.

When comparing the distribution of environmental impacts to that of value added it becomes obvious that the different supply chain stages have very different environmental intensities. Raw material production is characterised by a low value added share and high environmental footprint shares. The opposite is characteristic for the food trade industry and its direct suppliers (from the food industry).

The food trade industry has large environmental footprints, with the eutrophication footprint being most relevant (see Figure 4.49; share of the respective footprints in the global footprints compared to the share of the gross production value of the food trade industry in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.7.4.

4.7.3.2 Focus on biodiversity loss footprint

The focus footprint chosen for the Swiss food trade industry is the biodiversity loss footprint, since this is among the industry’s highest ranking footprints (cf. Table 3.2). As seen in Table 4.18 the global amount of biodiversity loss induced by the food trade in Switzerland adds up to 76’519 nano PDF*a.

Figure 4.50 highlights which industries (aggregated over all countries) are directly responsible for the biodiversity loss induced by Swiss food trade. The most important industry is cattle and dairy farming, with a share of 40 % in the total biodiversity loss footprint. Growing of cereals, oil seeds and vegetables, fruits and nuts follow with shares between 12 % and 18 %. All other industries are also from agriculture with the exception of forestry that reflects the importance of packaging in the supply chain. Other industries as well as supply chain stages apart from agriculture are negligible.

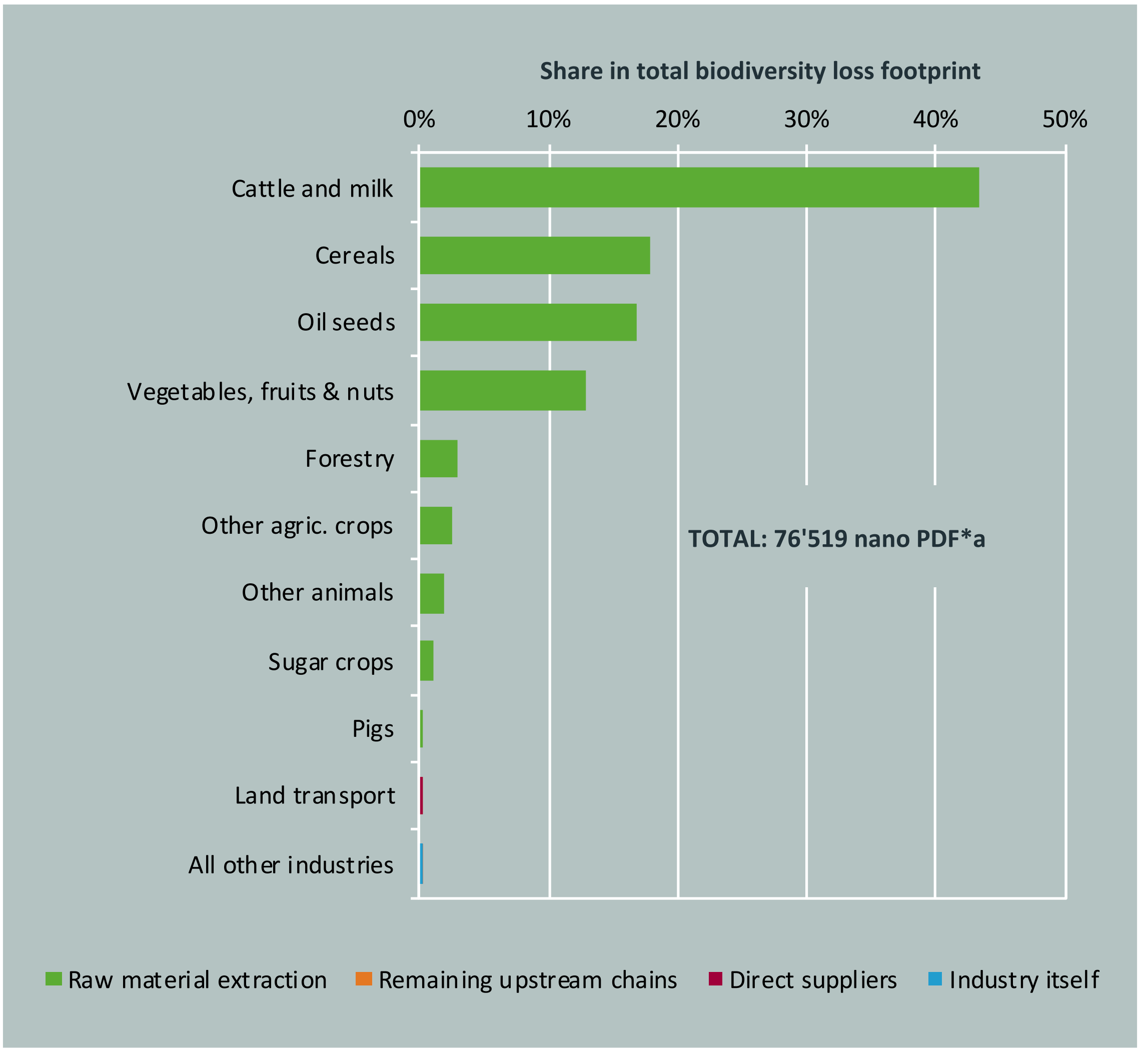

Figure 4.50: Biodiversity loss footprint caused by the industry 'Food trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

Figure 4.51 illustrates how the responsible companies are distributed across supply chain stages and countries. The diagram shows that only 13 % of the footprint are due to land use in Switzerland (mostly also by agriculture as raw material supplier) while the remaining land use takes place abroad.

The country differentiation of biodiversity loss reveals that the top ten countries are responsible only for 45 % of the total footprint. The remaining fraction is distributed across many countries. This reflects the large number of countries supplying food to Switzerland. Within the top ten, Brazil has the largest share with 13 % of the total footprint, Italy, Spain and Indonesia following with shares under 5 %. The large impact in Brazil and Latin America reflects the high land use for cattle farming in these countries and the above-average biodiversity loss attributed to land use in these regions. As mentioned in Chapter 2.3.5 modelling with Exiobase generally assumes that the environmental intensity of exports equals the average environmental intensity of the exporting industries. These results therefore may overestimate the effective biodiversity loss if cattle farming in Latin America for export diverges substantially from average cattle farming (e.g. if exported meat mainly stems from intensive cattle production).

A comparison with the value added distribution across countries (cf. Figure 4.48) reveals strong shifts. Some countries with large value added shares have low biodiversity footprint shares (e.g. Germany, France). The opposite holds for Latin American countries, where the footprint shares are much larger than value added shares. This demonstrates the large differences in environmental intensities in the respective countries.

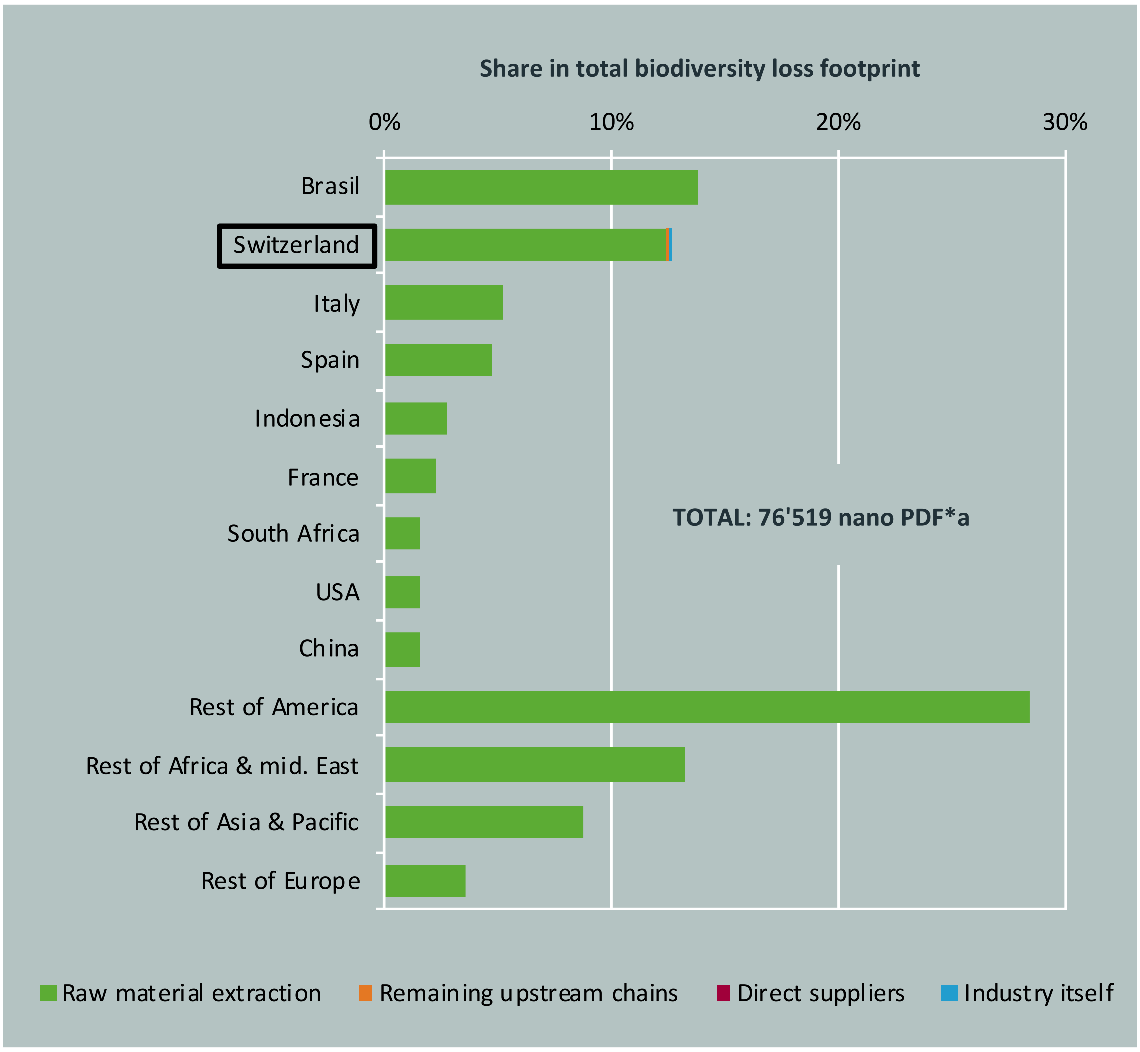

Figure 4.51: Biodiversity loss footprint caused by the Swiss industry 'Food trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

From a practical point of view it is useful to understand which direct intermediate inputs purchased by Swiss food trade are responsible (to what extent) for the total biodiversity loss footprint caused by the industry within its supply chains. The gained information should help the Swiss food trade discovering their scope of action when trying to reduce the biodiversity loss impacts they cause in the supply chain. The analysis presented in Figure 4.52 allocates the total biodiversity loss footprint to its domestic and foreign direct suppliers. For reasons of comparison the share of food trade ('industry itself') is also included.

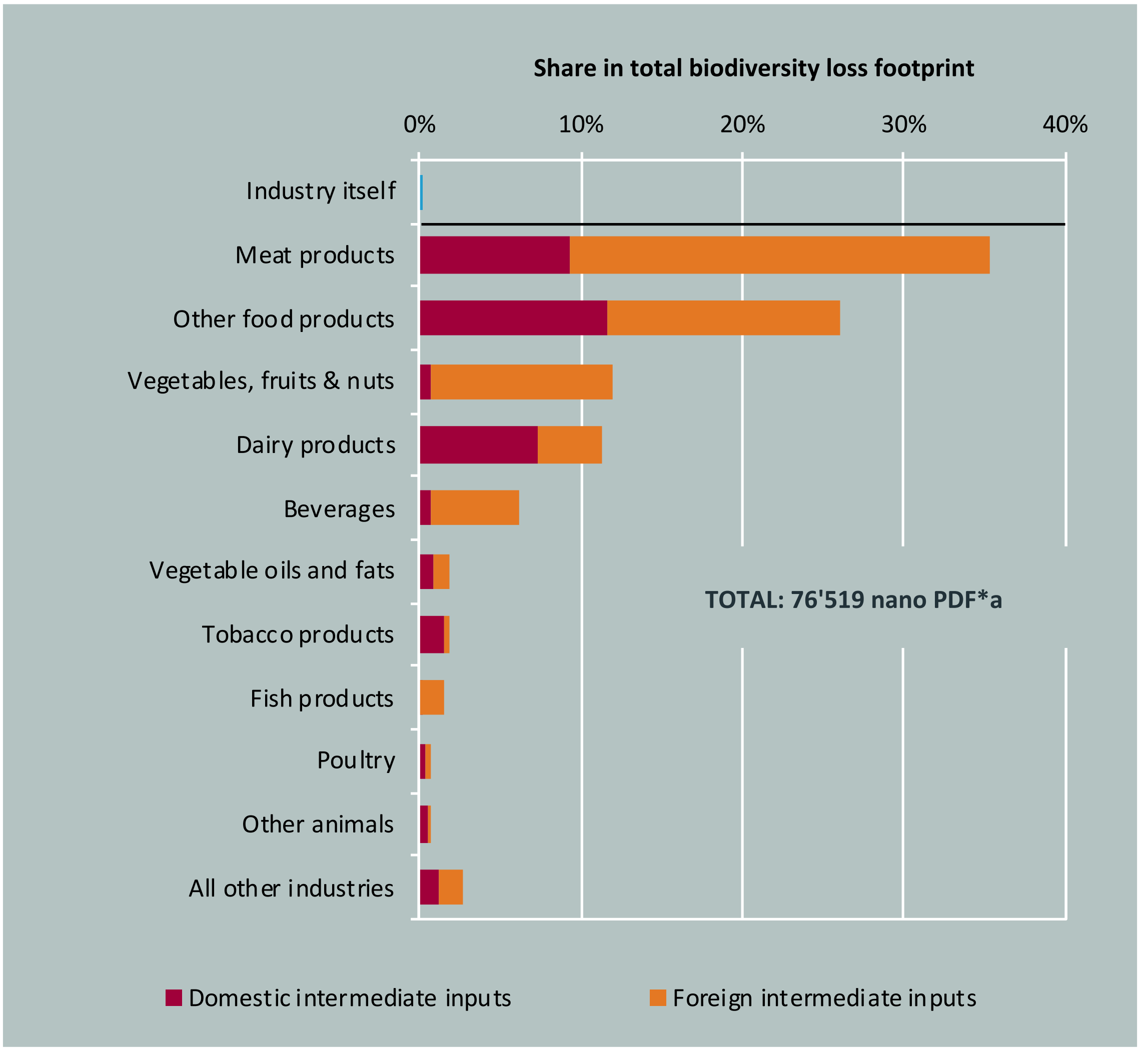

Figure 4.52: Biodiversity loss footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry 'Food trade' (Source: Calculations Rütter Soceco)

Meat and dairy products are the direct suppliers that carry most of the environmental burden (36 % of the total footprint). 'Other food products' are also important with over 26 % of the footprint, since these products also contain fractions of meat and milk products. Other important suppliers stem from 'growing of vegetables, fruits and nuts' and beverage manufacturing. Other direct suppliers are less relevant.

Compared to the results for other industries, domestic suppliers are more important, especially for meat and dairy products and other food products. The share of foreign suppliers is especially large for 'vegetables, fruits and nuts' and for beverages.

4.7.3.3 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

In terms of industries the water and the eutrophication footprint are completely dominated by agriculture, whereas for the greenhouse gas and the air pollution footprint other industries beside agriculture are responsible for noteworthy shares. These include in particular electricity generated from fossil fuels for both footprints as well as mining and quarrying activities (e.g. of fossil energy carriers or minerals) in the case of the greenhouse gas footprint and basic metals in the case of the air pollution footprint.

The country distribution of the footprints exhibits two basic patterns: the largest shares of the greenhouse gas, the air pollution as well as the eutrophication footprints are caused within Switzerland, followed by China, Germany and France. The water footprint in contrast is caused mostly in Spain, Turkey, Italy, China and the USA, whereas Switzerland is not ranked among the top ten regions. Countries outside the top ten still account for a large share of the water footprint with almost 40 %.

4.7.3.4 Environmental footprint according to the ecological scarcity method

The total environmental footprint of the Swiss food trade industry is 50’590 billion eco-points. Nearly three quarters of it is caused by imported goods (Figure 4.53). The remaining Swiss suppliers cause 22 % of the total environmental impacts, the direct Swiss suppliers 3.4 % and the industry itself only 0.3 %.

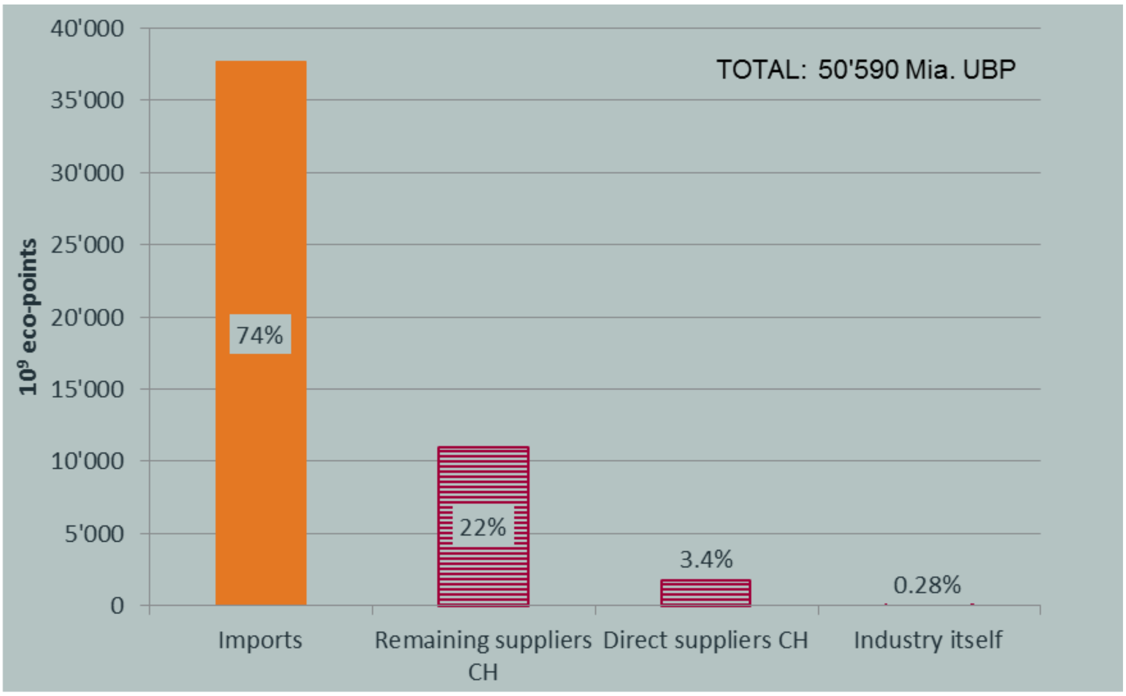

Figure 4.53: Environmental footprint in eco-points caused by the ‘Food trade’ by supply chain stages and imports (Source: Calculations treeze)

The environmental footprint of the Swiss food trade industry is determined by the impacts of the different food items traded (see Figure 4.54). The ten most important food categories explain 80 % of the total environmental impacts of the industry 'Traded foods'. The food products with the highest share in the total environmental footprint are the imports of coffee, tea, cocoa, spices etc. These products contribute 15 % of the total environmental impacts. Within this group, the cultivation of coffee and cocoa is most important. Especially the emissions of heavy metals and pesticides into the soil lead to a high environmental footprint of these food products.

The Swiss meat industry accounts for 14 % of the total environmental footprint; another 9 % stem from imported meat products. The Swiss meat industry is analysed in detail in Subchapter 4.2. Dairy products are responsible for 12 % of the total environmental footprint of food trade. The emissions associated with animal husbandry (ammonia, methane and nitrate) are most relevant for this industry. The remaining environmental impacts are largely linked to the production of animal feed (above all cereals).

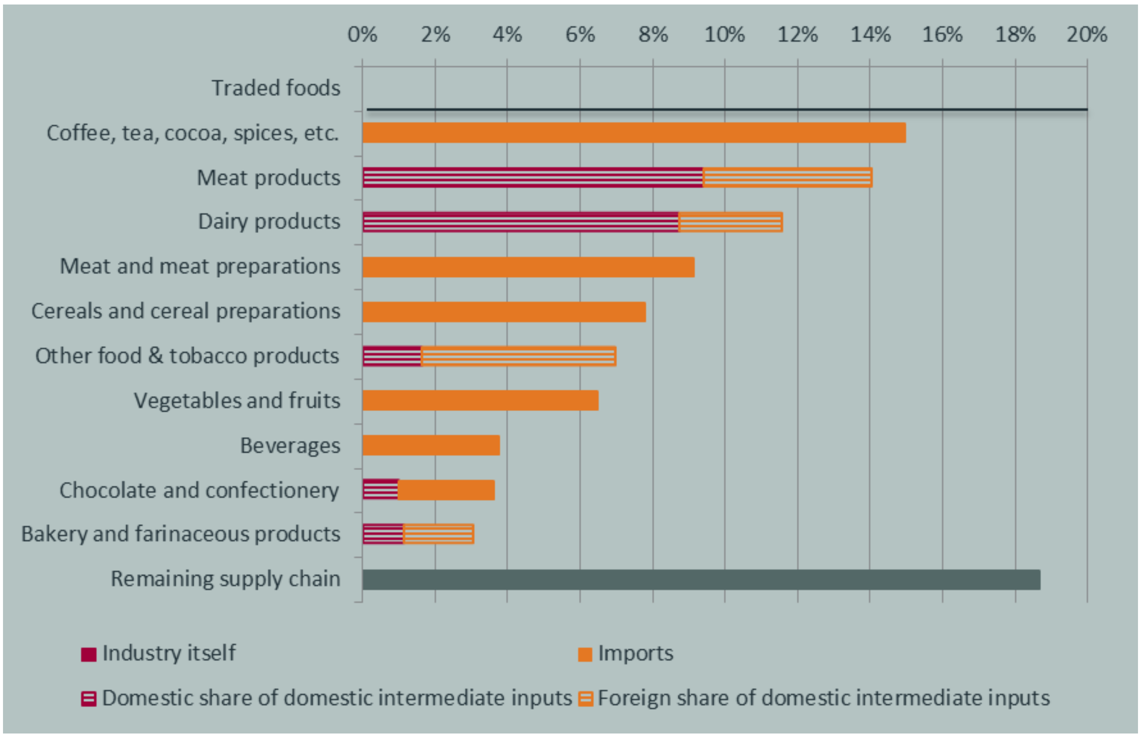

Figure 4.54: Environmental footprint caused by the direct suppliers of intermediate goods and services for the 'Food trade'. Remaining supply chain = all other direct suppliers (Source: Calculations treeze)

The import of cereals and cereal preparations causes 8 % of the total environmental footprint of traded foods. The import of pasta is most relevant, followed by the import of wheat and rice. 'Other food and tobacco products' account for 7 % of the environmental footprint of traded foods. The import of vegetable causes 6 % of the total environmental footprint (with the highest contributions from prepared or preserved vegetables, followed by the import of citrus fruits), the imported beverages (mainly wine) and the ‘chocolate and confectionery’ industry about 4 % each, followed by the ‘bakery and farinaceous products’ industry with 3 % of the total environmental impacts. For both the ‘other food and tobacco products’ and the ‘chocolate and confectionery’ industry, the cultivation of cocoa is the most important contributor to their environmental footprints.

4.7.3.5 Conclusion

The environmental impacts of food trade are dominated by the agricultural production. For the biodiversity and the total environmental footprint, meat is the most important food category (‘meat products’ and ‘meat and meat preparations’ in Figure 4.54). This is followed by ‘other food products’ and ‘vegetable and nuts’ for the biodiversity footprint and ‘coffee, tea, cocoa, spices etc.’ for the total environmental footprint. The next industry for both indicators is ‘dairy products’. Further food categories important for both indicators are ‘beverages’ and ‘tobacco products’.

For the biodiversity footprint, also ‘vegetable oils and fats’, ‘fish products’, ‘poultry’ and ‘other animals’ are among the ten most important contributing direct suppliers. For the total environmental footprint, the cereals are important (‘cereals and cereal preparations’, ‘bakery and farinaceous products’) as well as ‘chocolate and confectionery’.

A larger proportion of the biodiversity loss takes place abroad than of the total environmental footprint: Only 13% of the impact of the former occurs in Switzerland, but 26 % of the latter.

4.7.4 Comparison with the planetary boundaries

Figure 4.55 shows the share of the environmental footprints of the Swiss industry ‘Food trade’ in the respective global environmental footprints as well as the relative reduction needs. Of the environmental impacts analysed, the Swiss food trade industry contributes most to the eutrophication footprint. The second largest contribution is to the biodiversity loss footprint, followed by the air pollution and the greenhouse gas footprints. The industry’s shares in the global environmental impacts exceed its share in global gross production value for all indicators analysed.

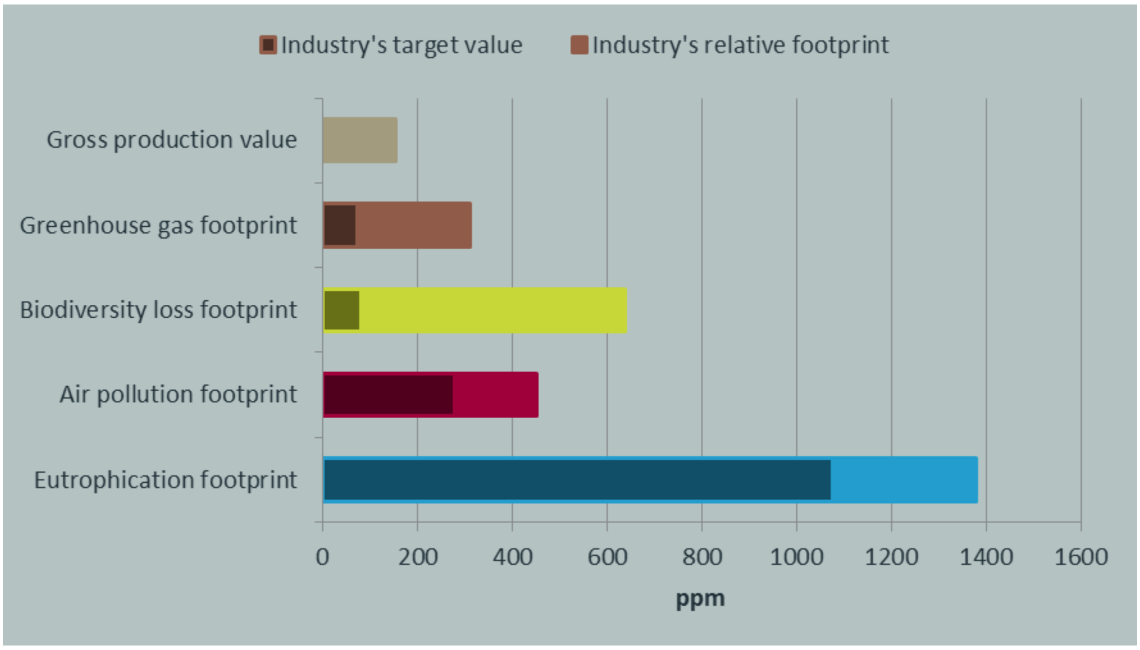

Figure 4.55: Share of environmental footprints caused by the Swiss industry 'Food trade' in global environmental footprints and respective planetary boundaries (Source: Calculations treeze)

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, the biodiversity loss footprint is identified as priority field of action for the Swiss food trade industry, followed by the eutrophication footprint.

Table 4.19 shows the water footprint of the 'Food trade' industry, differentiated after country, and the share of renewable water supply used in the respective country. 20 % of the water footprint of the 'Food trade' industry occurs in Spain, where 29 % of the renewable water supply is already used. Another 11 % stems from the United States, where more than three thirds of the sustainably usable amount are already used. 8 % each occur in Italy and China, where the sustainably useable share of 20 % is exceeded or almost reached. Also India and South Africa contribute to the water footprint of the 'Food trade' industry. In both countries, more than 20 % of the renewable water supply is used. In these countries, there is a need for action regarding the water footprint of the 'Food trade' industry.

Table 4.19: Water footprint of industry ‘Food trade’ differentiated after country and share of renewable water supply used in the respective countries

Country	Share of renewable water supply used	Water footprint industry ‘Food trade’ [Mm^3]	Share of total water footprint of the industry ‘Food trade’
Spain	29%	5133	20%
Turkey	17%	2743	11%
Italy	24%	1956	8%
China	20%	1921	8%
United States	16%	1688	7%
India	37%	1213	5%
Greece	13%	464	2%
South Africa	25%	277	1%
Portugal	11%	234	1%
Mexico	17%	168	1%
Remaining countries and unspecified regions		9789	38%

4.7.5 Measures for reducing environmental impacts

4.7.5.1 Focal areas for measures

The environmental footprint of the industry ‘Food trade’ is determined by the impacts of food production. Therefore, the agricultural production is the focal area which has to be addressed.

One possibility to reduce the impacts of the agricultural production is the reduction of food losses. This can e.g. be achieved by accepting and promoting fruits and vegetables without standard masses or with lower quality levels. Another possibility is the inclusion of inferior vegetables in processing. An improved cooperation with suppliers and producers can avoid losses due to excessive stocks. Also the reduction of the variety of perishable fresh products on offer at closing time (e.g. bread) combined with awareness-raising campaigns can reduce food losses.

Food waste in households could be reduced by optimising packaging, which extends the storage life of food. This includes the verification of the best-before dates and possible adjustments together with information campaigns on the meaning of the best before date. All products approaching the date of sale should be consequently liquidated.

If food losses are unavoidable, they should be recycled as high-quality as possible (e.g. as animal feed or in a biogas plant).

Another approach is to reduce the environmental impacts of agricultural production itself. Key areas according to the method of ecological scarcity are the emissions of heavy metals into soil (mainly through application of fertilisers and pesticides as well as atmospheric deposition), water pollutants (mainly nitrate), greenhouse gas emissions and air pollutants (ammonia, nitrogen oxides), then pesticide emissions as well as the use of water resources and land use. The impacts of agriculture can either be minimized by procuring products with an environmental label or through direct cooperation with suppliers. Direct cooperation with suppliers has the advantage that improvements can also be achieved in the basic assortment, which still accounts for the majority of food products.

A third approach is the promotion of food items with low environmental impacts, e.g. alternative protein sources such as tofu or pulses or novel foods (e.g. insect products). Preference should be given to short supply chains so that there is an opportunity to influence environmental standards in production.

4.7.5.2 Monitoring parameters

- Amount of food loss per kg of sold product
- Share of food items sold with a recommended environmental label[34] or produced according to equivalent standards
- Share of food items from known producers (share of known players in the supply chain)
- Share of producers who dispose of environmental indicators for their production

4.7.5.3 Instruments and guidelines

- Reduction of food waste:
    - United against waste: http://www.united-against-waste.ch/
    - https://www.save-food.org/
    - Spezifische Beratungsleistungen: http://www.foodways.ch/
    - http://www.coop.ch/de/labels/uenique.html

[34] There are major differences in the ecological requirements of labels. An evaluation of the various labels available in Switzerland can be found at www.labelinfo.ch.

    - National research program 69: http://www.nfp69.ch/de/projekte/wie-werden-nahrungsmittel-umweltfreundlicher/projekt-nahrungsmittelverluste
- Information about food labels
    - http://labelinfo.ch/
- Minimizing ecological impacts of agriculture:
    - Sustainable cocoa production: https://www.kakaoplattform.ch/
    - Sustainable meat production: see chapter 4.2.5.3
    - Sustainable milk production:
        - http://www.nfp69.ch/de/projekte/wie-werden-nahrungsmittel-umweltfreundlicher/projekt-nachhaltige-milchproduktion
        - https://www.swissmilk.ch/de/produzenten/medien/medienmitteilungen/2018/gemeinsamer-standard-fuer-eine-nachhaltige-milchproduktion/
    - Sustainability assessment in agriculture:
        - http://www.nfp69.ch/de/projekte/wie-werden-nahrungsmittel-umweltfreundlicher/projekt-nachhaltige-ernaehrungswirtschaft
        - https://www.hafl.bfh.ch/forschung-dienstleistungen/agrarwissenschaften/nachhaltigkeit-und-oekosysteme/nachhaltigkeitsbeurteilung/rise.html

http://www.fibl.org/de/themen/nachhaltigkeitsbewertung.htmlhttps://www.agroscope.admin.ch/agroscope/de/home/themen/umwelt-ressourcen/oekobilanzen.html

- Measures for reducing greenhouse gas emissions from agriculture:
    - https://agrocleantech.ch/de/
    - http://www.emission-impossible.ch
- Novel food sources
    - https://www.essento.ch/

4.8 Trade with clothing, textiles and footwear

4.8.1 Introduction

'Trade with clothing, textiles and footwear' is defined in this study as trade of clothing, textiles and footwear for household consumption. Starting point for the calculations are the household expenditures for these products according to the Swiss IOT. The economic and environmental footprints include retail and wholesale trade as well as production of clothing, textiles and footwear and their respective supply chains.

The industry ‘Trade with clothing, textiles and footwear’ (in short the clothing trade industry in the following) includes the following activities:

- Wholesale of clothing and footwear,
- Retail sale of clothing in specialised stores,
- Retail sale of footwear,
- Retail sale of clothing in non-specialised stores.

Table 4.20: Number of employees in the clothing trade industry (Source: FSO – STATENT).

Year	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	51’175	1.3%		
2015	47'578	1.2%	-1.8%	1.0%

In 2015 the Swiss clothing trade industry employed almost 48’000 people (FTE), corresponding to 1.2 % of the entire Swiss workforce. Employment has decreased since 2011 (see Table 4.20).

4.8.2 Economic impact

The total value added induced by the Swiss clothing trade industry amounts to 9’335 Mio. CHF[35]. Figure 4.56 shows how it is distributed across the different supply chain stages. The industry itself accounts for 29 % of total value added. Direct suppliers, including on the one hand the domestic and foreign clothing manufacturers and on the other hand other suppliers of the trade industry, generate 22 % of value added. The largest share is created by intermediate suppliers between raw material extraction and direct suppliers termed ‘remaining upstream chains’ in the figure (45 %). The fraction of value added generated by raw material extracting industries is small with 4 %.

[35] These and the following economic data refer to the year 2008.

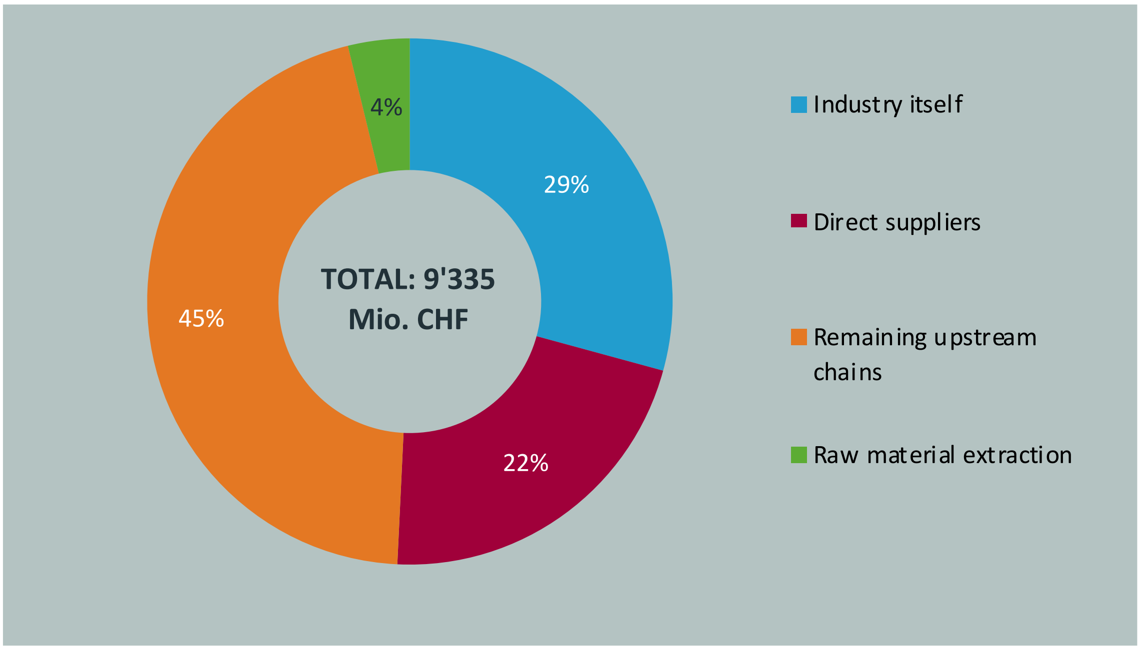

Figure 4.56: Total gross value added induced by the Swiss industry ‘clothing trade’, differentiated by supply chain stages (Source: Calculations Rütter Soceco)

In order to understand where - in geographical terms – the value added induced by the Swiss clothing trade industry is generated, Figure 4.57 shows the shares of induced value added differentiated by countries and supply chain stages.

The upper section of the figure displays the share of value added generated by the industry itself (29 %) as well as the shares generated within domestic (11 %) and foreign (60 %) supply chains. In total slightly more than 40 % of the value added is created in Switzerland.

Within the Swiss supply chains, the shares of value added generated by direct suppliers and industries in the remaining upstream chains are of similar size, whereas in the foreign supply chains the share of the direct suppliers is substantially lower. Still most of the direct suppliers of clothing trade are located outside Switzerland. Raw material suppliers (especially cotton and wool suppliers, but also mineral oil extraction as a raw material supplier for synthetic fibres) are completely situated outside Switzerland and mostly outside Europe.

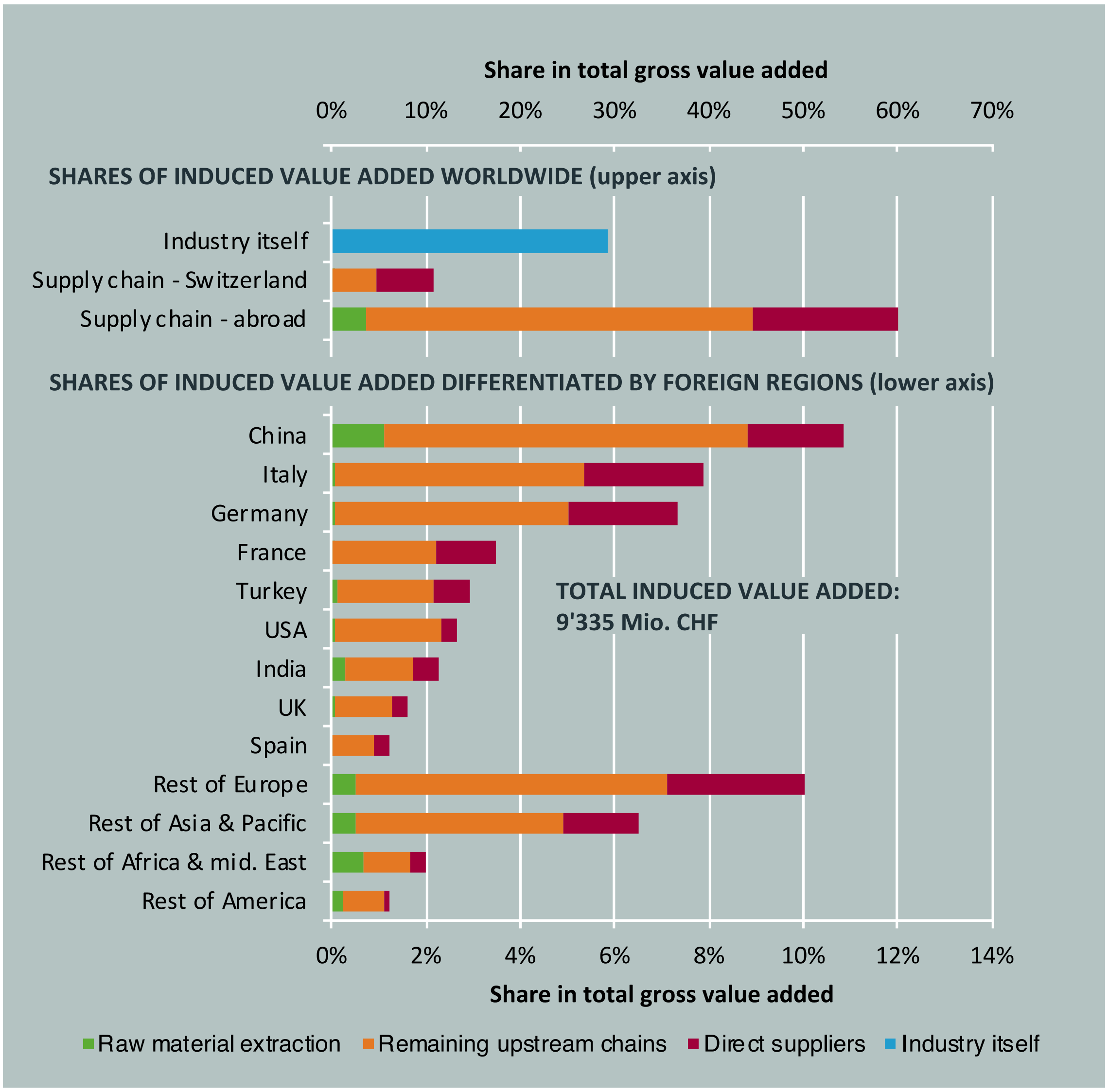

Figure 4.57: Total gross value added induced by the Swiss industry 'clothing trade', differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

The lower part of Figure 4.57 displays the share of foreign countries in the total value added generated by the clothing trade industry (lower scale). China takes the largest share of value added (11 %). Italy (8 %) and Germany (7 %) also have significant shares followed by France, Turkey, the USA, India and the UK. Countries outside the top eight account for another 21 %. In terms of supply chain stages, direct suppliers are relevant in many foreign countries, but companies from remaining upstream chains dominate in most countries. Raw material extraction is mainly located in China and the rest of the world regions.

4.8.3 Environmental impacts

4.8.3.1 Modelling adjustments for the clothing trade industry

We extended the data in Exiobase for the modelling of the clothing trade industry, since cotton farming does not seem to be implemented correctly with regard to the water footprint. Cotton can be used both for oil production (from cotton seeds) and for textile production (from cotton lint). In the water consumption data of Exiobase, cotton production seems to be solely allocated to the product group "oil seeds" according to the Exiobase documentation. Therefore water consumption of cotton production does not appear in the supply chain of textile manufacturing. We therefore calculated blue water consumption of cotton lint production by country from FAOSTAT data on cotton production and data from the water footprint network on water consumption. We included the resulting data into Exiobase and allocated the values to the product group "plant based fibres" for further calculation.

The first calculation results showed that vegetal agriculture apart from "growing of fibres" contributes strongly to the water footprint. Detailed analysis revealed that in the Chinese IO table of Exiobase the textiles, clothing and leather industry have significant inputs from agriculture and food industry (e.g. cereals, vegetables, meat, sugar etc.). This pattern does not appear for other important textile-producing countries. It is unclear whether these inputs relate to feeding of persons employed in the industry, to growing of animals supplying leather or wool or whether they are related to statistical artefacts stemming from IOT disaggregation in the construction of Exiobase. The same patterns appear for some Rest of the World regions that are partly modelled with input structures from the Chinese IOT. We therefore decided to exclude these inputs from the Chinese and the RoW region IOTs. Inclusion of these inputs would increase the footprints of Swiss clothing trade by between 17% for greenhouse gas emissions and 142% for eutrophication.

4.8.3.2 Overview

Table 4.21 contains an overview of the various environmental footprints caused by the Swiss clothing trade industry. On the one hand the footprints are reported in absolute terms, on the other hand as intensities in relation to gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

Table 4.21: Environmental footprints caused by the Swiss industry ‘clothing trade’ (Source: Calculations Rütter Soceco & Treeze)

Indicator	Unit	In absolute terms	Per M CHF gross output	Per M CHF gross value added
Greenhouse gas footprint	kt CO_2 eq	4'890	1.26	1.79
Biodiversity footprint	nano PDF*a	4'441	1.14	1.63
Water footprint	Mm^3	5'829	1.50	2.14
Air pollution footprint	t PM_{10} eq	11'582	2.98	4.24
Eutrophication footprint	t N eq	3'492	0.90	1.28
Environmental footprint	G-eco Pt.	3'932	1.01	1.44
Gross output (industry itself)	M CHF	3'883		
Gross value added (industry itself)	M CHF	2'730		

Figure 4.58 displays the share of supply chain stages in total impact as well as the share of the industry in the global impact for each footprint apart from the environmental footprint (and value added/gross production value for comparison reasons). It thus shows how much of the total environmental impact induced by clothing trade stems from the industry itself, how much is caused in the supply chain and how relevant each indicator for the Swiss clothing trade industry is.

The figure shows that the share of the clothing trade industry in its environmental footprint is negligible for all footprint indicators. The relevance of its direct suppliers is low compared to their share in value added. They account for between 5 % and 7 % of the respective footprints (apart from the biodiversity footprint). The major shares of footprints occur in the remaining upstream chains and raw material extraction. The remaining upstream chains (e.g. energy generation or production of plastic fibres) are mainly responsible for greenhouse gas emissions and air emissions. Raw material extraction causes large shares of the biodiversity footprint (100 %), the water (84 %) and the eutrophication footprint (76 %).

The clothing trade industry has large air pollution and greenhouse gas footprints (see Figure 4.58; share of the respective footprint in the global footprints compared to the share of the gross production value of the clothing trade industry in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.8.4.

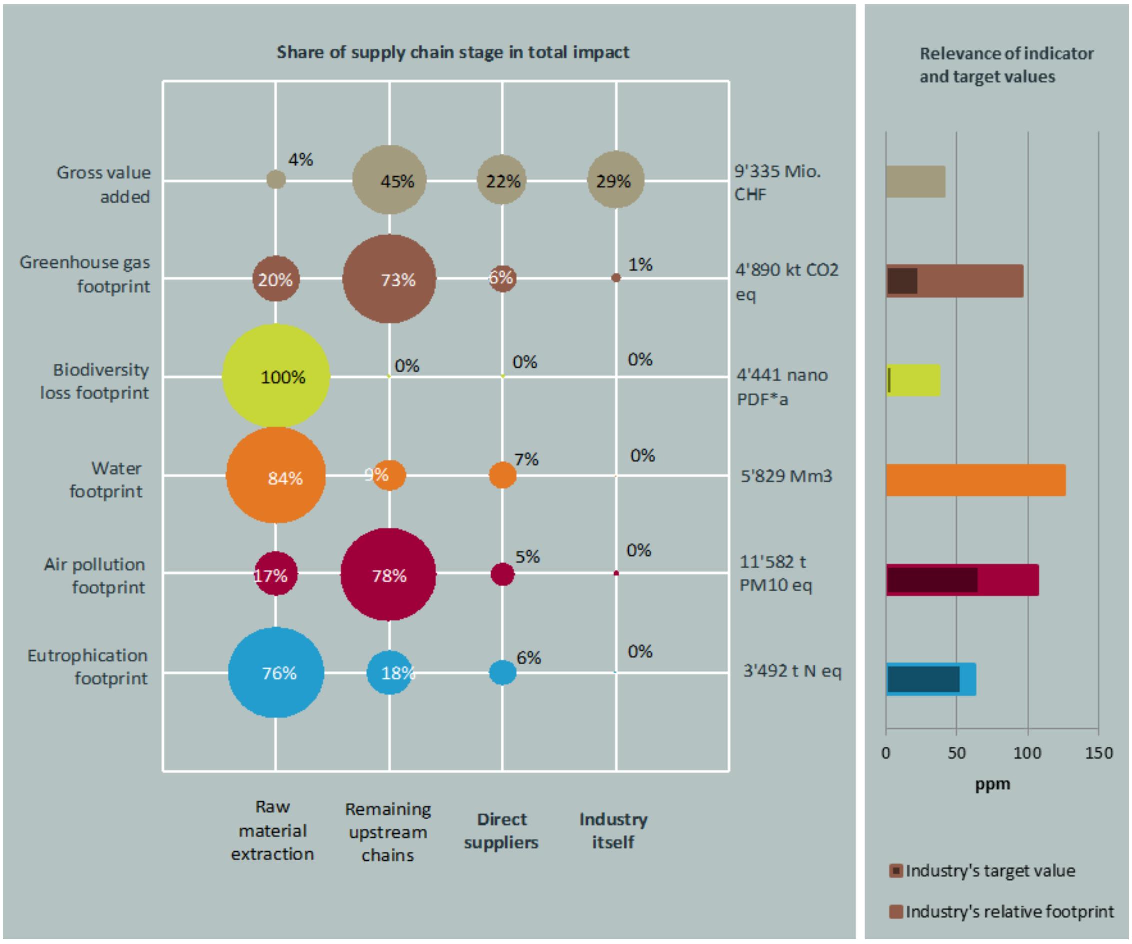

Figure 4.58: Environmental footprints caused by the Swiss industry ‘Clothing trade’ by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

4.8.3.3 Focus on water footprint

The focus footprint chosen for the Swiss clothing trade industry is the water footprint, since this is the industry’s highest ranking footprint (cf. Table 3.2). The water footprint equals a value of 5’829 M m^3 AWARE water consumption.

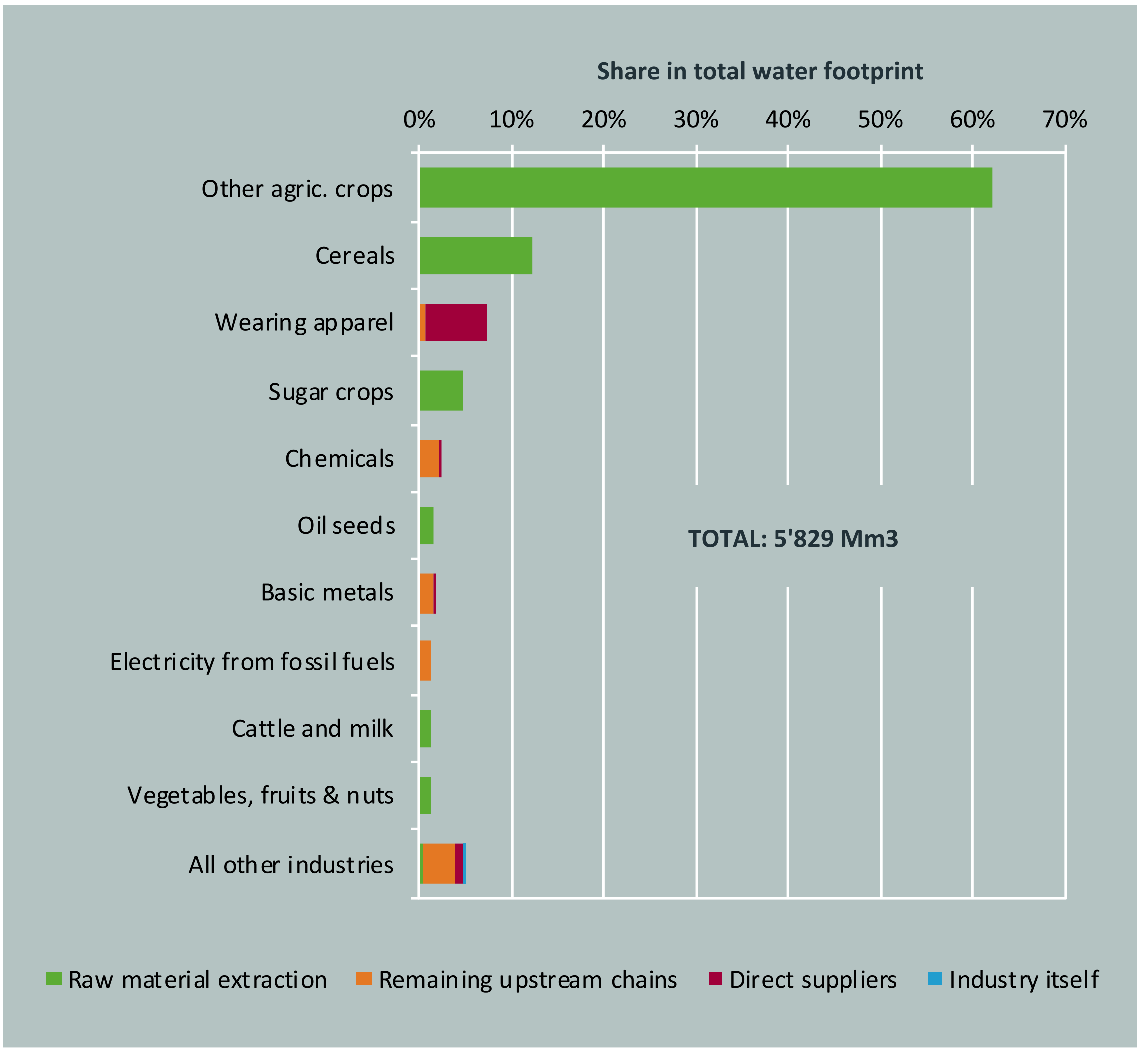

Figure 4.59: Water footprint caused by the industry ‘Clothing trade’ by supply chain stage and industry (Source: Calculations Rütter Soceco)

Figure 4.59 highlights which industries (aggregated over all countries) are responsible for the water consumption along the clothing trades supply chain. As suspected raw material suppliers from agriculture account for a major share, in particular the industry “other agricultural crops”, which contains cotton production (62 %)[36]. Other agricultural subsectors are related to feed stuffs used for animals supplying wool and plant-based raw materials used in the chemical industry and other industries. They might also be linked to nutrition of persons employed in the supply chain. The most important indus-

[36] This implies that other textile fibres such as viscose, modal or polyamide and polyester are less problematic in terms of water scarcity. However, this only applies to the effects on the availability of water. No statement can be made about the effects on water quality.

tries outside agriculture are the wearing apparel industry and the chemical industry. Basic metals production and electricity generation from fossil fuels also play a small role. Industries outside the top ten are responsible for less than 5 % of the water footprint.

The high importance of cotton production is also due to the selected indicator (water footprint), where cotton growing is of particular importance.

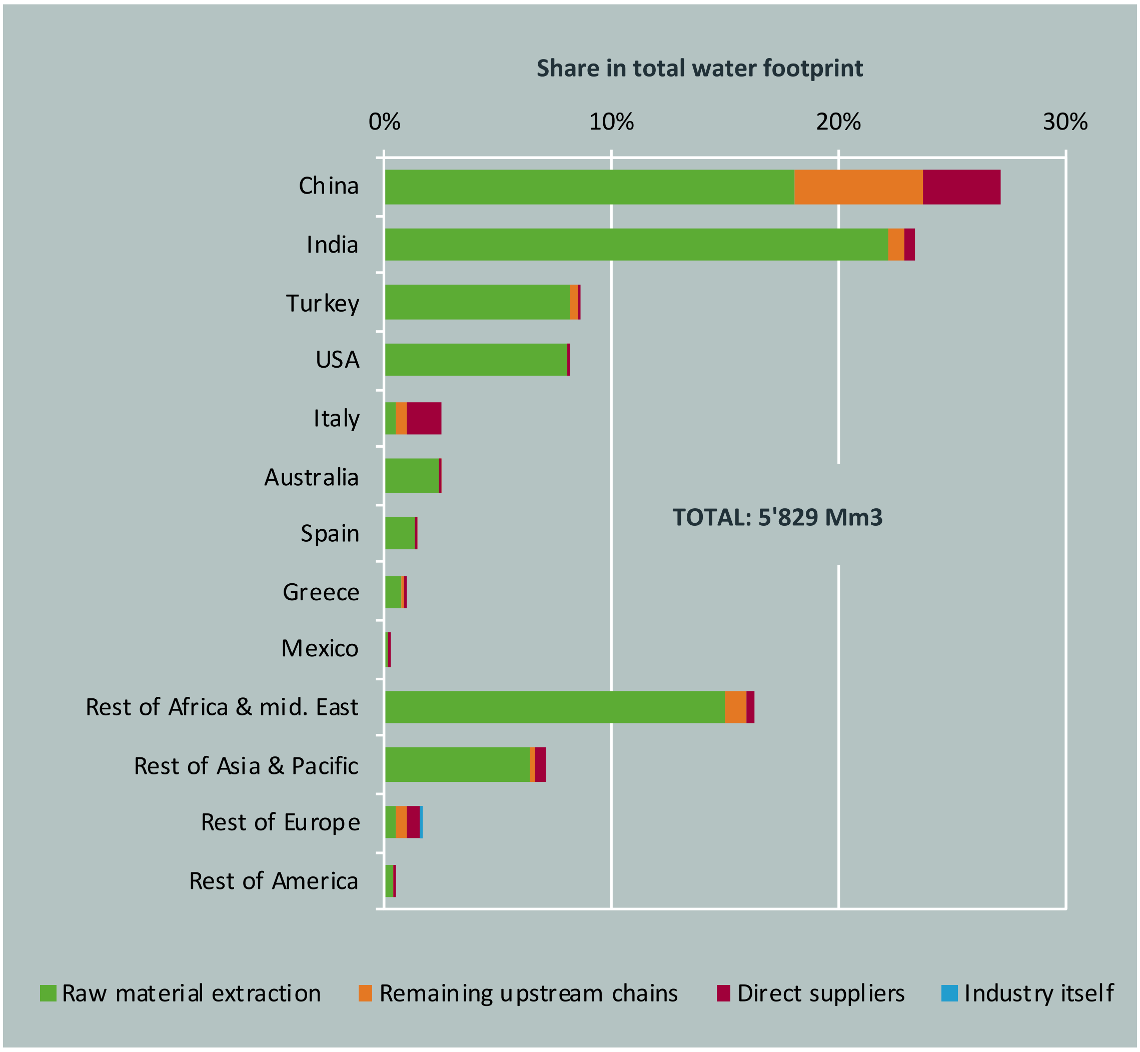

Figure 4.60: Water footprint caused by the Swiss industry ‘Clothing trade’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

Figure 4.60 illustrates how the responsible companies are distributed across supply chain stages and countries. The diagram shows that domestic water use is negligible. China and India have dominant shares in the water footprint with 27 % and 23 % respectively, followed by Turkey with 9 % and the USA with 8 %. Other countries with significantly smaller shares include Italy, Australia, Spain, Greece and Mexico. Countries outside the top 9 have a share of 25 %. While direct suppliers and remaining upstream chains are visible in the main source countries for Swiss clothing imports (especially China and Italy), raw material suppliers dominate in the other countries. The main producers of textile fibres are China, India, the US and Turkey.

From a practical point of view it is useful to understand which direct inputs purchased by the Swiss clothing trade are responsible (to what extent) for its total water footprint. This allows the companies to identify, which of their suppliers they should access with which priority in order to optimise the environmental performance of their supply chain. The analysis presented in Figure 4.61 allocates the water footprint caused by the Swiss clothing trade industry within the supply chain to domestic and foreign direct suppliers. Thus each direct supplying industry is presented with its own water footprint, including all water use along its own supply chain. The water use of the industry itself is shown for comparison reasons.

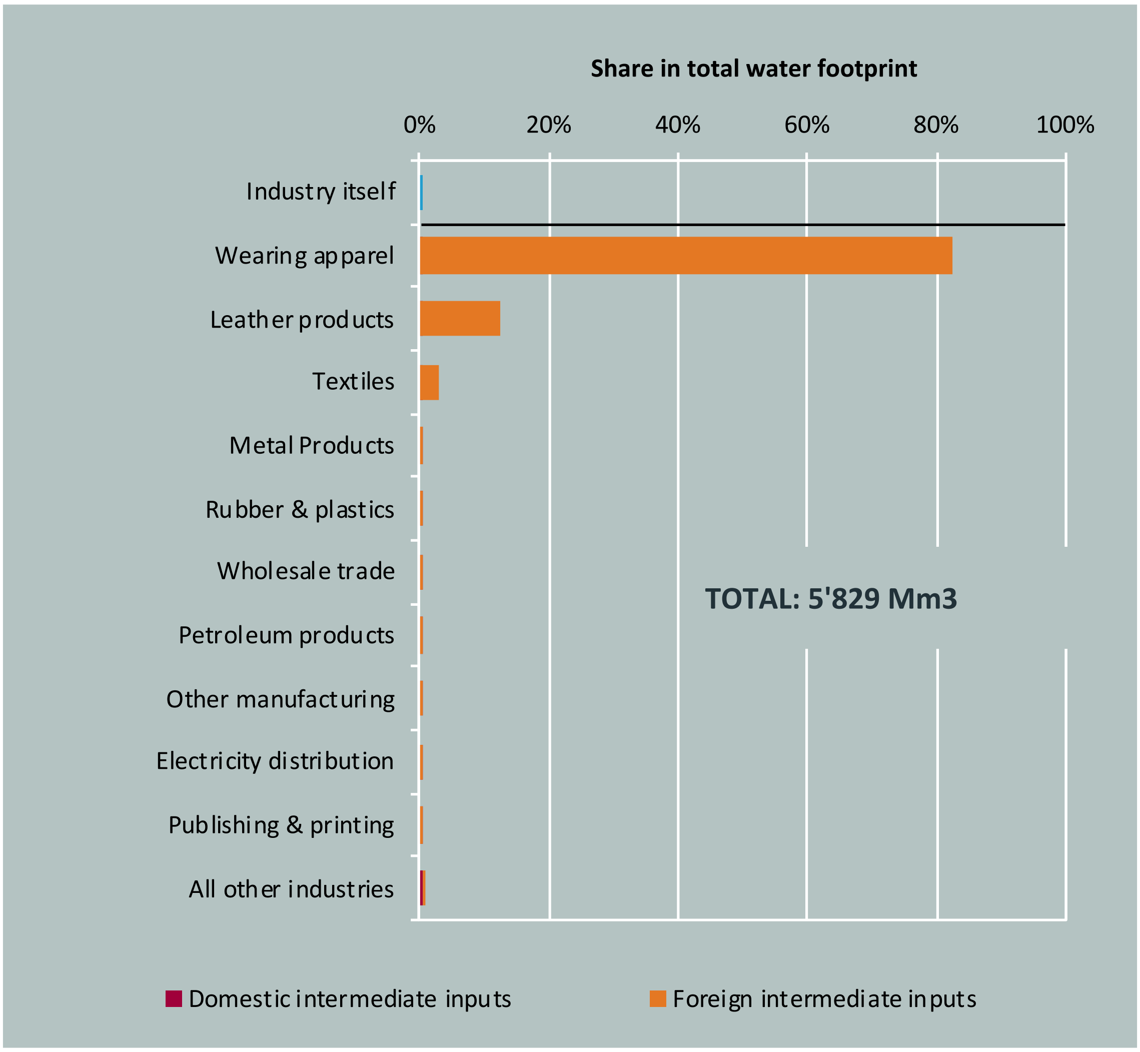

Figure 4.61: Water footprint caused by the direct suppliers of intermediate goods and services for the Swiss clothing trade industry (Source: Calculations Rütter Soceco)

Not surprisingly, almost 83 % of the water footprint is caused by wearing apparel suppliers[37], while leather product suppliers are responsible for 12 % and textiles producers (as direct suppliers to the Swiss clothing trade industry) for 4 %. These results confirm the intuition that clothing trade companies can fully focus on manufacturers of textiles, clothing and leather products as direct suppliers to optimise the environmental performance of their supply chain.

4.8.3.4 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

For the biodiversity and the eutrophication footprint raw material supply and especially agriculture are predominant. With regard to the country distribution, European countries are more prominent among the top ten countries for the eutrophication footprint as compared to the water footprint, even though their shares are small. The biodiversity footprint is spread among many countries. For the greenhouse gas footprint and the air emission footprint, the responsible industries are mainly electricity generation from fossil fuels and other energy use, mining and quarrying of energy carriers and minerals and water transport (regarding air emissions). The chemical industry, in which plastic fibres as another important raw material for clothing are produced, and clothing production also enter the top ten industries. With regard to the responsible countries of the supply chain, China dominates, followed by India, while the rest is distributed to many countries with much smaller emission shares.

4.8.3.5 Environmental footprint according to the ecological scarcity method

The total environmental footprint of the Swiss clothing trade industry is 3’932 billion eco-points. Nearly all of it is caused by imported goods (see Figure 4.62). The Swiss direct and indirect suppliers together cause only 3 % of the total environmental footprint, the industry itself 0.9 %.

[37] Without use phase. Water consumption for washing can account for more than half of the water consumption over the entire life cycle (Beton et al. 2014). In this study, the water and energy use for washing machines is considered in the use phase of household devices (see chapter 4.9).

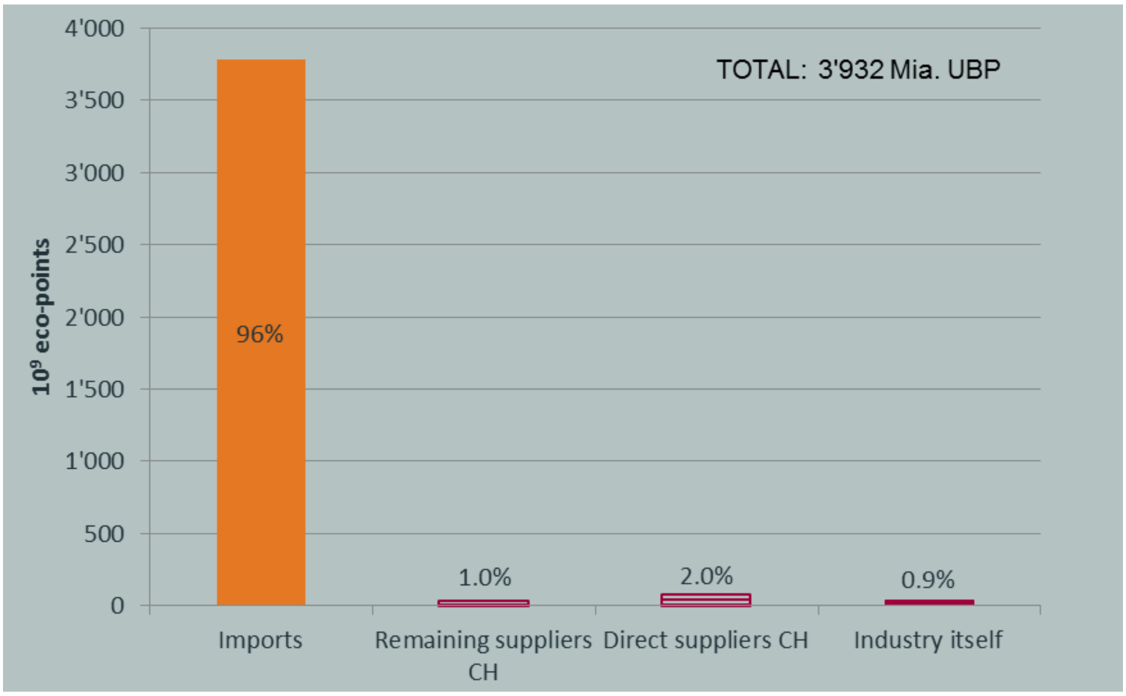

Figure 4.62: Environmental footprint in eco-points caused by the Swiss clothing trade industry by supply chain stages and imports (Source: Calculations treeze)

More than 70 % of the environmental impacts of the Swiss clothing trade industry are caused by the imports of articles of apparel and clothing accessories (see Figure 4.63). The import of footwear accounts for 7 % of the total environmental impacts. The ten most important contributors together are responsible for more than 85 % of the total environmental impacts of the traded clothes, textiles and footwear.

Most of the environmental footprint of imported clothing is due to the import of cotton products. About half of it can be attributed to the cultivation of cotton. The other half is generated during processing. About a third of the environmental footprint is due to the use of coal power in China.

The environmental footprint of footwear is due to the manufacturing of shoes. About 60 % of the impact stems from the electricity used for production, about 40 % comes from the tanned leather used. The chromium salts used for chrome tanning account for about 30 % of the environmental footprint of leather, another 20 % each stem from the rearing of the animals used as leather suppliers and process energy generation.

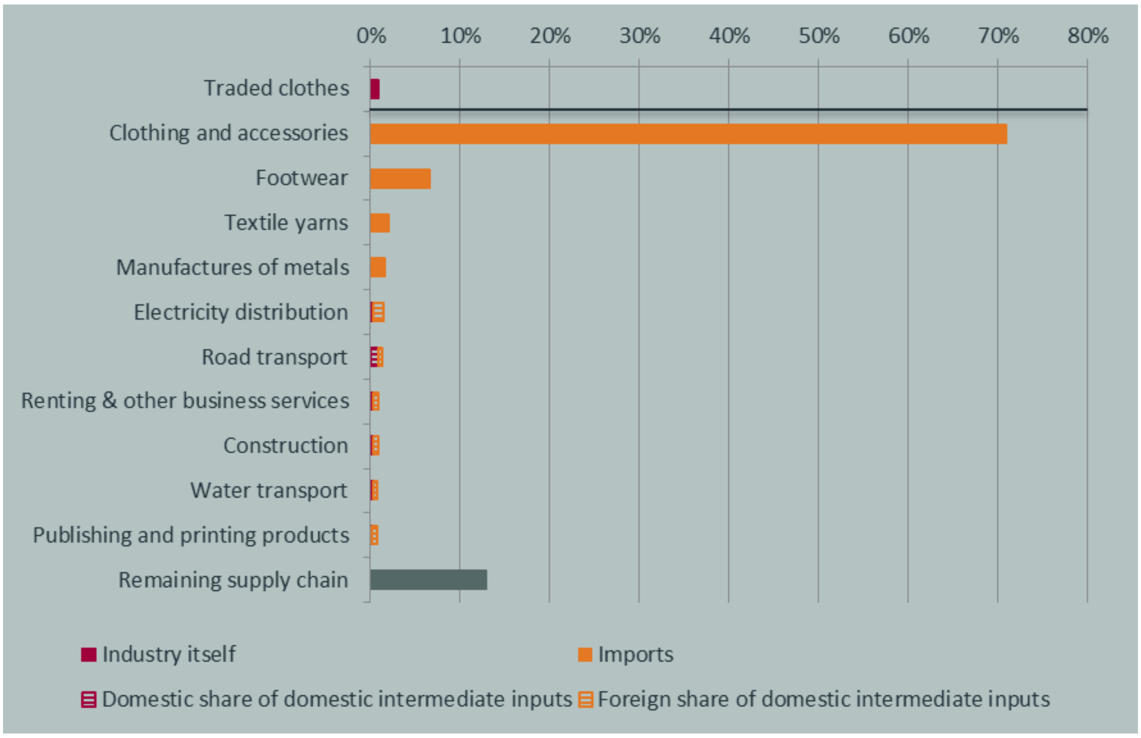

Figure 4.63: Environmental footprint caused by the direct suppliers of intermediate goods and services for the Swiss clothing trade industry. Remaining supply chain = all other direct suppliers (Source: Calculations treeze)

4.8.3.6 Conclusion

The environmental impacts of the Swiss clothing trade industry are completely dominated by imported clothes. About 70 % of the water and the total environmental footprints are due to the import of wearing apparel. For both indicators, the second most important contribution stems from the import of footwear, which amounts to more than 20 % of the water footprint and 7 % of the total environmental footprint. Contributions of Swiss direct suppliers or contributors outside the textile industry are negligible.

As a consequence, practically the entire water and total environmental footprints of the trade with clothes are generated abroad.

4.8.4 Comparison with the planetary boundaries

Figure 4.64 shows the share of the environmental footprints of the Swiss clothing trade industry in the respective global environmental footprints as well as the relative reduction needs. Of the environmental impacts analysed, the clothing trade industry contributes most to the air pollution and the greenhouse gas footprints. For those two indicators, but also for the eutrophication footprint, the industry's shares in the global environmental impacts exceed its share in global gross production value.

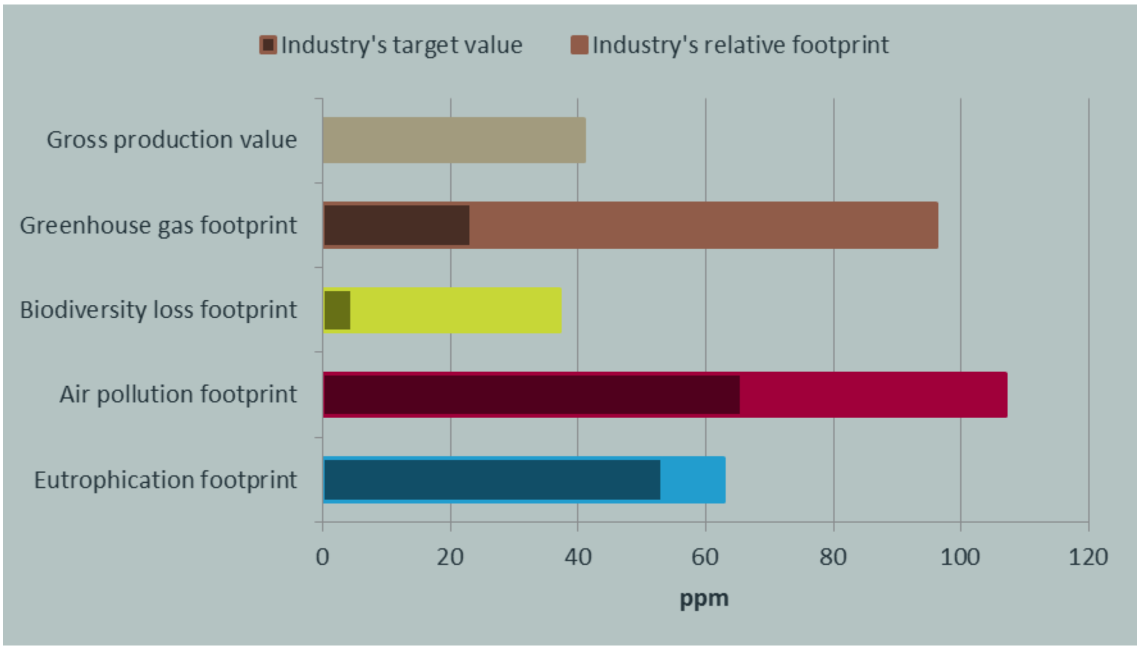

Figure 4.64: Share of environmental footprints caused by the Swiss industry 'Clothing trade' in global environmental footprints and respective planetary boundaries (Source: Calculations treeze)

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, for the Swiss 'Clothing trade' industry the greenhouse gas footprint is identified as priority field of action, followed by the air pollution and biodiversity loss footprints.

Table 4.22 shows the water footprint of the Swiss clothing trade industry, differentiated after country, and the share of renewable water supply used in the respective country. China and India account for over 50 % of the water footprint in Swiss clothing trade, with China making the largest contribution. In this country, the amount of sustainably usable water is almost reached, whereas in India it is exceeded by 17 %. Another 9 % and 8 % of the water footprint of the Swiss clothing trade industry occur in Turkey and the United States, where more than three quarters of the sustainable share are used. In total, over 50 % of the water consumption of the Swiss clothing trade industry takes place in countries with a higher water consumption than sustainably usable. Are countries like Turkey and the United states, where over three quarters of the sustainably usable share is used, included, over 70 % of the water footprint of the Swiss clothing trade industry takes places in countries with a critical water availability. In these countries, there is a need for action regarding the water footprint of the Swiss clothing trade industry.

Table 4.22: Water footprint of the Swiss clothing trade industry, differentiated after country and share of renewable water supply used in the respective countries

Country	Share of renewable water supply used	Water footprint Swiss clothing trade industry' [Mm^3]	Share of total water footprint of the Swiss clothing trade industry
China	20%	1585	27%
India	37%	1360	23%
Turkey	17%	500	9%
United States	16%	472	8%
Italy	24%	149	3%
Australia	5%	139	2%
Spain	29%	78	1%
Greece	13%	52	1%
Remaining countries and unspecified regions		1475	25%

4.8.5 Measures for reducing environmental impacts

4.8.5.1 Focal areas for measures

The most important starting point for reducing the environmental impacts of traded clothes, textiles and footwear is the production of cotton products. On one hand, the environmental impacts of cotton cultivation have to be reduced, on the other hand the impacts of the energy supply during production has to be tackled. Therefore, a sustainable supply chain management is necessary. Specific ecological requirements must be taken into account in purchasing criteria and specifications, e.g. by including environmental issues in framework agreements or a supplier code. Environmental topics can be anchored in regular target discussions with suppliers or joint projects can be implemented to identify suitable solutions for improvements. Another possibility is the replacement of critical raw materials through the use of more sustainable fibres (e.g. mechanically recycled polyester and nylon, organic flax and hemp, and recycled cotton and wool). For the best possible use of recycled fibres, fibre recovery without loss of quality should already be a central component of the design of a garment.

An important point is the increase in the service life of clothes. A high-quality manufacturing, the use of robust materials and a timeless design (keyword: slow fashion) can contribute to this. At the same time, consumers must be addressed. They can decisively foster the establishment of sustainably produced textiles through ecological purchasing and usage behaviour. This means, for example, targeted communication activities so that consumers regain awareness of how much work and resources are involved in the production of a piece of clothing. The aim is that consumers will value the quality of a garment again and the willingness to pay for ecological benefits is increased. The advantages of alternatives to cotton must also be communicated to suppliers and customers. For enhancing the life span of clothing, larger intervals between the different collections could be supportive as well and would furthermore give more room for innovation and development.

4.8.5.2 Monitoring parameters

- Sales and share of sales of cotton clothes made from sustainably produced cotton (i.e. with organic and Fairtrade labels)
- Proportion of recycled fibres in purchasing volume (yarns, fabrics, clothes)
- Amount of fossil energy carriers used in the supply chain per CHF revenue
- Share of known players in the supply chain
- Purchasing volume and share of suppliers reporting on their environmental impacts (e.g. environmental audits, sustainability assessments etc.)

4.8.5.3 Instruments and guidelines

- Initiatives
  - Swiss sustainable textiles initiative: https://www.bafu.admin.ch/bafu/de/home/themen/wirtschaft-konsum/fachinformationen/nachhaltige-textilien.html
  - Amfori BEPI and BSCI platform: https://www.amfori.org/content/amfori-bepi
  - Get changed! The fair fashion network: https://getchanged.net/
  - Organic cotton community platform: www.organiccotton.org
- Standards
  - All fibres
    - OEKO-TEX: https://www.oeko-tex.com
      - STEP (Sustainable Textile Production) over the whole supply chain
      - Standard 100
  - Natural fibres
    - Global Organic Textile Standard (GOTS): https://www.global-standard.org/de

        - Internationaler Verband der Naturtextilwirtschaft (IVN) certified BEST: https://naturtextil.de/qualitaetszeichen/qualitaetszeichenbest/
    - Cotton
        - Organic cotton (cultivation): bioRe: https://www.biore.ch/
        - Better cotton initiative (BCI): www.bettercotton.org
        - Cotton made in Africa (CmiA): http://www.cottonmadeinafrica.org/en/
        - Fairtrade cotton: https://www.fairtrade.net/products/cotton.html
    - Synthetic fibres
        - Bluesign system (Input Stream Management): https://www.bluesign.com
    - Recycled fibres:
        - GRS (Global Recycled Standard) and RCS 100 (Recycled Claim Standard) https://textileexchange.org/integrity/
        - Cradle to Cradle Certified: https://www.c2ccertified.org/
- Sustainability assessments and rankings:
    - Of fibres
        - Material snapshots and summaries: https://textileexchange.org/material-snapshots-and-summaries/
        - MADE-BY Benchmark for fibres: http://www.made-by.org/wp-content/uploads/2014/03/Benchmark_environmental_condensed_240118.pdf
        - Higg Materials Sustainability Index: https://msi.higg.org/page/msi-home
    - Of the cultivation of natural fibres
        - https://www.fibl.org/de/themen/smart/methode.html
    - Of companies in the textile sector:
        - Sustainable cotton ranking (WWF): http://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Report_Sustainable_Cotton_Ranking_2017.pdf
    - Concerning water: Water risk filter WWF: http://waterriskfilter.panda.org/; Water risk report: https://d2hawiim0tjbd8.cloudfront.net/downloads/wwf_guideline_cleaner_production_textile_2018.pdf

4.9 Trade with household devices

Trade with household devices is defined in this study as trade of household devices for household consumption. Starting point for the calculations are the household expenditures for these products according to the Swiss IOT. The economic and environmental footprints include retail and wholesale trade as well as production of household devices and their respective supply chains.

The industry 'Trade with household devices' thus includes the following activities with regard to household devices:

- Wholesale of electrical household appliances,
- Wholesale of computers, computer peripheral equipment,
- Wholesale of electronic and telecommunications equipment and parts,
- Retail sale of information and communication equipment in specialised stores,
- Retail sale of electrical household appliances in specialised stores,
- Retail sale via mail order houses or via Internet.

Wholesale trade may include international trade activities that are not related to household consumption and wholesale and retail trade may include sales to companies[38]. In 2015 the industry employed 48'000 people (FTE) corresponding to 1.2% of the entire Swiss workforce. Employment has declined since 2011 (see Table 4.23.

Table 4.23: Employment in trade with household devices (Source: FSO – STATENT).

Year	Employed persons (in FTE)	Share in total employment	Average annual growth rate	Average annual growth rate of Swiss workforce
2011	51'223	1.3%		
2015	48'313	1.2%	-1.5%	1.0%

4.9.1 Economic impact

The total value added induced by the Swiss trade with household devices industry amounts to 8'452 Mio. CHF[39]. Figure 4.65 shows how it is distributed across the different supply chain stages. The industry itself generates 27 % of the induced value added. While the direct suppliers (23 %) and the supply chain stages 'remaining upstream

[38] It is not possible to separate trade for households and for companies in the industry statistics.

[39] These and the following economic data refer to the year 2008.

chains' (48 %) are accountable for substantial value added shares, the fraction of value added imputable to raw material extracting industries (2 %) is almost negligible.

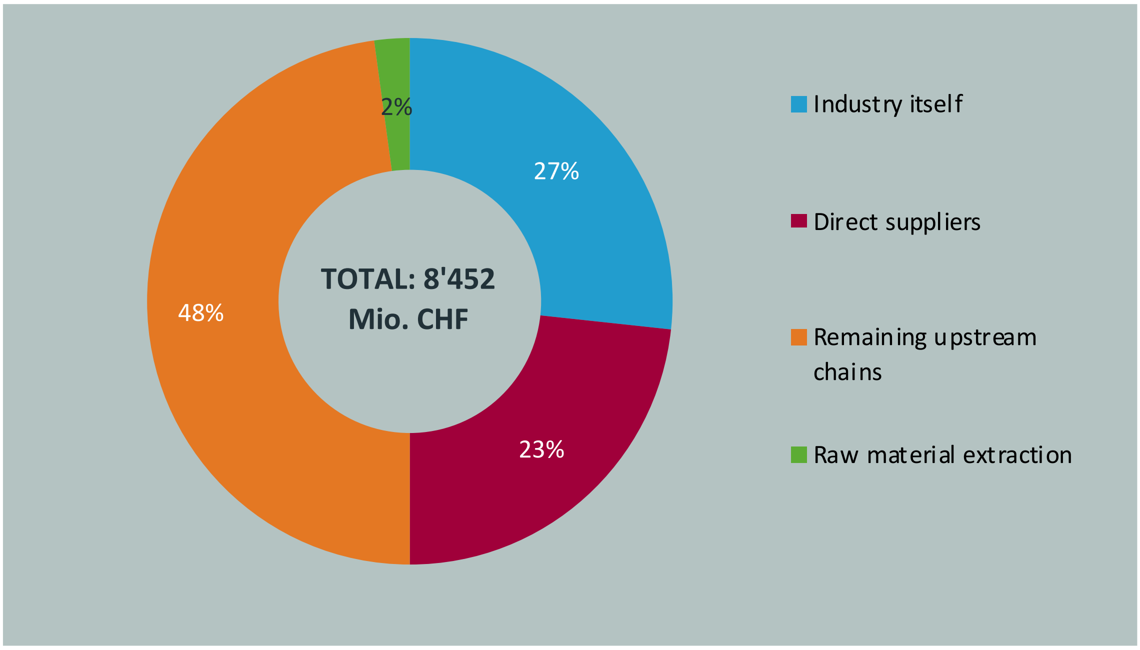

Figure 4.65: Total gross value added induced by the Swiss industry 'Trade with household devices', differentiated by supply chain stages (Source: Calculations Rütter Soceco)

In order to understand where - in geographical terms – the value added induced by the Swiss trade with household devices industry is generated, Figure 4.66 shows the shares of induced value added differentiated by countries and supply chain stages.

The upper section of the figure displays the share of value added generated by the industry itself (27 %) as well as the shares generated within domestic (22 %) and foreign (51 %) supply chains. More than half of the value added generated within the supply chains is created abroad while the rest is created in Switzerland.

Within the Swiss supply chains, the shares of value added generated by direct suppliers and industries in the remaining upstream chains are of similar size, whereas in the foreign supply chains the share of the direct suppliers is substantially lower. It also catches the eye that the share of value added induced in raw material extraction industries in foreign supply chains is considerably larger than in Swiss supply chains.

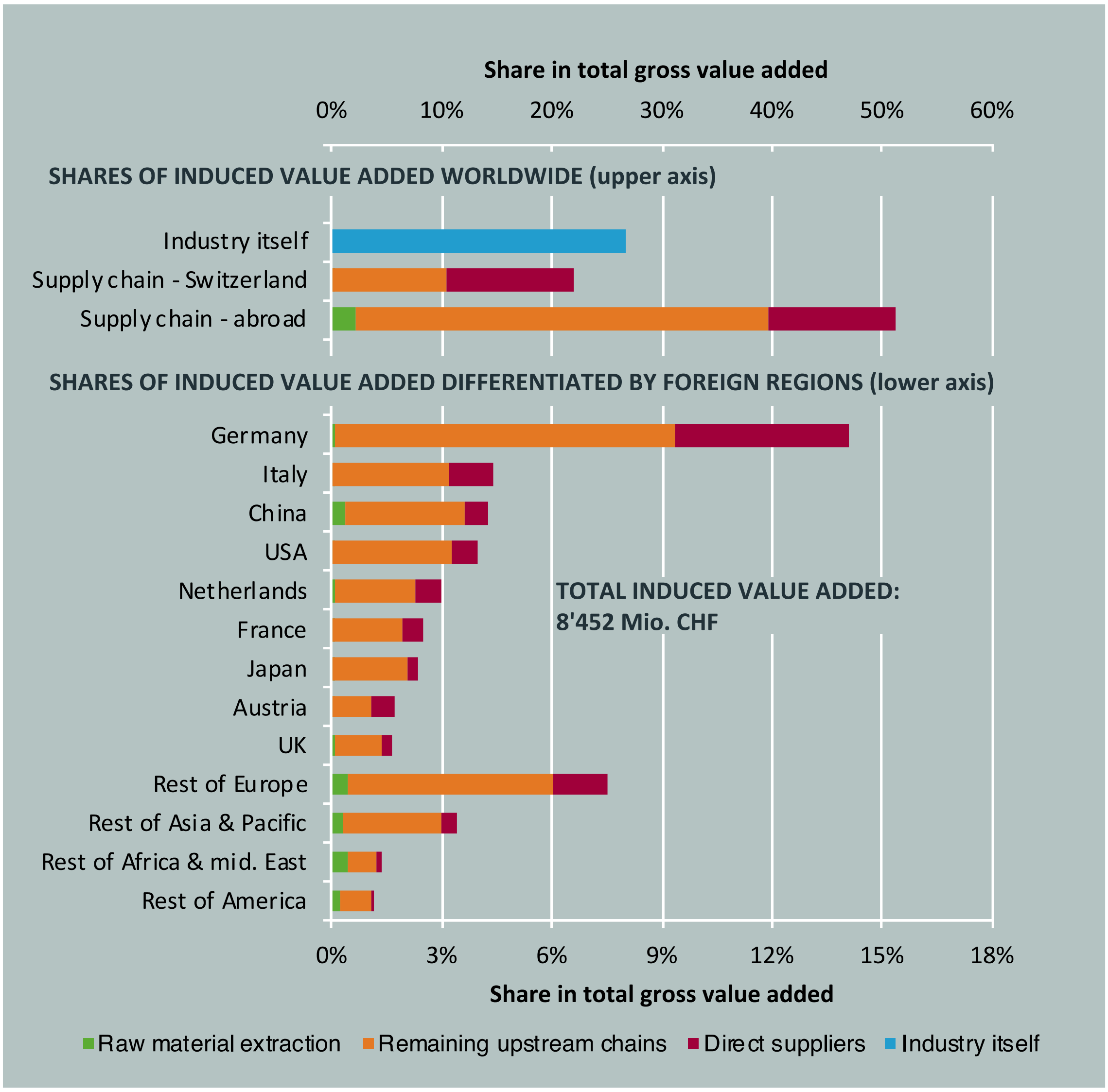

Figure 4.66: Total gross value added induced by the Swiss industry 'Trade with household devices', differentiated by supply chain stages and countries / regions (Source: Calculations Rütter Soceco)

Turning the attention to the lower part of Figure 4.66 one can see that Germany (14 % of the total valued added caused abroad) and the Italy (4 %) are those foreign countries in which the Swiss health industry induces the largest amounts of value added "creation". In terms of supply chain stages, it's noticeable that the largest portions of value added in raw material extraction industries are generated in Africa and the middle east, the rest of America, Asia and Europe as well as in China, whereas there is almost no value added created in raw material extracting industries amongst the European countries.

4.9.2 Environmental impacts

4.9.2.1 Overview

Table 4.24 contains an overview of the total environmental footprints caused by household devices trade in Switzerland. On the one hand the footprints are reported in absolute terms, on the other hand as intensities in relation to gross output as well as to gross value added of the industry itself. It should be noticed that the different footprints cannot be compared amongst each other since they are completely different measures with different units.

Table 4.24: Environmental footprints caused by the Swiss industry 'Trade with household devices' (Source: Calculations Rütter Soceco & Treeze).

Indicator	Unit	In absolute terms	Of which in the use phase	Of which in production	Per M CHF gross output (only production)	Per M CHF gross value added (only production)
Greenhouse gas footprint	kt CO_2 eq	3'908	1'227	2'681	0.77	1.19
Biodiversity footprint	nano PDF*a	1'398	14	1'384	0.40	0.61
Water footprint	Mm^3	1'376	608	768	0.22	0.34
Air pollution footprint	t PM_{10} eq	8'319	1'984	6'335	1.81	2.81
Eutrophication footprint	t N eq	1'447	120	1'327	0.38	0.59
Environmental footprint	G-eco Pt.	5'966	2'444	3'521	1.01	1.56
Gross output (industry itself)	M CHF	3'493				
Gross value added (industry itself)	M CHF	2'257				

Aiming to understand the supply chain stages in which the different environmental impacts take place, Figure 4.67 displays the share of supply chain stages in total impact as well as the share of the industry in the global impact for all footprints apart from the total environmental footprint (and value added/gross production value for comparison reasons). The figure also includes the environmental impacts from the use phase of the household devices (mainly electricity and water use for household appliances).

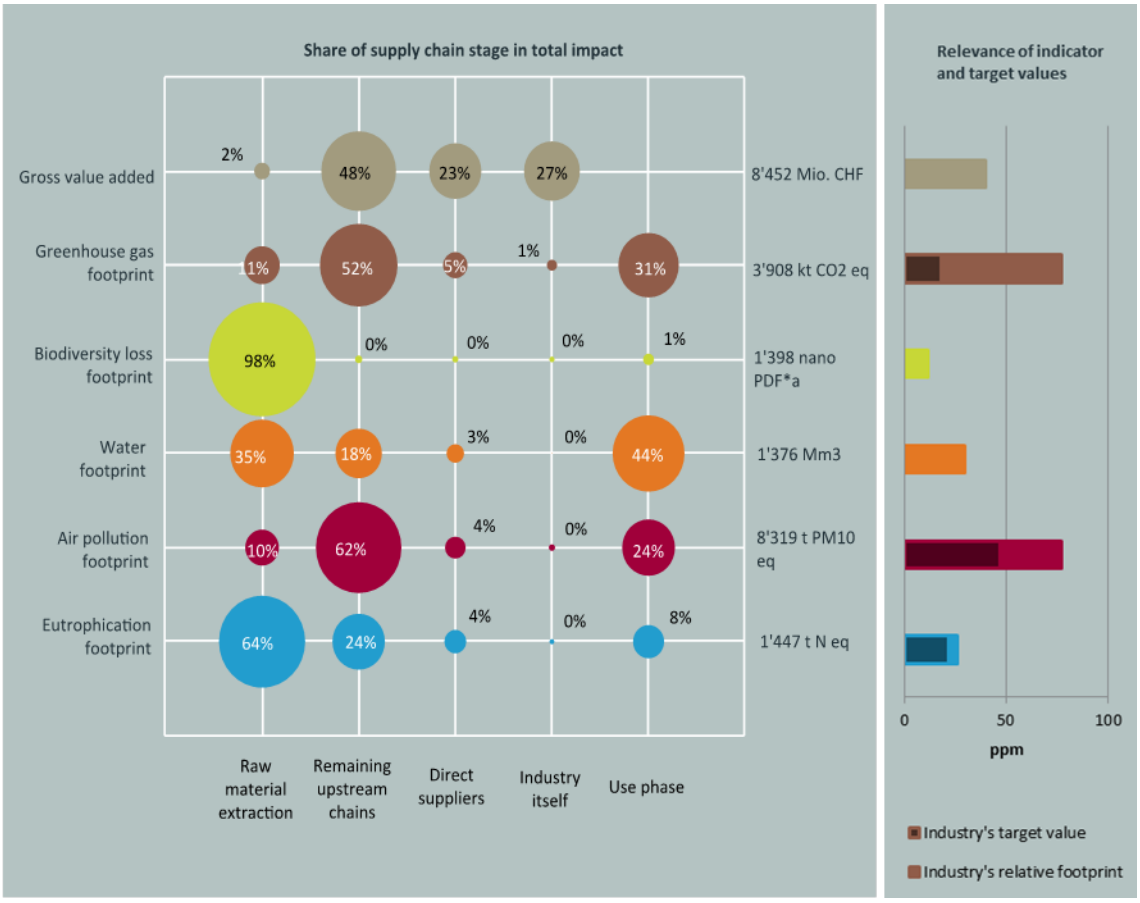

Figure 4.67: Environmental footprints caused by the Swiss industry 'Trade with household devices' by supply chain stages, share of the industry in global gross production value and global environmental footprints as well as the reduction necessary to comply with the planetary boundaries (Source: Calculations Rütter Soceco and treeze)

The use phase plays a significant role for several footprints. It accounts for 31 % of the greenhouse gas footprint, 44 % of the water footprint and 24 % of the air pollution footprint. Its share is much smaller for the biodiversity loss footprint and the eutrophication footprint. The influence of Swiss household device trade itself is negligible for all footprints. It is small for the direct suppliers of equipment trade, especially including the manufacturers of the household devices, who have footprint shares between 0 % and 5 %. Regarding the greenhouse gas and the air pollution footprint, the remaining upstream suppliers account for the major shares with 52 % and 62 % respectively. Their shares are still significant for the water and the eutrophication footprint (18 % and 24 % respectively). As is most other cases the raw material suppliers are responsible for most of the biodiversity and the eutrophication footprint (98 % and 64 % respectively). They account for 35 % of the water footprint.

The comparison of these results with the distribution of value added along the supply chain shows the specific environmental intensities of supply chain stages. The share of household device trade itself and its direct suppliers (50 %) is significantly larger than its footprint shares. The value added share of the remaining upstream chains is comparable to the greenhouse gas and the air pollution footprint shares, but larger than their other footprint shares. The share of raw material suppliers in the environmental footprints is generally larger than their value added share. Thus the environmental intensity of raw material suppliers is the highest among the supply chain stages, followed by the remaining upstream chains, and lowest for the trade industry and its direct suppliers.

The trade with household devices has large greenhouse gas and air pollution footprints (see Figure 4.67; share of the respective footprints in the global footprints compared to the share of the gross production value of the trade with household devices in the gross production of the entire global economy). Details on the necessary reduction in order to comply with the planetary boundaries can be found in section 4.9.3.

4.9.2.2 Focus on air pollution footprint

The focus footprint chosen for the Swiss household device trade industry is the air pollution footprint. As seen in Table 4.24 the global amount of air emissions induced by this industry adds up to 8’319 t PM_{10} eq.

Figure 4.68 highlights which industries of the supply chain (aggregated over all countries) emit the air pollutants. The largest emitter is the basic metals industry with 28 % of the total footprint followed by ‘electricity from fossil fuels’ which is accountable for another 20 %. Water transport, mining and quarrying and petroleum products are the next important industries. Overall basic industries, raw material extraction and energy generation dominate the results. The relevance of cattle and milk production is mainly due to food supply to the persons employed in the supply chain companies. Air pollution in the use phase is mainly due to electricity consumption. The figure shows which product groups contribute to the air pollution footprint.

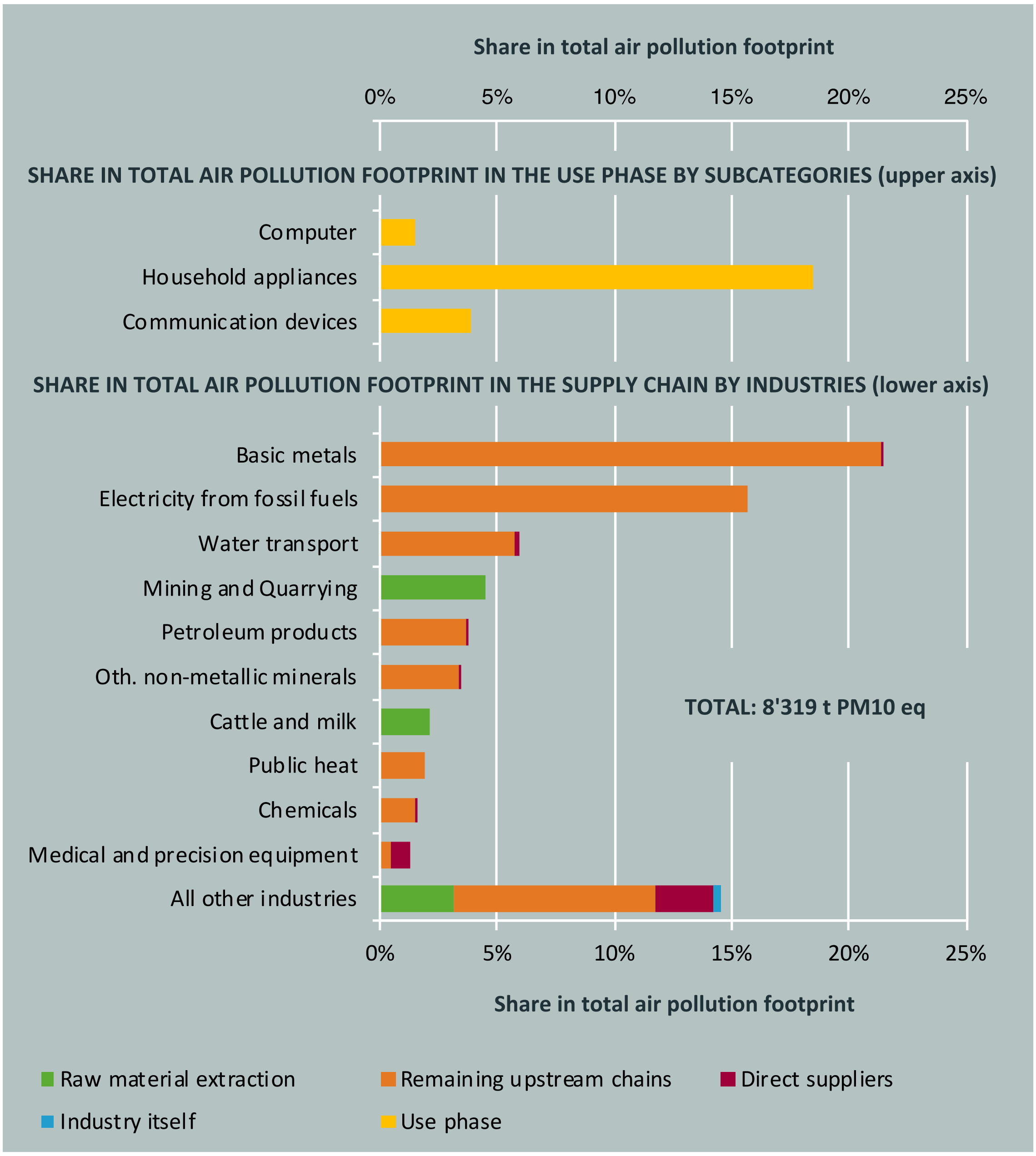

Figure 4.68: Air pollution footprint caused by the industry 'Trade with household devices' by supply chain stage and supplying industries (Source: Calculations Rütter Soceco)

Figure 4.69 illustrates how the responsible companies are distributed across supply chain stages and countries and again includes the use phase that occurs in Switzerland. The diagram shows that, apart from the use phase, only 2 % of the footprint are due to emissions in Switzerland, while the remaining emissions take place abroad.

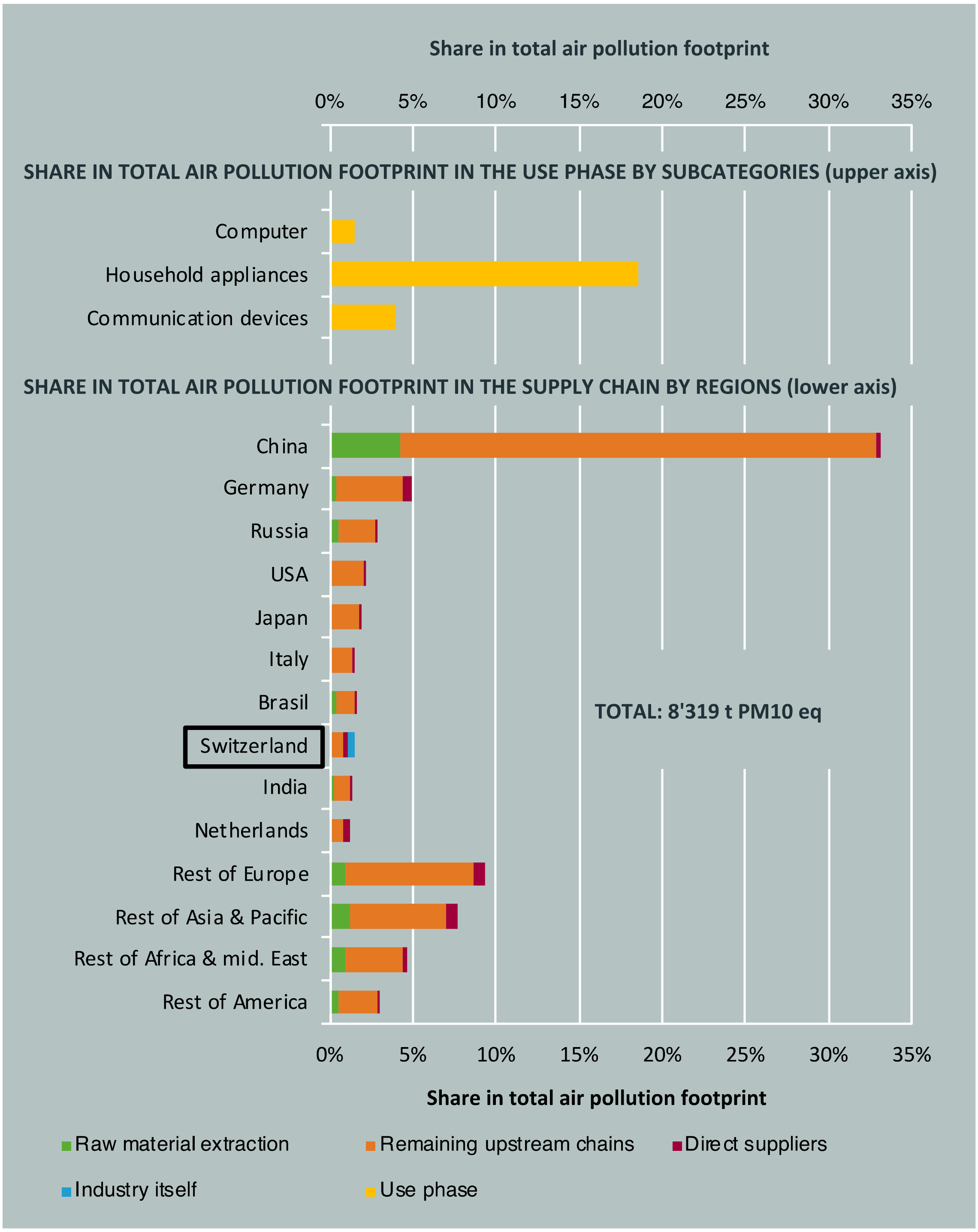

Figure 4.69: Air pollution footprint caused by the Swiss industry 'Trade with household devices', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

The country differentiation of air emissions reveals China, Germany, Russia and the US to be the largest foreign polluters in the context of the supply chains of Swiss household device trade with the share of China as an important exporter of household devices being especially large. In comparison to the value added distribution across countries (cf. Figure 4.66) China and Russia are ranked much higher when measuring in air emissions. This is due to the (in average) higher air emission intensities in those countries when compared to western countries such as Germany or the US. Non-specified countries account for approximately 35 % of the total footprint.

From a practical point of view it is useful to understand which direct intermediate inputs purchased by the Swiss household device trade industry are responsible (to what extent) for the total air emissions caused by the industry within the supply chains. The gained information should help the household device trade industry discovering their scope of action when trying to reduce the air emissions they cause in the supply chain. The analysis presented in Figure 4.70 allocates the air emissions caused by household device trade within the supply chain to domestic and foreign direct suppliers. For reasons of comparison the shares of household device trade (‘industry itself’) and of the use phase are also included.

The emissions are mainly caused by the household device manufacturers, situated in the machinery, communication equipment, office machinery, precision and electrical equipment industries. These are direct suppliers to the household device trade. Since household devices are mainly imported from foreign countries such as Germany, Italy or China, the respective suppliers are mainly located outside Switzerland.

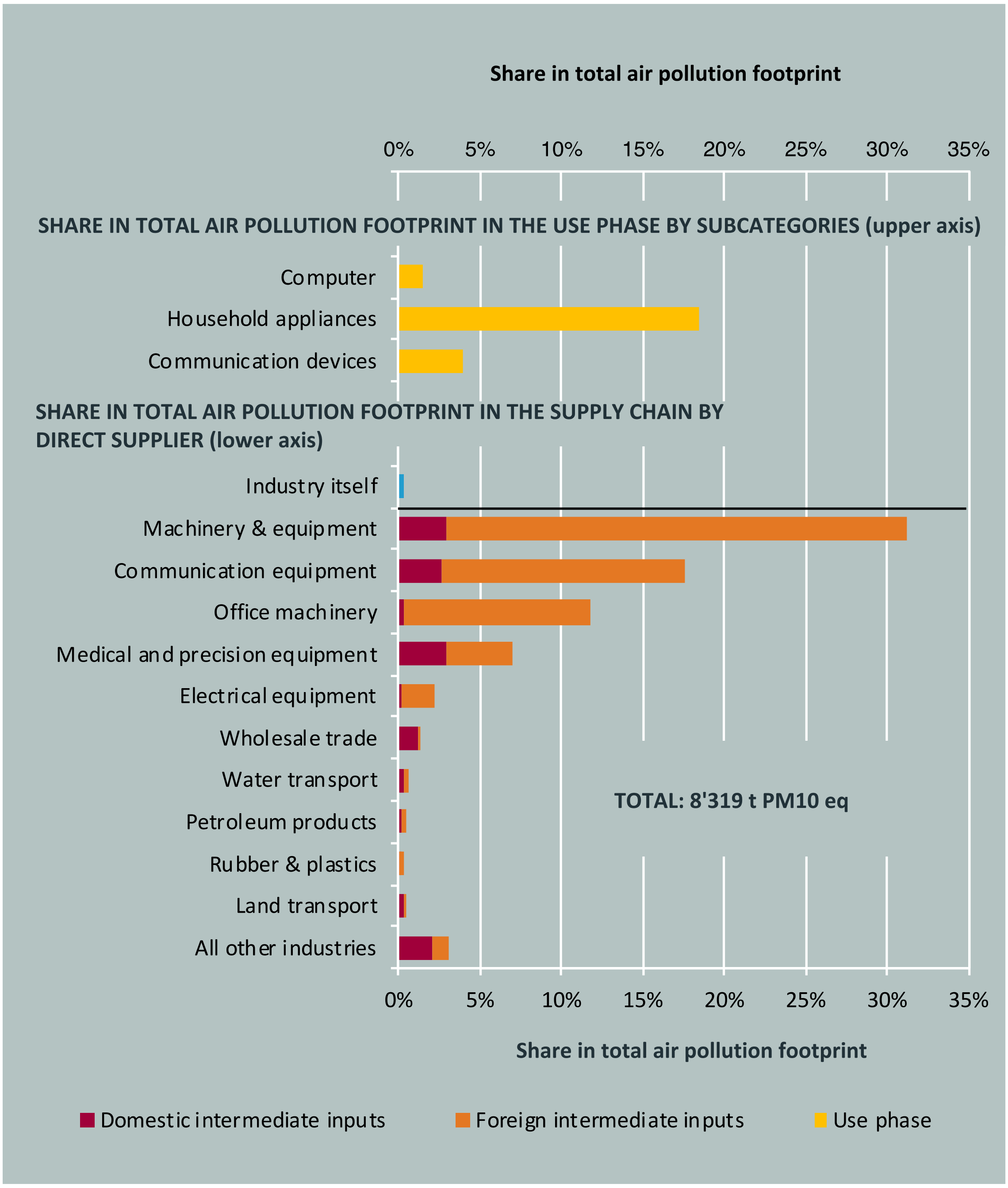

Figure 4.70: Air pollution footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Trade with household devices', the industry itself and the use phase (Source: Calculations Rütter Soceco)

4.9.2.3 Further environmental impacts

In the following the results for the other environmental impacts are briefly summarised. The respective figures can be found in the annex.

The greenhouse gas footprint is caused mainly by the following industries: Electricity from fossil fuels, basic metals, mining and quarrying and water transport. For the biodiversity and the eutrophication footprint raw material supply and especially agriculture are as usual predominant. However, for both footprints there are also other industries which are responsible for important fractions: forestry for the biodiversity footprint and disposal activities for the eutrophication footprint.

With regard to the country distribution, the greenhouse gas and the eutrophication footprint caused abroad are attributed to China, several European countries and the US. The footprints caused within Switzerland are substantial for the greenhouse gas and the eutrophication footprint.

4.9.2.4 Environmental footprint according to the ecological scarcity method

The total environmental footprint of the 'Trade with household devices' is 3'521 billion eco-points. Nearly all of it is caused by imported goods (Figure 4.71). The Swiss direct and indirect suppliers together cause only 3.5 % of the total environmental footprint, the industry itself only 0.9 %.

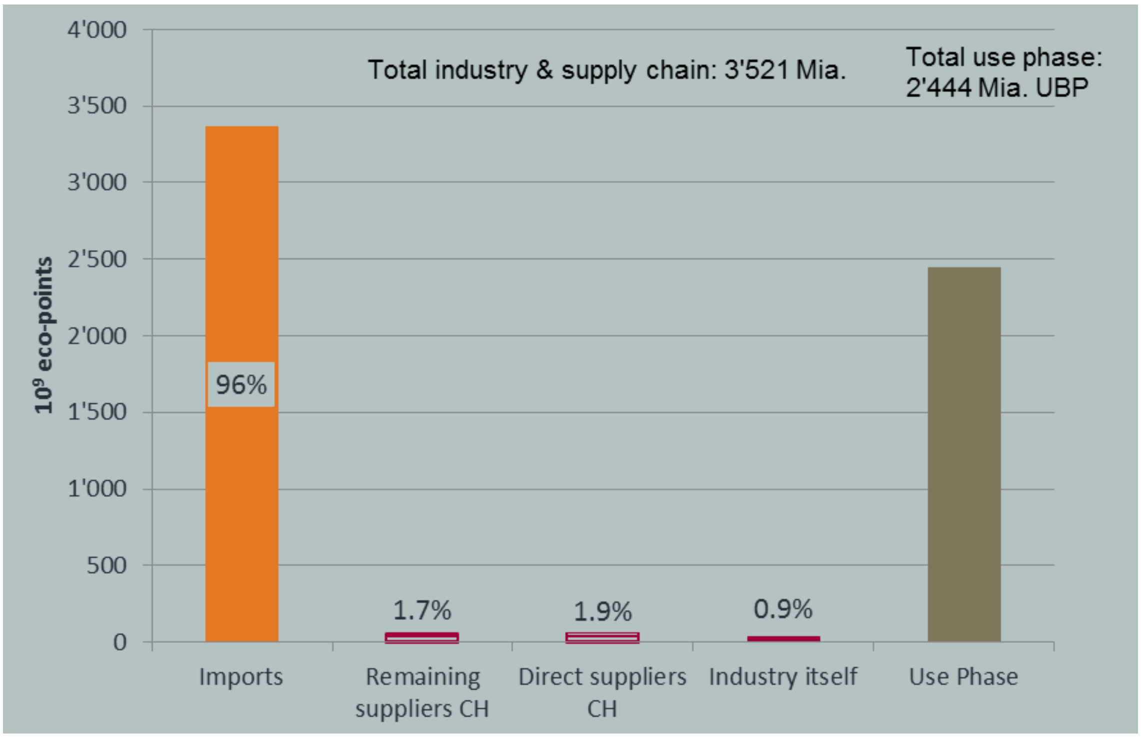

Figure 4.71: Environmental footprint in eco-points caused by the 'Trade with household devices' by supply chain stages and imports including the use phase of the household devices (Source: Calculations treeze)

The environmental footprint during the use phase of the household devices amounts to 2'444 billion eco-points per year. This is 69 % of the annually caused environmental footprint through the trade with household devices. The increased energy efficiency of household appliances, the relatively short lifetime of IT equipment, the still increasing market of appliances as well as the relatively clean electricity mix are reasons why the environmental impacts of the supply chain are higher than those of the use phase.

The ten largest contributors together explain more than 75 % of the environmental footprint of traded household devices (see Figure 4.72). The four largest contributions come from the import of ‘Telecommunications; sound apparatus and equipment’, ‘Electrical machinery, apparatus and appliances’, ‘Office and automatic data-processing machines’ and ‘General industrial machinery and equipment’. They contribute 18 %, 13 %, 12 % and 7 %, respectively, to the environmental footprint. Most of their footprint is caused by the raw material production (metals) and the energy use in manufacturing. The two most important Swiss industries are the ‘Machinery & equipment’ industry (described in detail in Subchapter 4.4) and the ‘Medical and precision equipment’ industry (including watches and optical products) with each 6 % of the environmental footprint. Also for those industries, most of the environmental impacts occur abroad and is due to metal production and energy use. The imports of ‘specialized machinery’ and ‘communication equipment’ cause about 5.5 % each of the total environmental impacts of household appliances. 2 % are caused by the use of electricity.

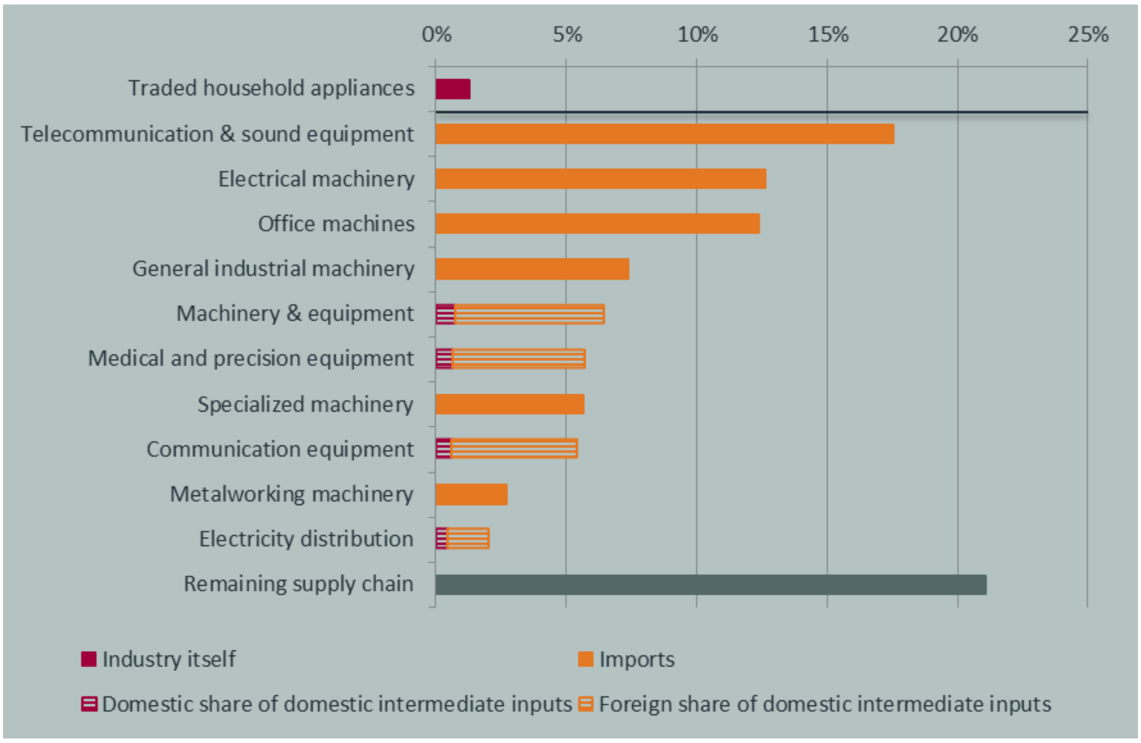

Figure 4.72: Environmental footprint caused by the direct suppliers of intermediate goods and services for the ‘Trade with household devices’. Remaining supply chain = all other direct suppliers (Source: Calculations treeze)

4.9.2.5 Conclusion

For both the air pollution and the total environmental footprint, the largest share of their impact occurs abroad. This is due to imported appliances and machinery. For both indicators, the most important direct contributors are the manufacturers of different household appliances such as (electrical) machinery, communication equipment, office machines and precision instruments, which are mainly located outside Switzerland.

The Swiss household device trade industry itself only generates less than one percent of its air pollution and total environmental footprint. Even if the use phase makes a significant contribution to the environmental impacts of household appliances, the contribution of the production phase is higher for all footprints.

4.9.3 Comparison with the planetary boundaries

Figure 4.73 shows the share of the environmental footprints of the Swiss industry 'Trade with household devices' in the respective global environmental footprints as well as the relative reduction needs. The Swiss 'Trade with household devices' industry contributes most to the greenhouse gas and the air pollution footprints. The contributions to the eutrophication and biodiversity loss footprint are smaller and below the industry's shares in the global gross production value.

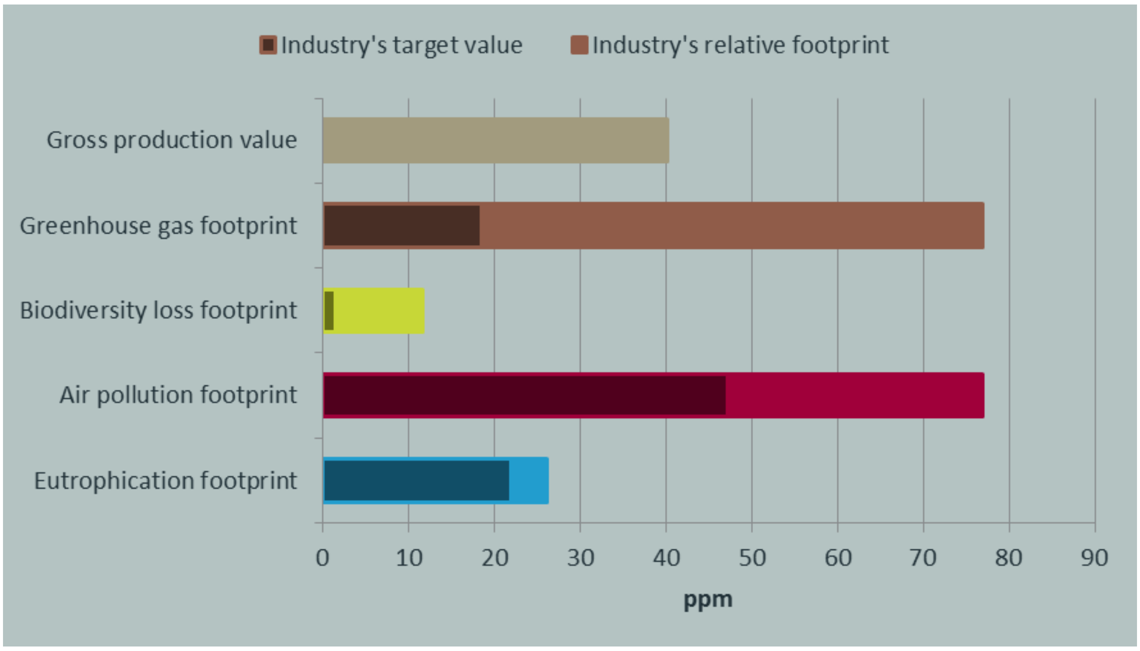

Figure 4.73: Share of environmental footprints caused by the Swiss industry 'Trade with household devices' in global environmental footprints and respective planetary boundaries (Source: Calculations treeze)

The biodiversity and the greenhouse gas footprint have the highest relative reduction needs. Taking into account the share of industry in the global impact and the relative need for reduction, for the Swiss 'Trade with household devices' industry the greenhouse gas footprint is identified as priority field of action, followed by the air pollution footprint.

Table 4.25 shows the water footprint of the industry ‘Trade with household devices’, differentiated after country, and the share of renewable water supply used in the respective country. Over 50 % of the water consumption of the industry ‘Trade with household devices’ occurs in China. In this country, the share of sustainably usable water is almost reached. Other countries with minor contributions to the water consumption of the industry ‘Traded household devices’, but a water consumption which is higher than the sustainably usable share, are India, Italy, Spain and South Africa. In the United States and Turkey, more than three quarters of the sustainably usable share are already used. In these countries, there is a need for action regarding the water footprint of the industry ‘Trade with household devices’.

Table 4.25: Water footprint of industry ‘Trade with household devices‘ differentiated after country and share of renewable water supply used in the respective countries

Country	Share of renewable water supply used	Water footprint industry ‘Trade with household devices’ [Mm^3]	Share of total water footprint of the industry ‘Trade with household devices’
China	20%	403	53%
India	37%	39	5%
Italy	24%	28	4%
United States	16%	25	3%
Spain	29%	14	2%
Turkey	17%	8	1%
Australia	5%	6	1%
Remaining countries and unspecified regions		236	31%

4.9.4 Measures for reducing environmental impacts

4.9.4.1 Focal areas for measures

Most of the environmental footprint of the traded household appliances is related to the production of the traded goods, many of them imported products. Metals used for the devices and energy use during production cause the most important contributions. The use phase of the traded goods augments their environmental footprint by two third[40]. Effective measures for reducing the environmental footprint of traded household appliances therefore include the production and use of the devices. Energy efficiency is important for both stages. For the traded goods, a sustainable supply chain management is essential, including the reduction of the environmental impacts of the raw materials (especially metals) used. Therefore, different possibilities exist (see chapter 4.3.5.1): Specific requirements e.g. related to energy efficiency must be taken into account in purchasing criteria and specifications, e.g. by including environmental issues in framework agreements or a supplier code. Environmental topics can be anchored in regular target discussions with suppliers or joint projects can be implemented to identify suitable solutions for improvements. Other possibilities are the replacement of critical raw materials, e.g. through the use of recycled materials, easily repairable devices or the maximization of the service life of the products.

4.9.4.2 Monitoring parameters

- Share of known players in the supply chain
- Share of purchased appliances from producers with known measures for reducing their environmental impacts (according to agreements with producer, certification schemes, collaboration with producer etc.)
- Amount of fossil energy used for the production of the appliances
- Share of products with a label related to a low energy use during use
- Energy use during the use of the products (kW per hour)

4.9.4.3 Instruments and guidelines

- Industry standards:
  - Fachverband Elektroapparate für Haushalt und Gewerbe Schweiz: http://www.fea.ch/de/oekologie/
- Energie-Agentur-Elektrogeräte: https://www.eae-geraete.ch/
  - Association of ICT providers Switzerland (SWICO): http://www.swico.ch/de/aktivitaeten/energieeffizienz
  - Digitaleurope: http://www.digitaleurope.org/Our-Work/Digital-Sustainability-Policy-Group
- Energy efficiency during use phase:

[40] The importance of the use phase varies depending on the device. In some cases, it can also be negligible ("production-relevant" devices, see Böni & Hischier (2018)

- Energieetikette: https://www.energieschweiz.ch/page/de-ch/energieetiketten/
- Energy efficient electronic devices: http://www.energystar.ch/
- Household appliances and TV sets: https://www.compareco.ch/de/
- Energy efficient and environmentally friendly products: https://www.topten.ch/

- Metal production
  - Guidelines from the International Council on Mining and Metals (ICMM): http://www.icmm.com/en-gb
  - Standards of the Aluminium Stewardship Initiative (ASI): https://aluminium-stewardship.org/

5 Synthesis

5.1 Economic impact

The analysis of economic impacts demonstrates how supply chains span across industries and countries for all analysed industries. Significant shares of total value added are induced in foreign countries. However the ratios of direct value added of the focal industries, of value added induced in Switzerland and abroad are very industry-specific and difficult to generalise. For most industries raw material extraction accounts for minor shares of induced value added. The results indicate the complexity of supply chains and hint to which suppliers in which industries and countries companies can address to manage their supply chains and to optimise their environmental performance.

5.2 Environmental footprints

The environmental footprints of the industries analysed are influenced by the size of the industries and by their environmental intensities. Table 5.1 gives an overview of the environmental footprints of all the eight industries that were analysed in detail and their share in the global footprints.

The environmental footprints of the industries are highly industry specific and difficult to generalise. The food related industries meat production and food trade cause significant environmental impacts with regard to almost all indicators, especially if measured by their environmental intensity per unit of value added. They cause particularly high eutrophication and biodiversity loss footprints. The industry ‘Food trade’ has the highest shares of its footprints in the global impacts (150 to 1400 ppm). This shows the high environmental intensity and relevance of food products.

Other industries clearly have their hotspots in greenhouse gas emissions and air pollution, especially real estate services, machinery and household equipment trade. ‘Real estate services’ is also an industry with relatively high shares in the global impacts (55 to 500 ppm). Its high greenhouse gas and air pollution footprints are due to its high needs in (fossil) energy in manufacturing building materials and during the use phase of the buildings.

For textiles trade the water and the greenhouse gas footprint are especially important. The chemical industry displays no clear focus, while the health and social work industry as a service industry is characterised by relatively lower but still substantial footprints.

Table 5.1: Overview of absolute environmental footprints and share of Swiss industries (incl. supply chain) in global footprints and global gross production value for the industries analysed in detail (Source: calculations Rütter Soceco & treeze)

NOGA	Industry	Gross value added	Gross prod. value	Greenhouse gas footprint		Biodiversity footprint		Water footprint	Air pollution footprint		Eutrophication footprint		Total Environmental footprint
		M CHF	ppm	kt CO_2 eq	ppm	nano PDF*a	ppm	Mm^3	t PM_{10} eq	ppm	t N eq	ppm	G-eco Pt.
15.1	Processing of meat	1'163	22	4'419	87	11'301	94	1'361	16'635	154	21'865	393	11'039
24 w/o 24.4	Chemical industry, w/o pharmaceutical industry	6'227	109	8'681	171	10'849	90	3'663	14'315	132	8'825	159	13'844
29	Manufacturing of machinery and equipment	12'462	233	10'031	197	5'602	47	2'348	23'090	213	4'859	87	13'853
70, 97	Real estate activities incl. private households	50’064	191	24’286	478	6’631	55	3’707	28’254	261	7’173	129	26’605
85	Health and social work	33'959	167	8'290	163	9'302	78	3'229	15'345	142	12'119	218	12'887
51-52	Food trade	10'066	154	15'681	309	76'519	638	25'587	48'734	450	76'578	1377	50'469
51-52	Textiles trade	2'730	41	4'890	96	4'441	37	5'829	11'582	107	3'492	63	3'932
51-52	Household equipment trade	2'257	40	3’908	77	1’398	12	1’376	8’319	77	1’447	26	5’966

With regard to the relevance of supply chain stages, the biodiversity, the water and the eutrophication footprints are dominated by raw material extraction and production, respectively. For the greenhouse gas and the air pollution footprint also other supply chain stages can be important, usually the intermediate suppliers between raw material extraction and direct suppliers. The effect of the industry itself is mostly small, if not negligible. The chemical industry has the highest share of own industrial emissions with 14 % of greenhouse gas emissions over the entire supply chain.

For many industries, most of the environmental impacts occur abroad. Exceptions are the ‘meat production’ industry, where a substantial share of its environmental impacts occurs in Switzerland and the industries ‘real estate services’ and ‘household devices trade’ that exhibit significant impacts in the use phase. The geographical proximity of environmental impact and triggering industry should simplify the introduction of improvement measures. It is more difficult for industries where a large part of the environmental impacts occur in far-off countries. An aggravating factor is that small demand for supply chain inputs in countries with high environmental intensities can strongly influence the overall environmental impact of the supply chain. For these industries, key data on their own supply chain and sustainable supply chain management are central.

5.3 Comparison with the planetary boundaries

The priority of the individual environmental indicators for the recommendation of reduction measures was determined on the basis of a combination of information on global reduction requirements and the share of the respective industry in the global impact. Across all eight focal industries, the greenhouse gas footprint proved to be the environmental impact with the highest priority for reduction measures. Except for the ‘Meat production’ and the ‘Food trade’ industries, the greenhouse gas footprint has the highest or second highest share in the global emissions for all industries analysed. Combined with the second highest global reduction requirements, mitigation measures regarding greenhouse gas emissions should have a high priority for all Swiss industries. For the two food-related industries (‘Meat production’ and ‘Food trade’), the biodiversity loss footprint was the indicator with the highest need for action. Even though the share of the biodiversity footprints of the Swiss industries in the global impact is not that high (rank 3 to 4), the high reduction requirement leads to a high priority of this indicator for food-related industries. This is explained by the high relevance of agriculture for the biodiversity loss. For other industries with a high need in food or other agricultural products (‘Production of chemical products’ and ‘Health and social work’ industries), the reduction of the biodiversity loss has the second highest priority (after the greenhouse gas footprint).

The share of the industries’ air pollution footprint in the global emissions is often similar to the share of the greenhouse gas footprint. This is most likely because similar processes contribute to both indicators (combustion of fossil fuels). As the global reduction need for the air pollution footprint is assumed to be lower than for the greenhouse gas footprint, this indicator has overall a lower priority for reduction measures. Furthermore, a reduction in greenhouse gas emissions will likely lead to a reduced air pollution footprint.

The indicator with – over all industries – the lowest priority for reduction measures is the eutrophication footprint. The reason for this is the low global reduction need for eutrophication. However, the Swiss reduction requirement for eutrophication is considerably higher than the global one. Given that for industries related with food products (Food trade', 'Meat production' and 'Health and social work'), their share in the global emissions is highest for eutrophication, reduction measures regarding eutrophication are particularly relevant for agriculture.

5.4 Measures for reducing environmental impacts

The measures aimed at reducing the environmental impact of Swiss companies can be categorised into two groups: On the one hand, there are measures within Switzerland to comply with the objectives of Swiss environmental policy and Swiss obligations; on the other hand, there are further measures being taken in the supply chain which often affect foreign companies. The results of this study show that in all industries, most of the environmental impacts do not occur in the industry itself, but in its supply chain. Measures to reduce the environmental impact of Swiss industries should therefore imperatively include the supply chains, regardless of whether the companies concerned are located in Switzerland or abroad.

As a first step, transparency over the supply chain should be created as far as possible. The main aim is to target those parts of the supply chain that are relevant from an environmental point of view. This knowledge allows the identification of hotspots in the supply chain and the development of targeted measures adapted to the respective manufacturer or raw material producer. At the end, supply chains that meet high ecological standards can be specifically developed. This can also include a simplification of the supply chain or a reduction in the number of suppliers.

For implementing environmental improvements in the supply chains, there are various options. Specific environmental requirements can be taken into account in purchasing criteria and specifications. For this purpose, framework agreements or supplier codes can be concluded, or compliance can be checked by presenting certificates or by audits of suppliers. Cooperation with suppliers can lead to knowledge transfer and capacity building among suppliers worldwide.

The products themselves are also an important area of action. Through longer lifespans, lower material consumption or the use of more sustainable product components product design changes can be an important lever for reducing environmental impacts in the supply chain. This field of measures has a high innovation potential both for the procuring company and the (pre-)suppliers and is especially relevant for industries with high impacts during the use phase.

For industries related with food production or food trade, agriculture is the most important stage to be addressed. Reducing food waste has major leverage effects.

A crucial area affecting all industries is energy supply. In order to reduce greenhouse gas emissions below the limits of the earth's carrying capacity, it is essential to replace fossil fuels with renewable energy sources at all stages of the supply chain and in the respective industry itself. This should be accompanied by measures to increase the energy efficiency. This applies not only to production but also to the use phase. The use phase can play a very large role in the environmental impact of a product (e.g. in buildings, but also in electrical appliances). Suitable production methods with the aim of minimising environmental impacts during the use phase can make major contributions to the compliance with the planetary boundaries.

6 Conclusions and outlook

6.1 Results

Most of the environmental impacts of Swiss industries occur in their supply chain, often abroad. To reduce the environmental impacts, Swiss industries should therefore include their supply chains and e.g. implement multilateral action plans.

Specific knowledge of the own supply chain is essential for identifying individual environmental hotspots and developing measures. Companies can use the information gained in this study as a starting point for analysing their environmental hotspots.

Specific life cycle assessments can help to identify environmental hotspots in supply chains of individual companies and to monitor the effectiveness of improvement measures. However, large differences in environmental intensities require high geographical resolution of supply chain information.

Exiobase delivers high country and industry resolution and extensive environmental data. The data used in this study have global coverage and make it possible to address selected thematic environmental footprints. However, the global capture of Swiss supply chains requires large amounts of data. Uncertainties exist primarily due to the uncertainties in the basic data and the evaluation for individual industries is partly at the limit of the available data resolution. Plausibility checks and a 'critical' use of the results are therefore very important. The use of two different methods for calculating the environmental impacts made detailed plausibility checks possible, but was also very time-consuming.

6.2 Outlook

The integration of a sustainable supply chain management in the corporate environmental management and environmental reporting of Swiss companies should be further promoted and advanced.

As a further step, policy measures (e.g. border compensation levies on greenhouse gas emissions) should be examined. For facilitating the identification of hotspots regarding water scarcity and biodiversity loss, automated tools, where the relevant data is readily provided, should be developed.

On the part of the data basis, the data quality in the economic and the environmental part of MRIOT should further be improved. The inclusion of a wider range of pollutants and resources in the EE-MRIOT would lead to a more comprehensive data base for environmental analyses and e.g. allow assessing further environmental impacts.

Furthermore, improved and more regionalised Life Cycle Inventory data on production could further enhance the accuracy of the results obtained.

References

Beton A., Dias D., Farrant L., Gibon T., Guern Y. L., Desaxce M., Perwueltz A. and Boufateh I. (2014) Environmental Improvement Potential of textiles (IMPRO Textiles). Joint Research Centre (JRC), Luxembourg.

Böni H. and Hischier R. (2018) Weiter- und Wiederverwendung von elektrischen und elektronischen Geräten. Ökologische und ökonomische Analyse. Schlussbericht. Empa, St. Gallen.

Boulay A.-M., Bare J., Benini L., Berger M., Lathuillière M., Manzardo A., Margni M., Motoshita M., Núñez M., Pastor A. V., Ridoutt B., Oki T., Worbe S. and Pfister S. (2017) The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on Available WAter REmaining (AWARE). In: The International Journal of Life Cycle Assessment, pp. 1-11, 10.1007/s11367-017-1333-8.

Bundesrat S. (2017) Massnahmen an der Quelle zur Reduktion der Mikroverunreinigungen in den Gewässern. Bericht des Bundesrates in Erfüllung des Postulats 12.3090 Hêche vom 7. März 2012, Bern.

CDP, WRI and WWF (2015) SECTORAL DECARBONIZATION APPROACH (SDA): A method for setting corporate emission reduction targets in line with climate science, retrieved from: www.sciencebasedtargets.org/downloads.

CDP, United Nations Global Compact, WRI and WWF (2017) Science-based Target Setting Manual. 4/4/2017, Version 3.0. Carbon Disclosure Project, United Nations Global Compact, Word Resources Institute, World Wide Fund for Nature, Geneva.

Chaudhary A., Verones F., de Baan L. and Hellweg S. (2015) Quantifying Land Use Impacts on Biodiversity: Combining Species–Area Models and Vulnerability Indicators. In: Environmental Science & Technology, 49(16), pp. 9987-9995.

Chaudhary A., Pfister S. and Hellweg S. (2016) Spatially Explicit Analysis of Biodiversity Loss due to Global Agriculture, Pasture and Forest Land Use from a Producer and Consumer Perspective. In: Environmental Science & Technology, 50, pp. 3928–3936.

COSO and WBCSD (2018) Enterprise Risk Management. Applying enterprise risk management to environmental, social and governance-related risks. Preliminary Draft. Committee of Sponsoring Organizations of the Treadway Commission, World Business Council for Sustainable Development.

Dao H., Friot D., Peduzzi P., Bruno C., Andrea D. B. and Stefan S. (2015) Environmental limits and Swiss footprints based on Planetary Boundaries. UNEP/GRID-Geneva & University of Geneva, commissioned by the Swiss Federal Office for the Environment (FOEN), Geneva, Switzerland.

Daub C.-H., Winistörfer H. and Weber M.-C. (2016) Umweltziele von Unternehmen in der Schweiz. Fachhochschule Nordwestschweiz / Zürcher Hochschule für Angewandte Wissenschaften, Olten / Winterthur.

Droz H. and Hellweg P. D. S. (2018) Analyse der Umweltwirkung der MEM-Industrie. ETH Zürich, Zürich.

ecoinvent Centre (2010) ecoinvent data v2.2, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland, retrieved from: www.ecoinvent.org.

European Commission (2011) A renewed EU strategy 2011-14 for Corporate Social Responsibility COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, Brussels, Belgium, retrieved from: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0681:FIN:EN:PDF.

European Commission (2014) DIRECTIVE 2014/95/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. In: L 330/1 (ed. Commission E.), Brussels.

Frischknecht R. and Büsser Knöpfel S. (2013) Swiss Eco-Factors 2013 according to the Ecological Scarcity Method. Methodological fundamentals and their application in Switzerland. Environmental studies no. 1330. Federal Office for the Environment, Bern, retrieved from: http://www.bafu.admin.ch/publikationen/publikation/01750/index.html?lang=en.

Frischknecht R., Nathani C., Stolz P., Wyss F. and Itten R. (2015) Extension of a Disaggregated Input-Output Table with Environmental Data for the Year 2008. treeze Ltd / Rütter Soceco AG, commissioned by the Swiss Federal Office for the Environment (FOEN), Uster / Rüschlikon, Switzerland.

Frischknecht R. and Jolliet O. (ed.) (2016) Global Guidance on Environmental Life Cycle Impact Assessment Indicators, Volume 1. United Nations Environment Programme, UNEP, Paris.

Frischknecht R., Messmer A., Stolz P. and Tuchschmid M. (2016) mobitool - Grundlagenbericht. Hintergrund, Methodik & Emissionsfaktoren. Schweizerische Bundesbahnen SBB, Bundesamt für Energie BFE, Swisscom, Öbu, Bern, retrieved from: http://www.mobitool.ch/typo_static/fileadmin/tools/mobitool-Hintergrundbericht.pdf.

Frischknecht R., Nathani C., Alig M., Stolz P., Tschümperlin L. and Hellmüller P. (2018a) Umwelt-Fussabdrücke der Schweiz: Zeitlicher Verlauf 1996-2015. treeze Ltd / Rütter Soceco AG, im Auftrag des Bundesamts für Umwelt (BAFU), Uster / Rüschlikon.

Frischknecht R., Nathani C., Alig M., Stolz P., Tschümperlin L. and Hellmüller P. (2018b) Umwelt-Fussabdrücke der Schweiz: Zeitlicher Verlauf 1996-2015 - Technischer Bericht. treeze Ltd / Rütter Soceco AG, commissioned by the Swiss Federal Office for the Environment (FOEN), Uster / Rüschlikon.

Fuglestvedt J. S., Shine K. P., Berntsen T., Cook J., Lee D. S., Stenke A., Skeie R. B., Velders G. J. M. and Waitz I. A. (2010) Transport impacts on atmosphere and climate: Metrics. In: Atmospheric Environment, 44(2010), pp. 4648–4677.

Goedkoop M., Heijungs R., Huijbregts M. A. J., De Schryver A., Struijs J. and van Zelm R. (2009) ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition. Report I: Characterisation, NL, retrieved from: lcia-recipe.net/.

Höhne N., den Elzen M. and Escalante D. (2014) Regional GHG Reduction Targets Based on Effort Sharing: A Comparison of Studies. In: Climate Policy, 14(1), pp. 122-147.

IPCC (2007) The IPCC fourth Assessment Report - Technical Summary. Cambridge University Press., Cambridge.

Jungbluth N., Nathani C., Stucki M. and Leuenberger M. (2011) Environmental impacts of Swiss consumption and production: a combination of input-output analysis with life cycle assessment. Environmental studies no. 1111. ESU-services Ltd. & Rütter + Partner, commissioned by the Swiss Federal Office for the Environment (FOEN), Bern, CH, retrieved from: www.esu-services.ch/projects/ioa/ or www.umwelt-schweiz.ch.

Jungmichel N., Schampel C. and Weiss D. (2017) Umweltatlas Lieferketten - Umweltwirkungen und Hot-Spots in der Lieferkette. adelphi / Systain, Berlin / Hamburg.

KBOB, eco-bau and IPB (2016) KBOB Ökobilanzdatenbestand DQRv2:2016; Grundlage für die KBOB-Empfehlung 2009/1:2016: Ökobilanzdaten im Baubereich, Stand 2016. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: www.ecoinvent.org.

Kissling-Näf I., Bernath K., Seyler C., Fussen D., Jungbluth N. and Stucki M. (2013) RessourcenEFFizienz Schweiz REFF; Grundlagenbericht zur Ressourceneffizienz und Rohstoffnutzung. Ernst Basler & Partner, ESU-services GmbH, Zürich.

Lee D. S., Pitari G., Grewe V., Gierens K., Penner J. E., Petzold A., Prather M. J., Schumann U., Bais A., Berntsen T., Iachetti D., Lim L. L. and Sausen R. (2010) Transport impacts on atmosphere and climate: Aviation. In: J Atmosenv, 2010(44), pp. 4678–4734, 10.1016/j.atmosenv.2009.06.005, retrieved from: http://ac.els-cdn.com/S1352231009004956/1-s2.0-S1352231009004956-main.pdf?_tid=2127a67595d8edf6c516e912c49c4240&acdnat=1333532417_ad6f8409ad87089beac3d618cce3f283.

LRV (2009) Luftreinhalte-Verordnung vom 16. Dezember 1985 (LRV): (Stand am 1.1.2009). 814.318.142.1. Schweizerischer Bundesrat, retrieved from: www.admin.ch/ch/d/sr/c814_318_142_1.html.

Messmer A. and Frischknecht R. (2016a) Life Cycle Inventories of Air Transport Services. treeze Ltd., Uster.

Messmer A. and Frischknecht R. (2016b) Umweltbilanz Strommix Schweiz 2014. treeze Ltd., Uster.

Nathani C., Stolz P., Tribaldos T., Schmid C., Schneider M., Frischknecht R., Itten R., Wyss F. and Kopainsky B. (2016) Estimation of a Swiss environmentally extended input-output table with a disaggregated agri-food sector. Rütter Soceco AG / treeze Ltd. / Flury & Giuliani, Rüschlikon / Uster / Zürich.

Nemecek T., Bengoa X., Lansche J., Mouron P., Riedener E., Rossi V. and Humbert S. (2015) Methodological Guidelines for the Life Cycle Inventory of Agricultural Products. Quantis and Agroscope, Lausanne and Zurich, Switzerland.

Sabag Muñoz O. and Gladek E. (2017) One planet approaches. Methodology mapping and pathways forward. Metabolic, Amsterdam.

Steffen W., Richardson K., Rockström J., Cornell S. E., Fetzer I., Bennett E. M., Biggs R., Carpenter S. R., de Vries W., de Wit C. A., Folke C., Gerten D., Heinke J., Mace G. M., Persson L. M., Ramanathan V., Reyers B. and Sörlin S. (2015) Planetary boundaries: Guiding human development on a changing planet. In: Science, 347(6223), pp. 736-747.

treeze Ltd. (2017) Life cycle inventory database: datasets compliant with ecoinvent protocol v2 and provided in EcoSpold v1 data format. treeze Ltd., Uster, CH, retrieved from: www.treeze.ch.

United Nations (2015) Resolution adopted by the General Assembly on 25 September 2015: Transforming our world: the 2030 Agenda for Sustainable Development. United Nations General Assembly, New York, USA.

A Annex

A.1 Meat processing

A.1.1 Greenhouse gas footprint

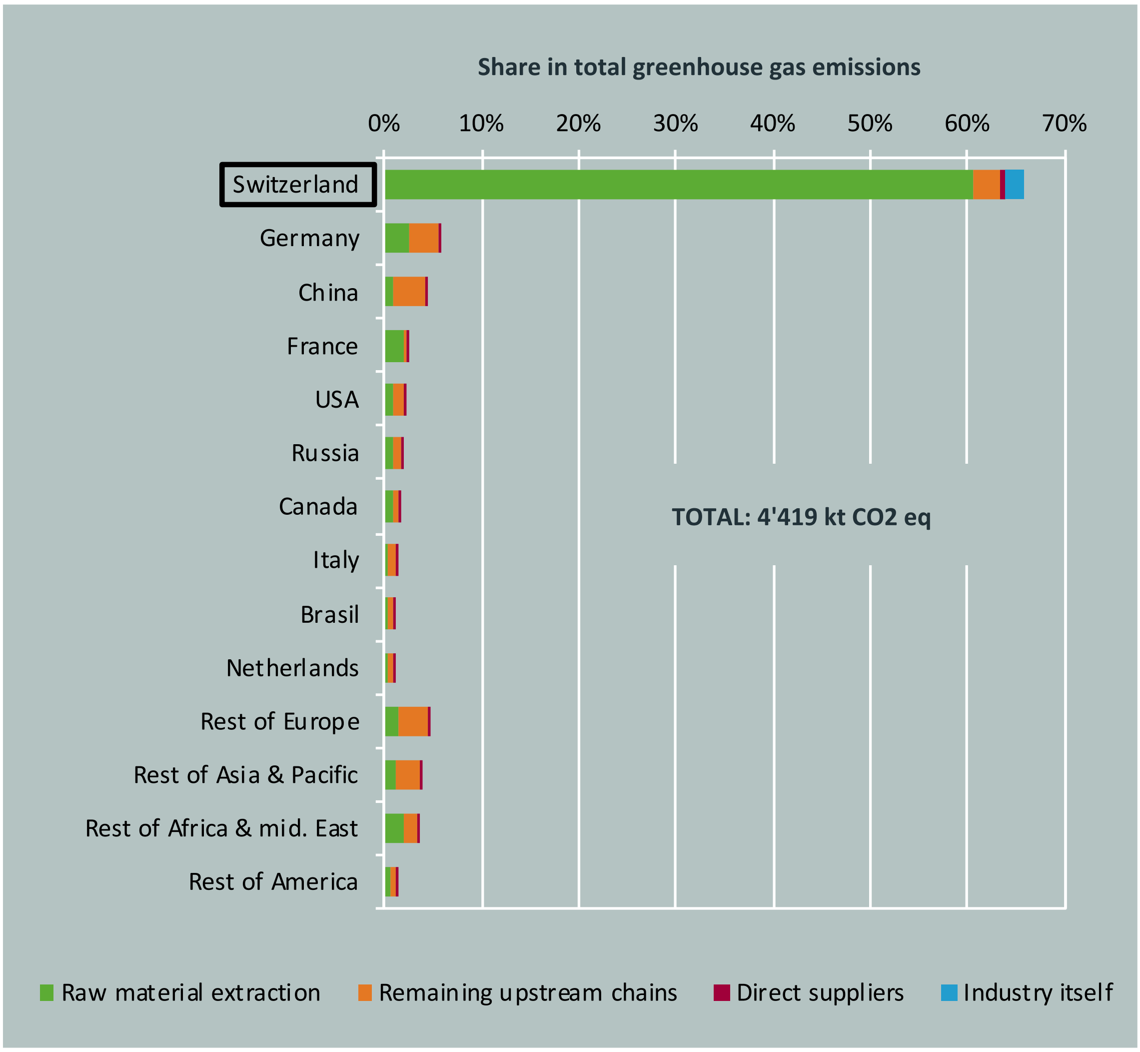

Fig. A.1.1.1: Greenhouse gas footprint caused by the Swiss industry 'Meat processing', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

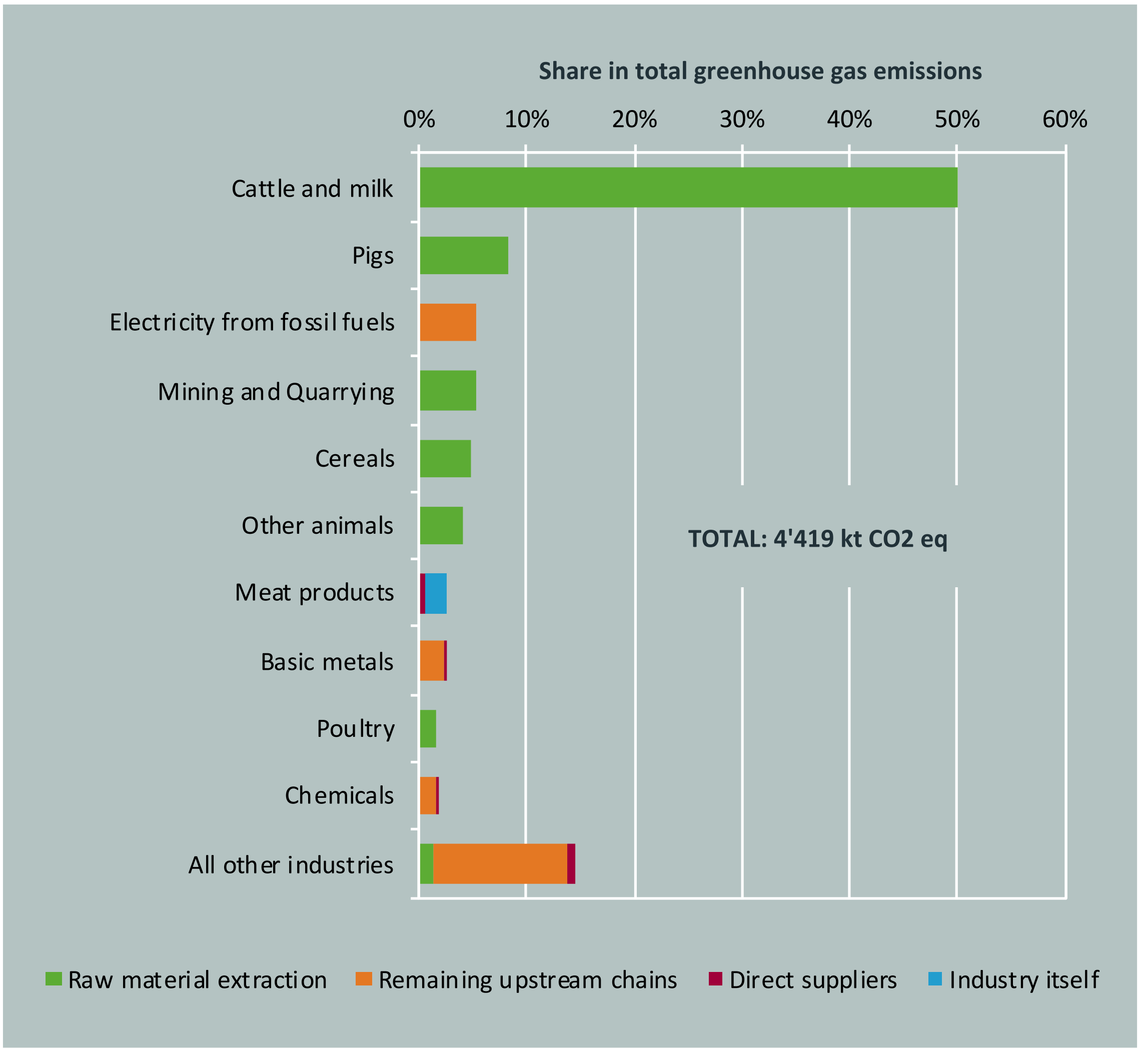

Fig. A.1.1.2: Greenhouse gas footprint caused by the industry ‘Meat processing’ by supply chain stage and industry (Source: Calculations Rütter Soceco)

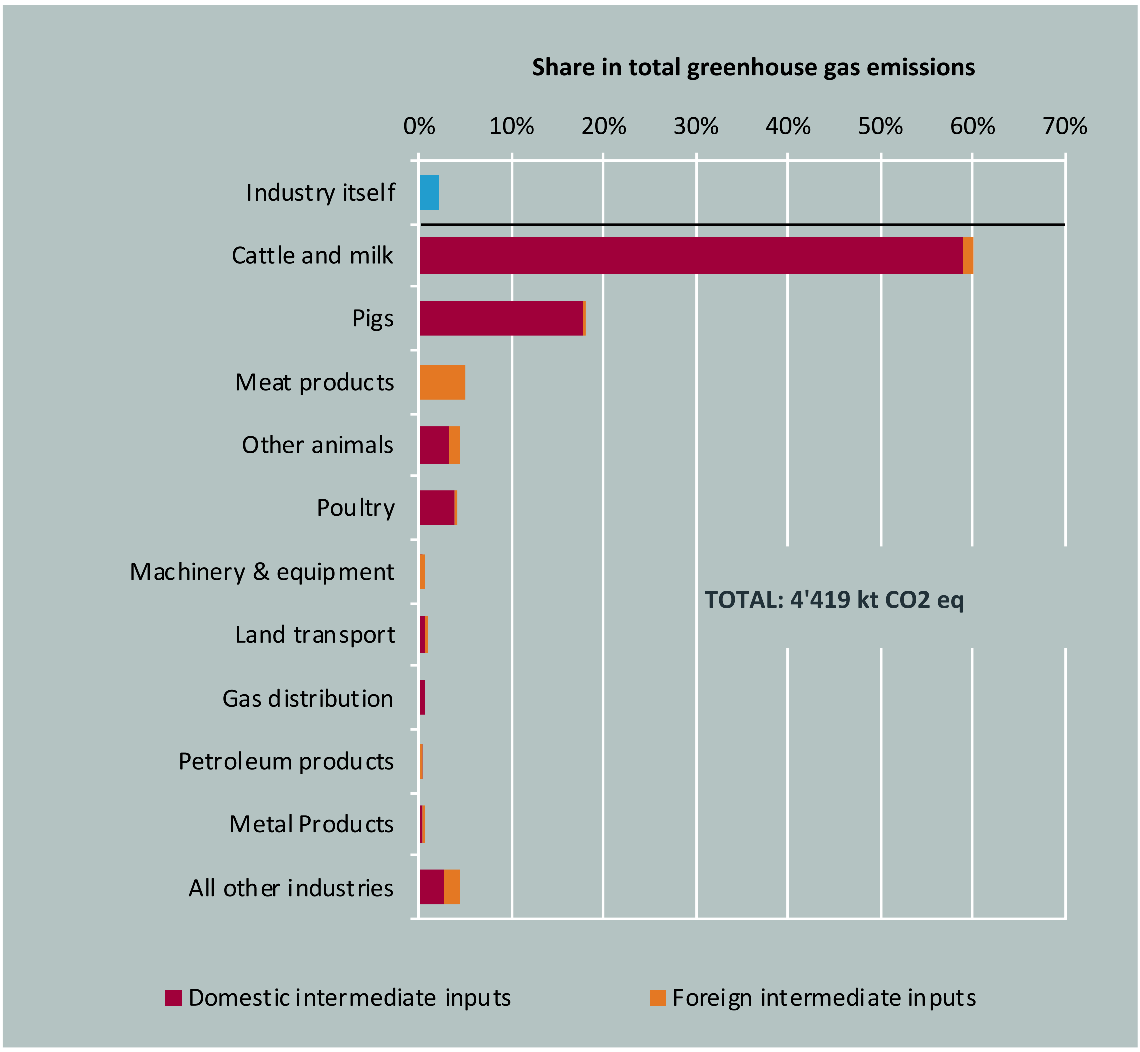

Fig. A.1.1.3: Greenhouse gas footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Meat processing’ (Source: Calculations Rütter Soceco)

A.1.2 Biodiversity loss footprint

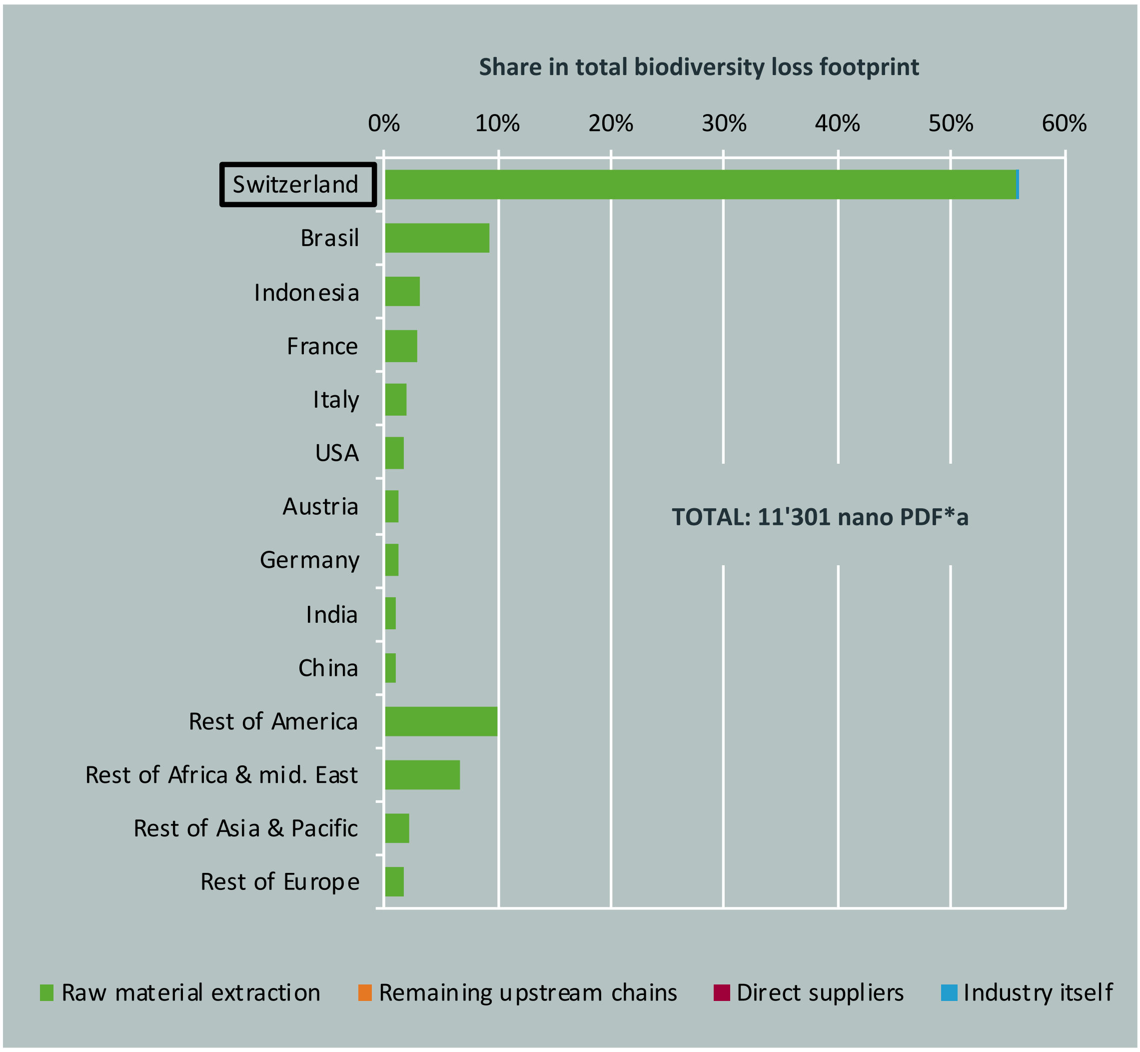

Fig. A.1.2.1: Biodiversity loss footprint caused by the Swiss industry 'Meat processing', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

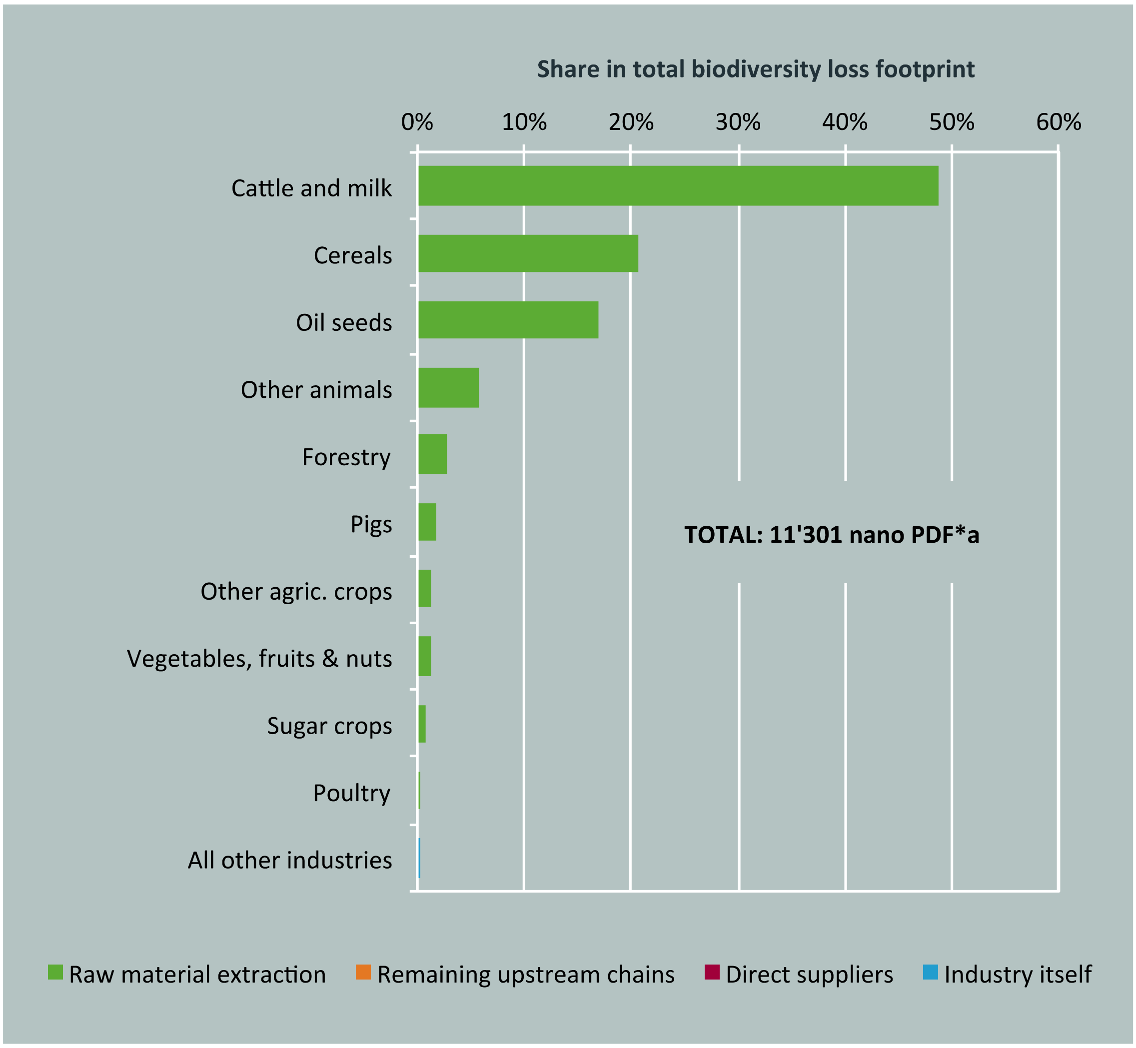

Fig. A.1.2.2: Biodiversity loss footprint caused by the industry 'Meat processing' by supply chain stage and industry (Source: Calculations Rütter Soceco)

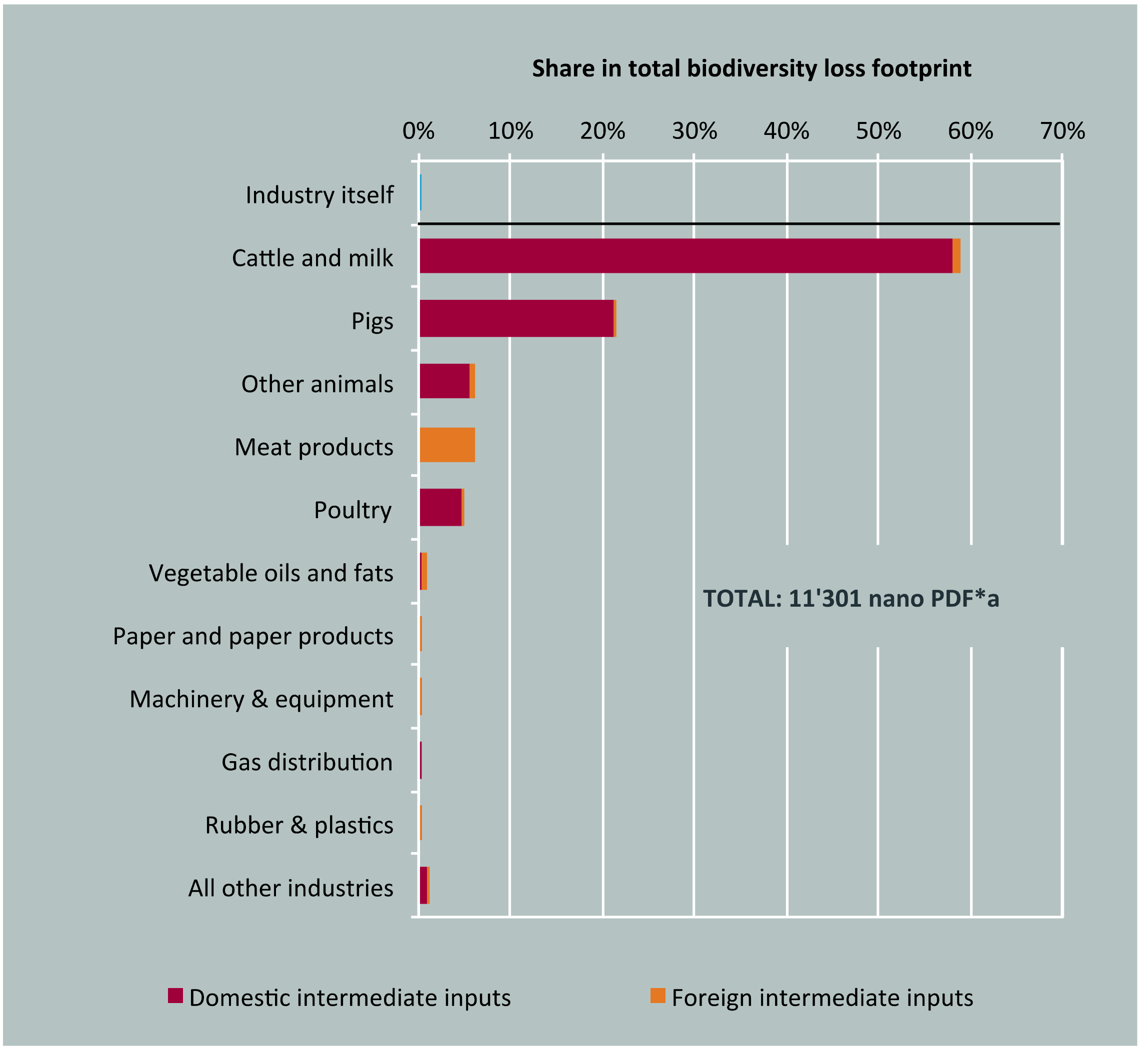

Fig. A.1.2.3: Biodiverstiy loss footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Meat processing’ (Source: Calculations Rütter Soceco)

A.1.3 Water footprint

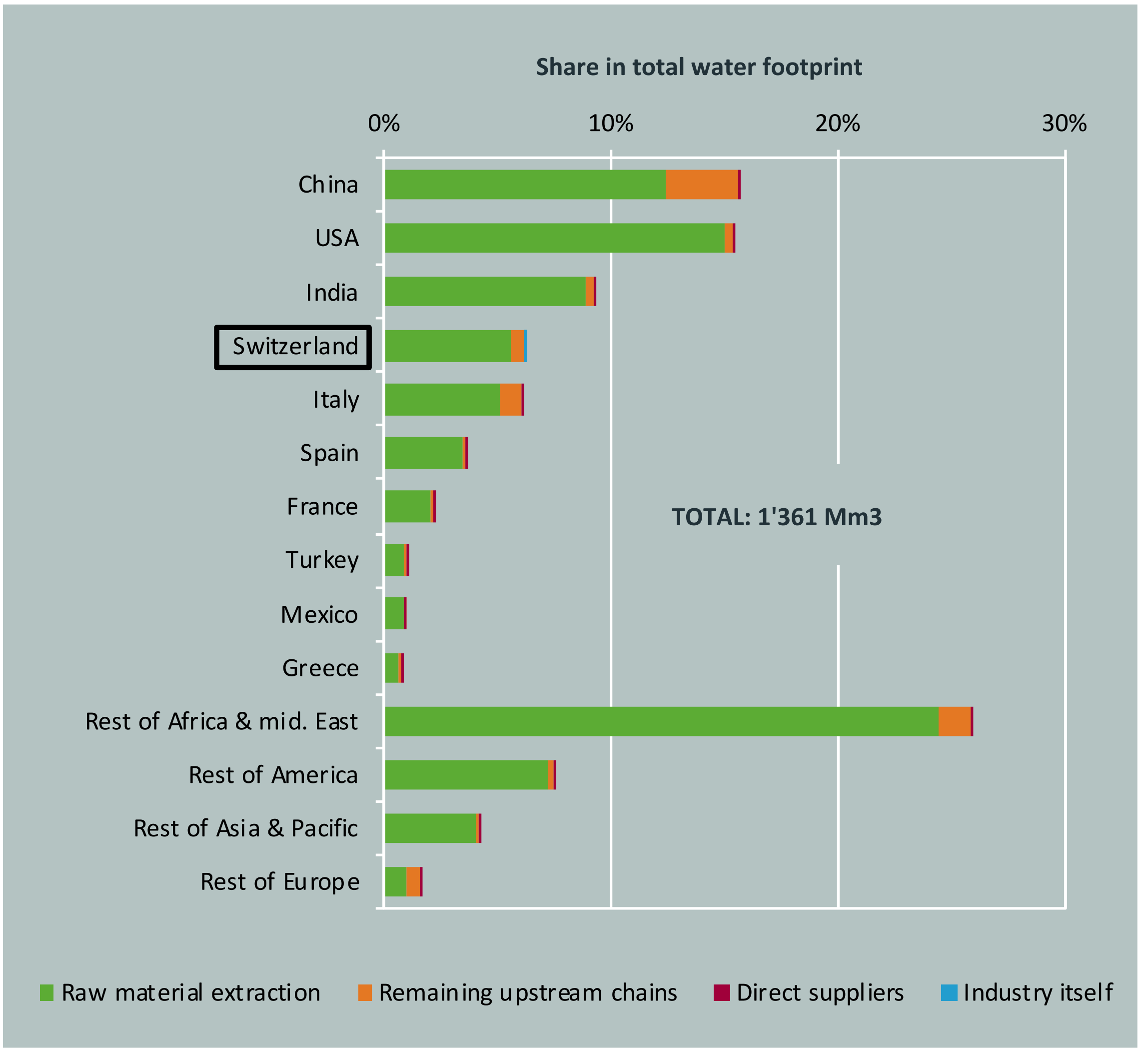

Fig. A.1.3.1: Water footprint caused by the Swiss industry 'Meat processing', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

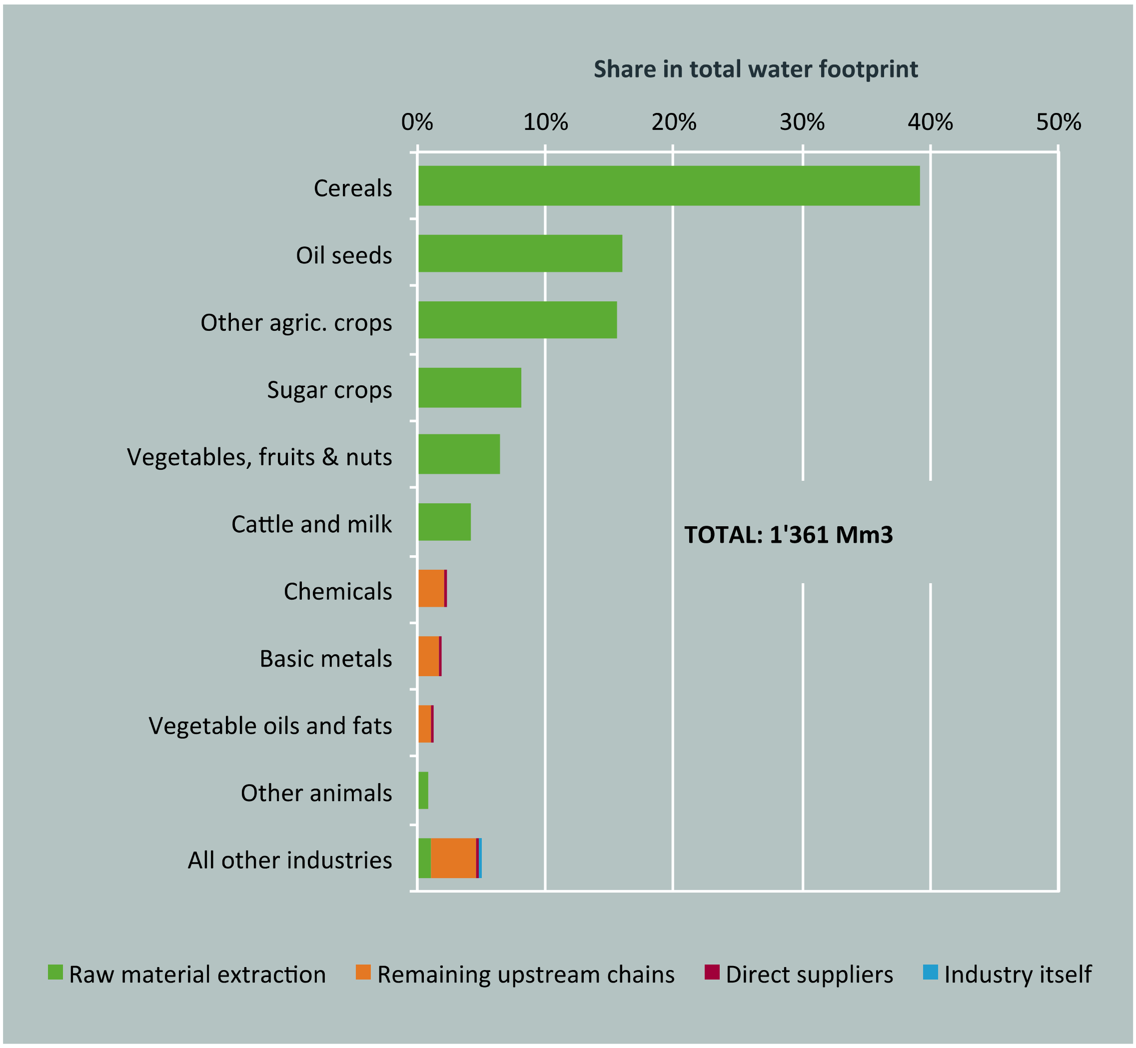

Fig. A.1.3.2: Water footprint caused by the industry 'Meat processing' by supply chain stage and industry (Source: Calculations Rütter Soceco)

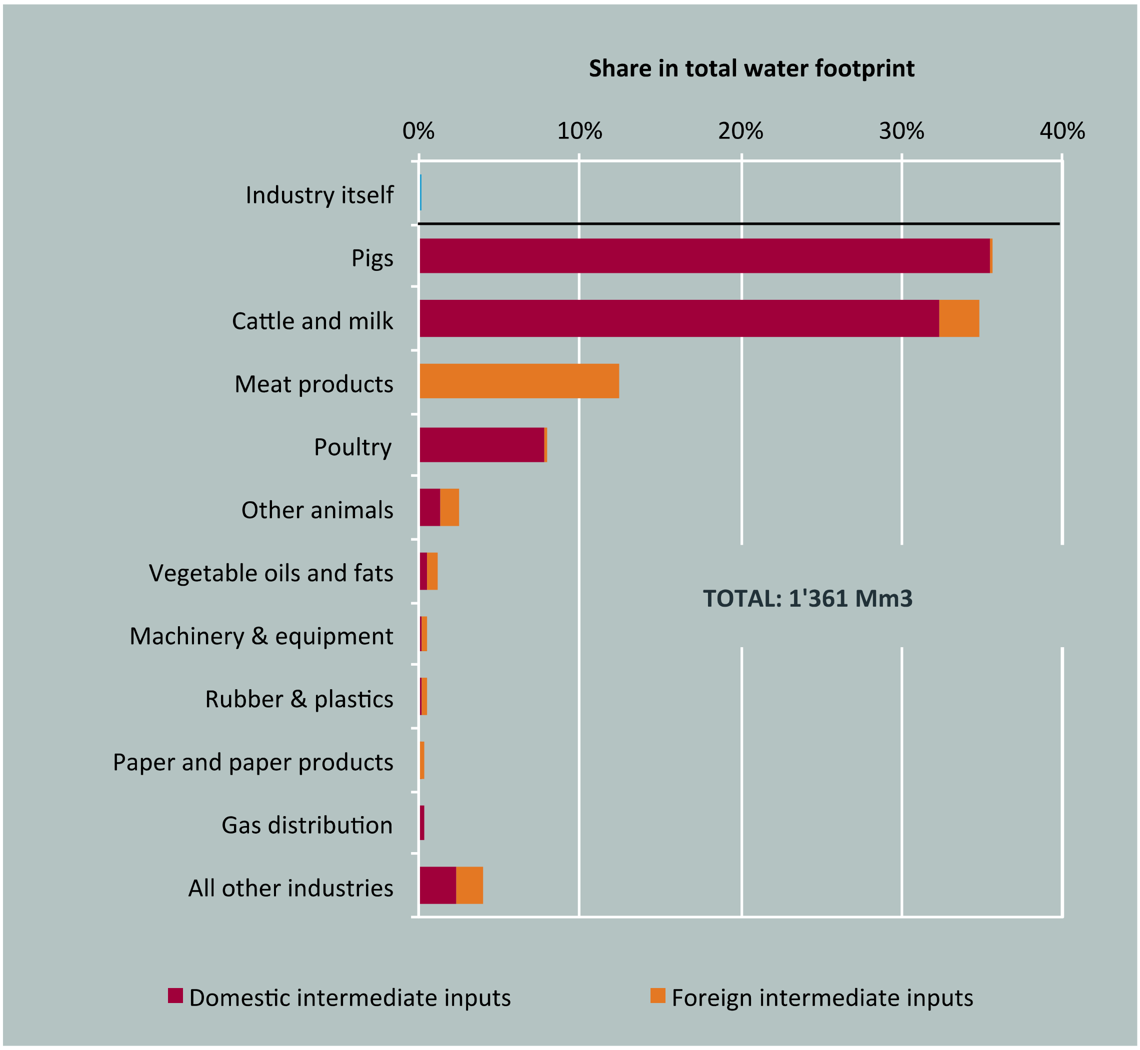

Fig. A.1.3.3: Water footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Meat processing' (Source: Calculations Rütter Soceco)

A.1.4 Air pollution footprint

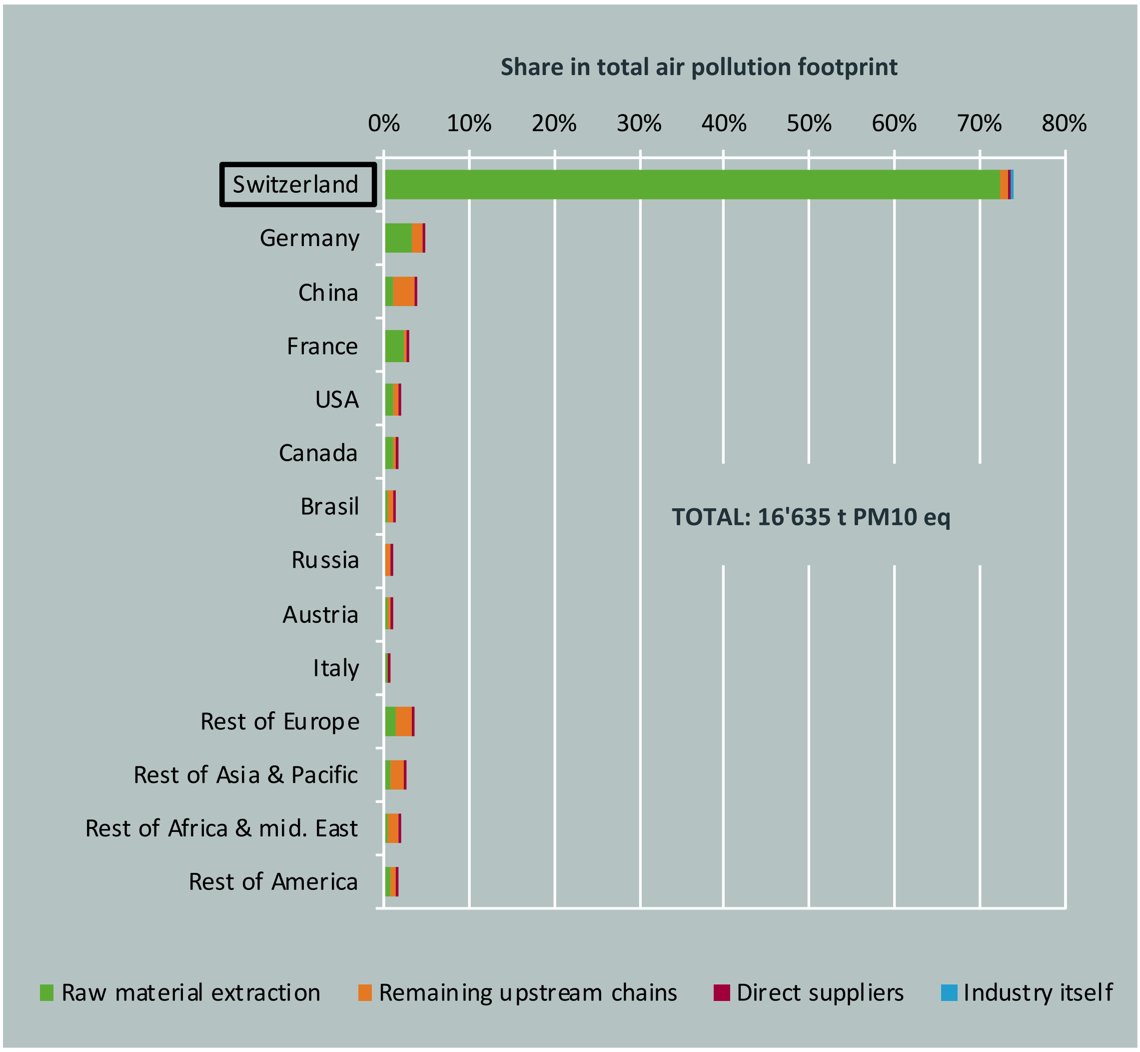

Fig. A.1.4.1: Air pollution footprint caused by the Swiss industry 'Meat processing', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

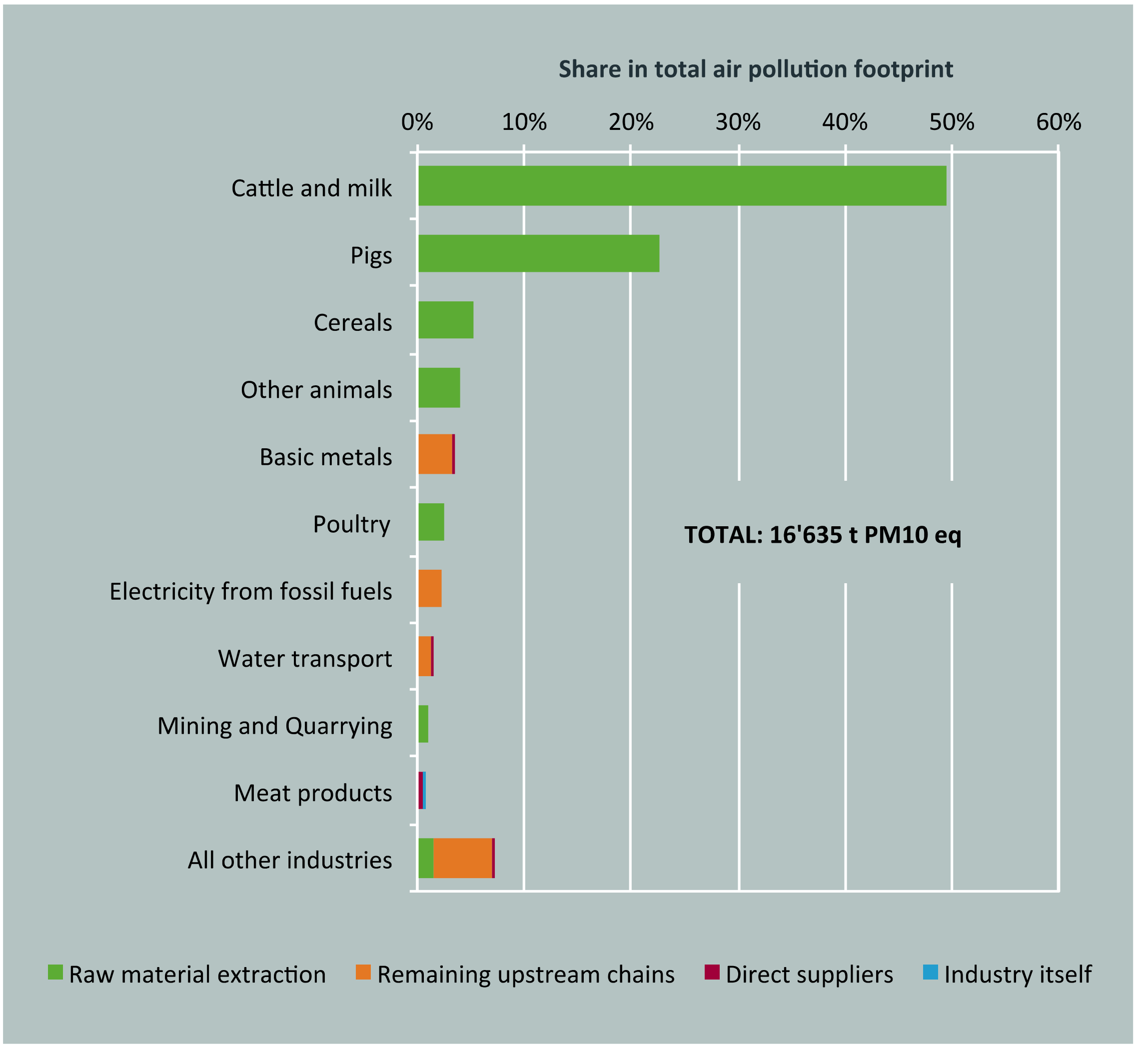

Fig. A.1.4.2: Air pollution footprint caused by the industry 'Meat processing' by supply chain stage and industry (Source: Calculations Rütter Soceco)

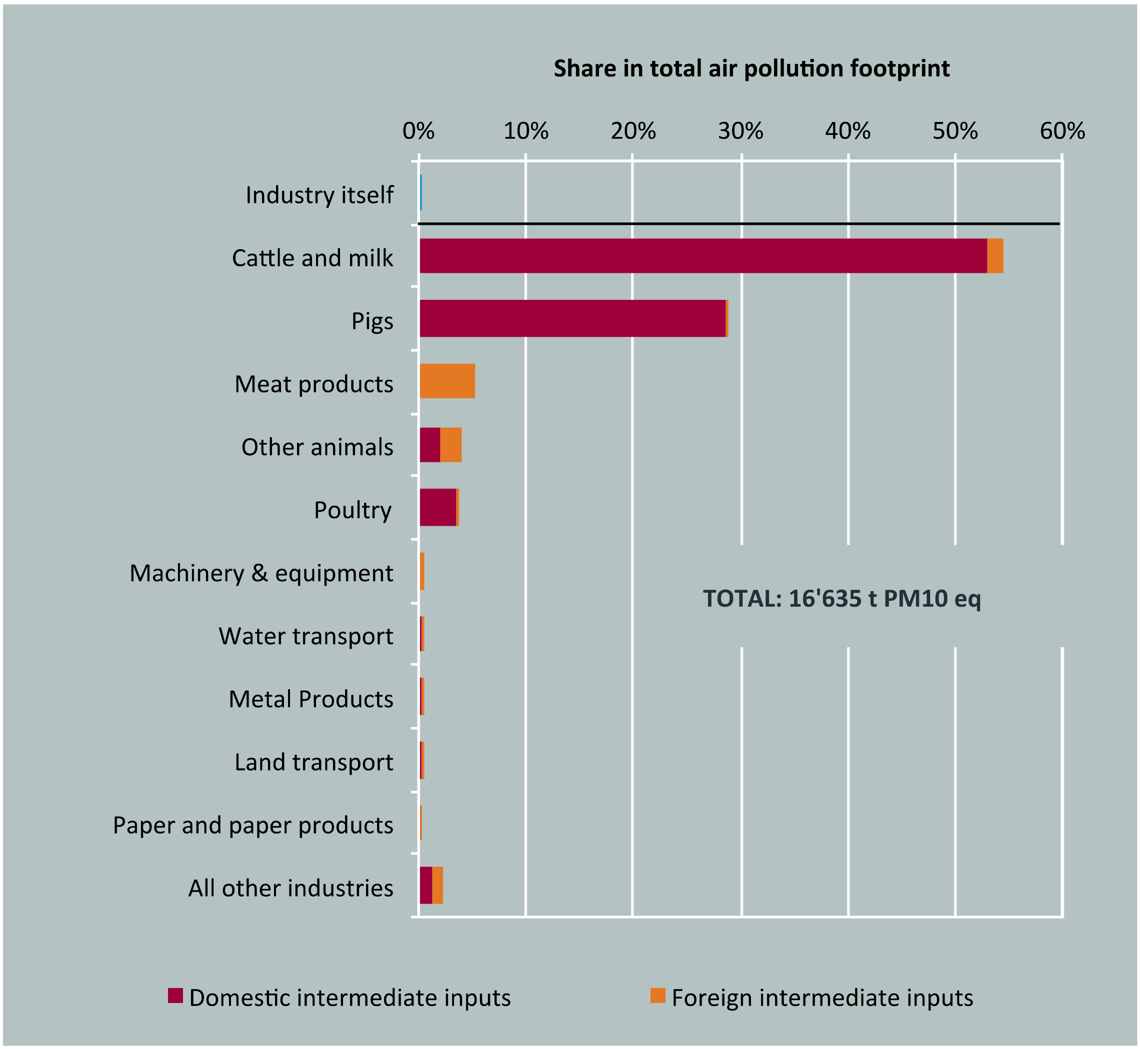

Fig. A.1.4.3: Air pollution footprint caused by the direct suppliers of intermediate goods and services for the Swiss industry 'Meat processing' (Source: Calculations Rütter Soceco)

A.2 Chemical industry

A.2.1 Biodiversity loss footprint

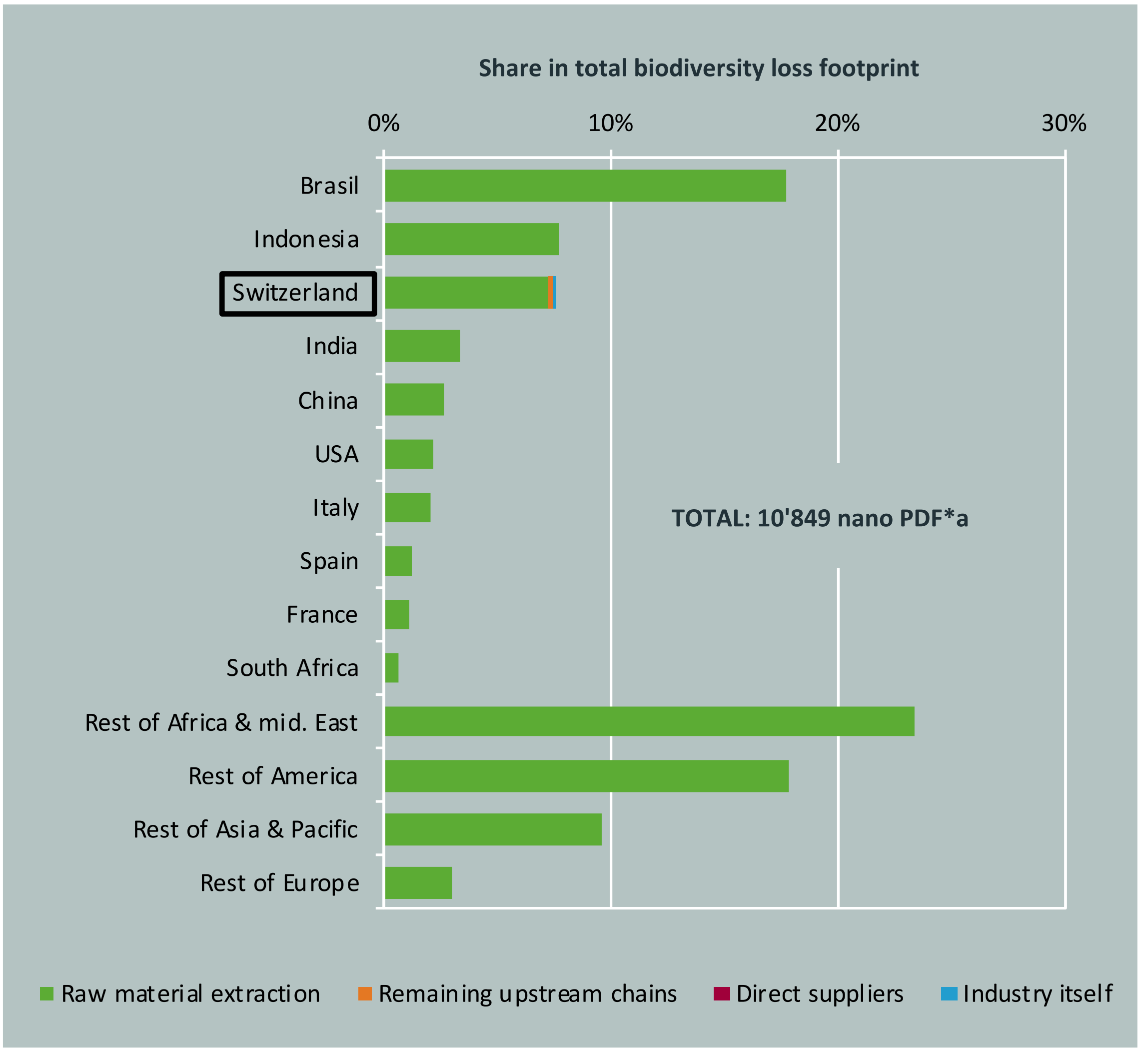

Fig. A.2.1.1: Biodiversity loss footprint caused by the Swiss industry 'Production of chemical products', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

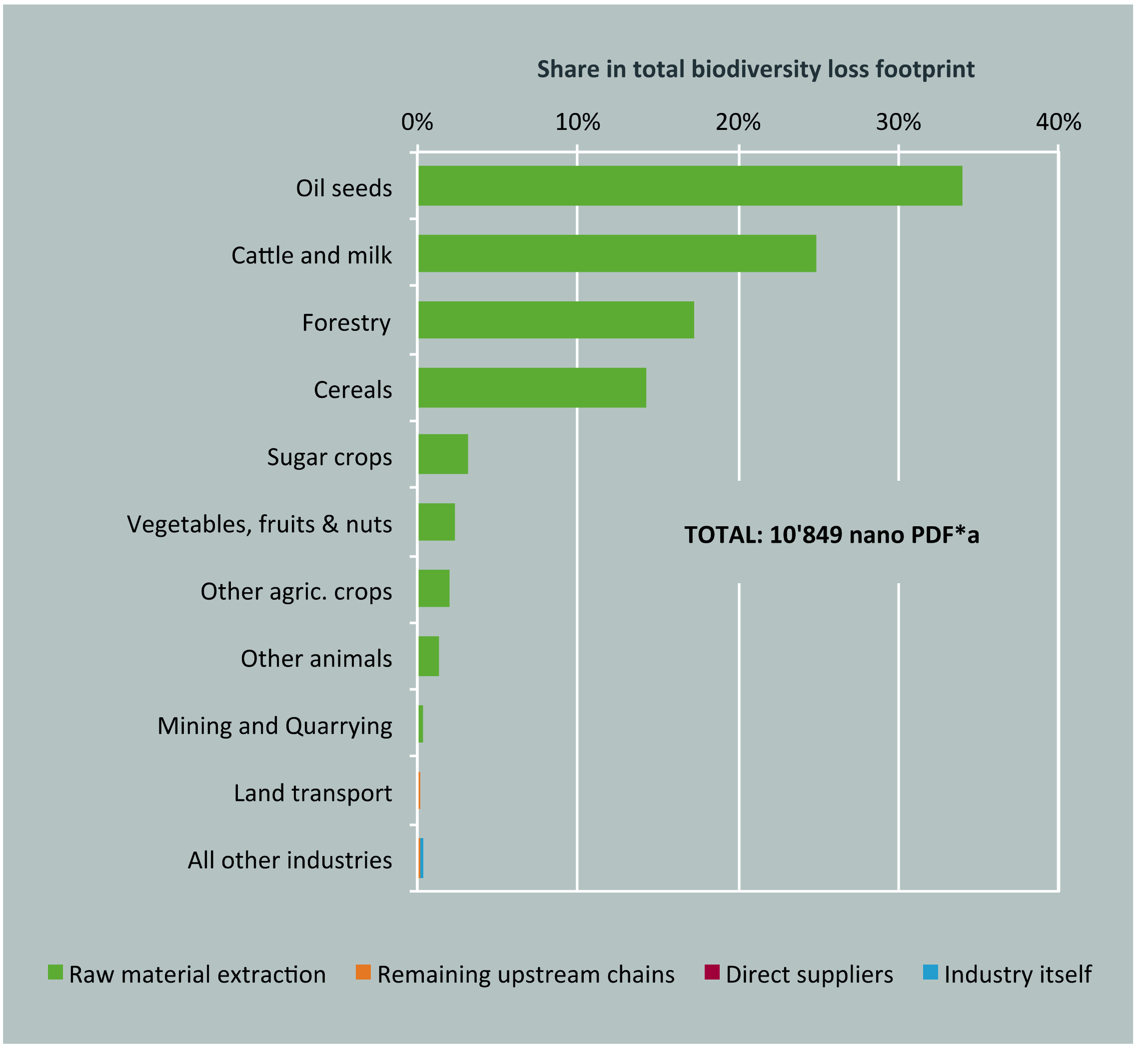

Fig. A.2.1.2: Biodiversity loss footprint caused by the industry 'Production of chemical products' by supply chain stage and industry (Source: Calculations Rütter Soceco)

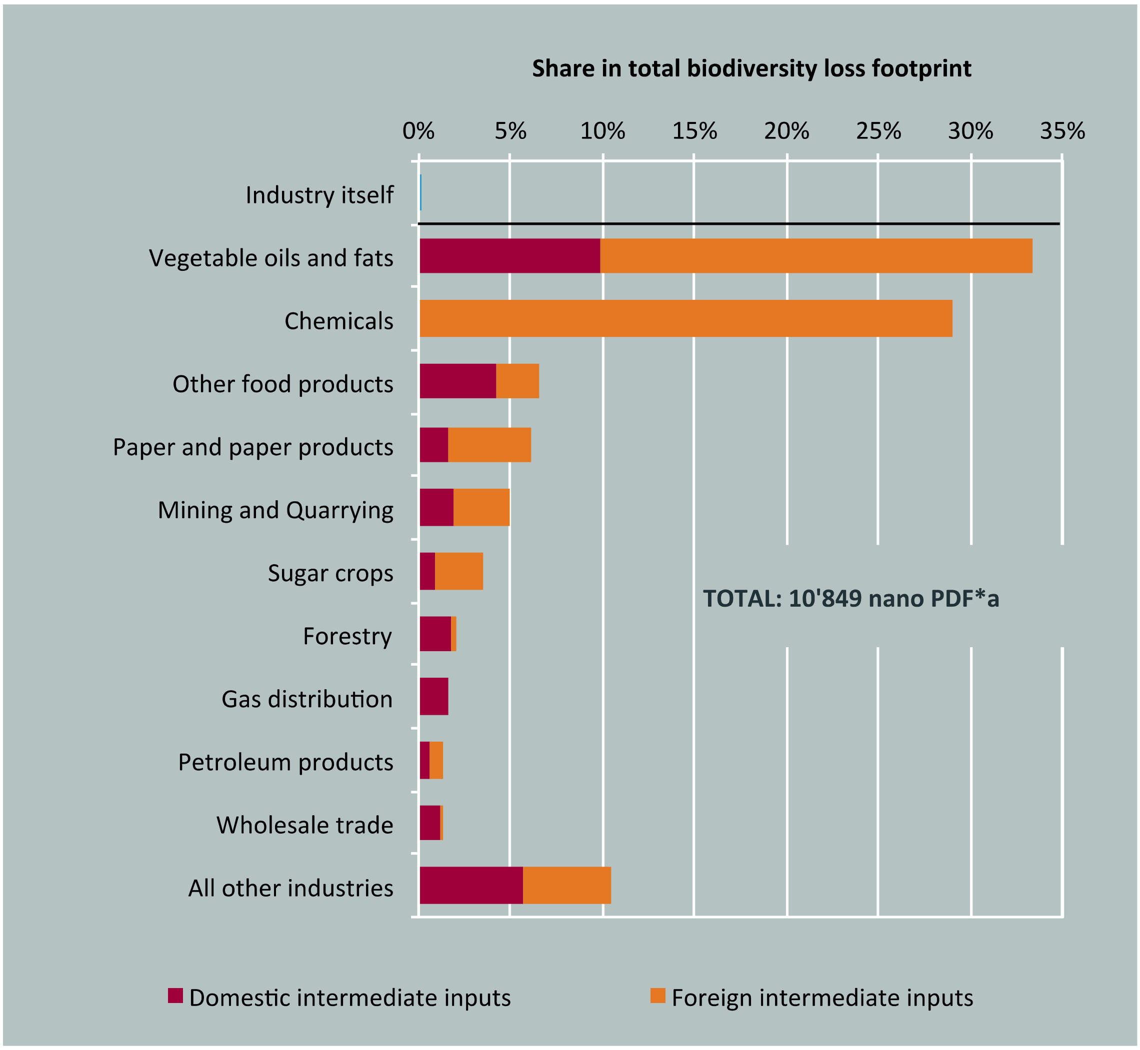

Fig. A.2.1.3: Biodiverstiy loss footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Production of chemical products’ (Source: Calculations Rütter Soceco)

A.2.2 Water footprint

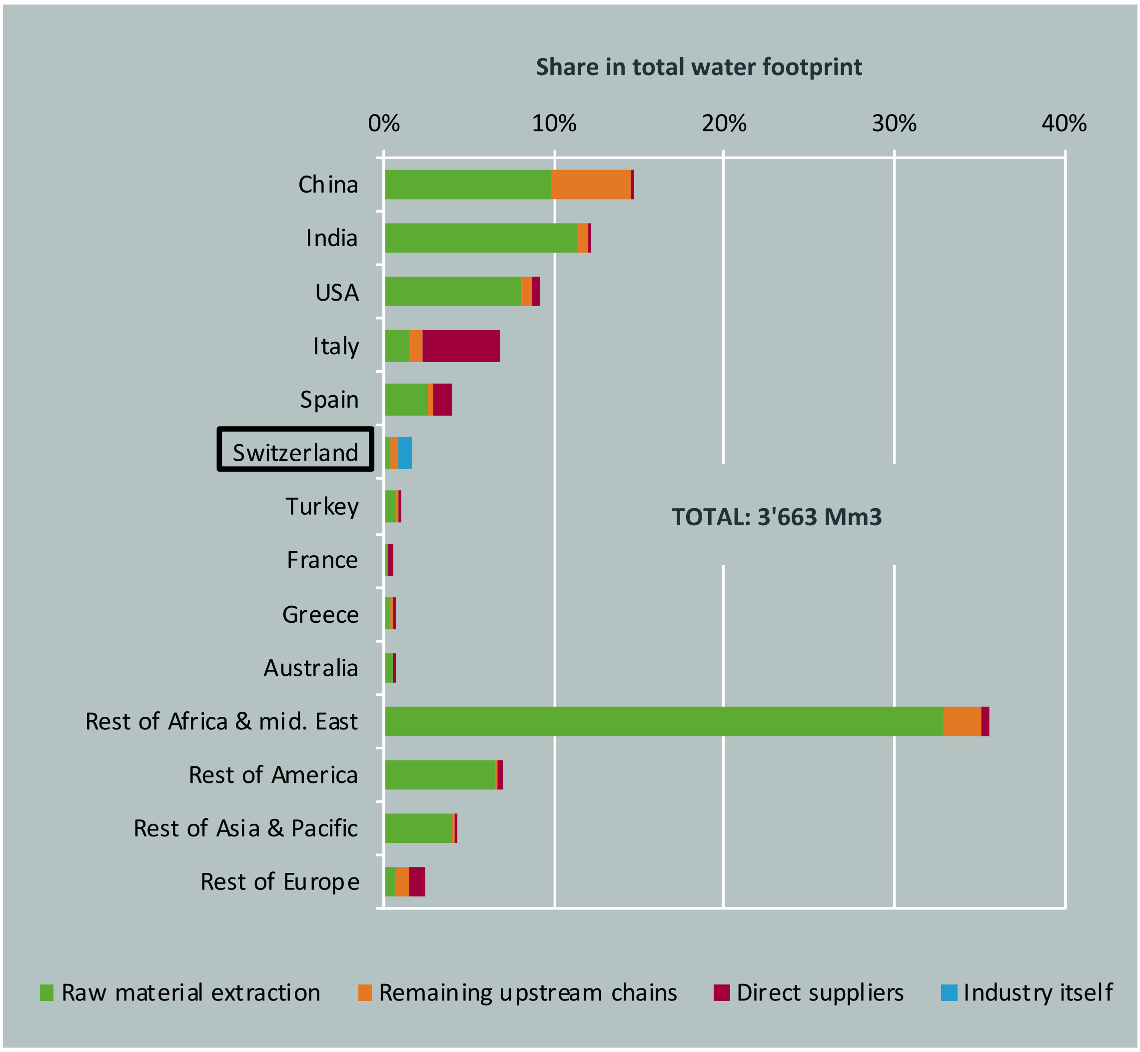

Fig. A.2.2.1: Water footprint caused by the Swiss industry 'Production of chemical products', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

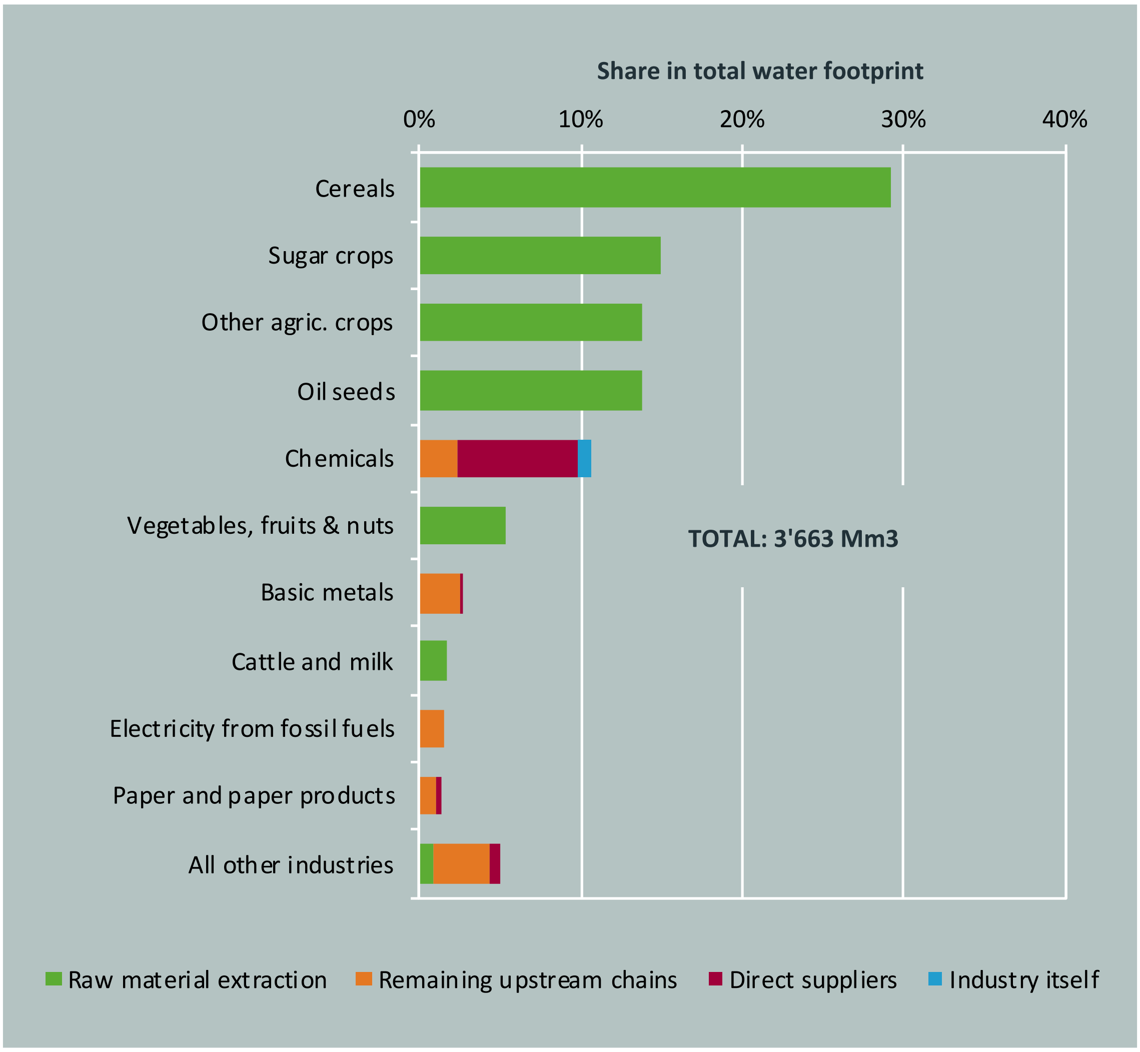

Fig. A.2.2.2: Water footprint caused by the industry 'Production of chemical products' by supply chain stage and industry (Source: Calculations Rütter Soceco)

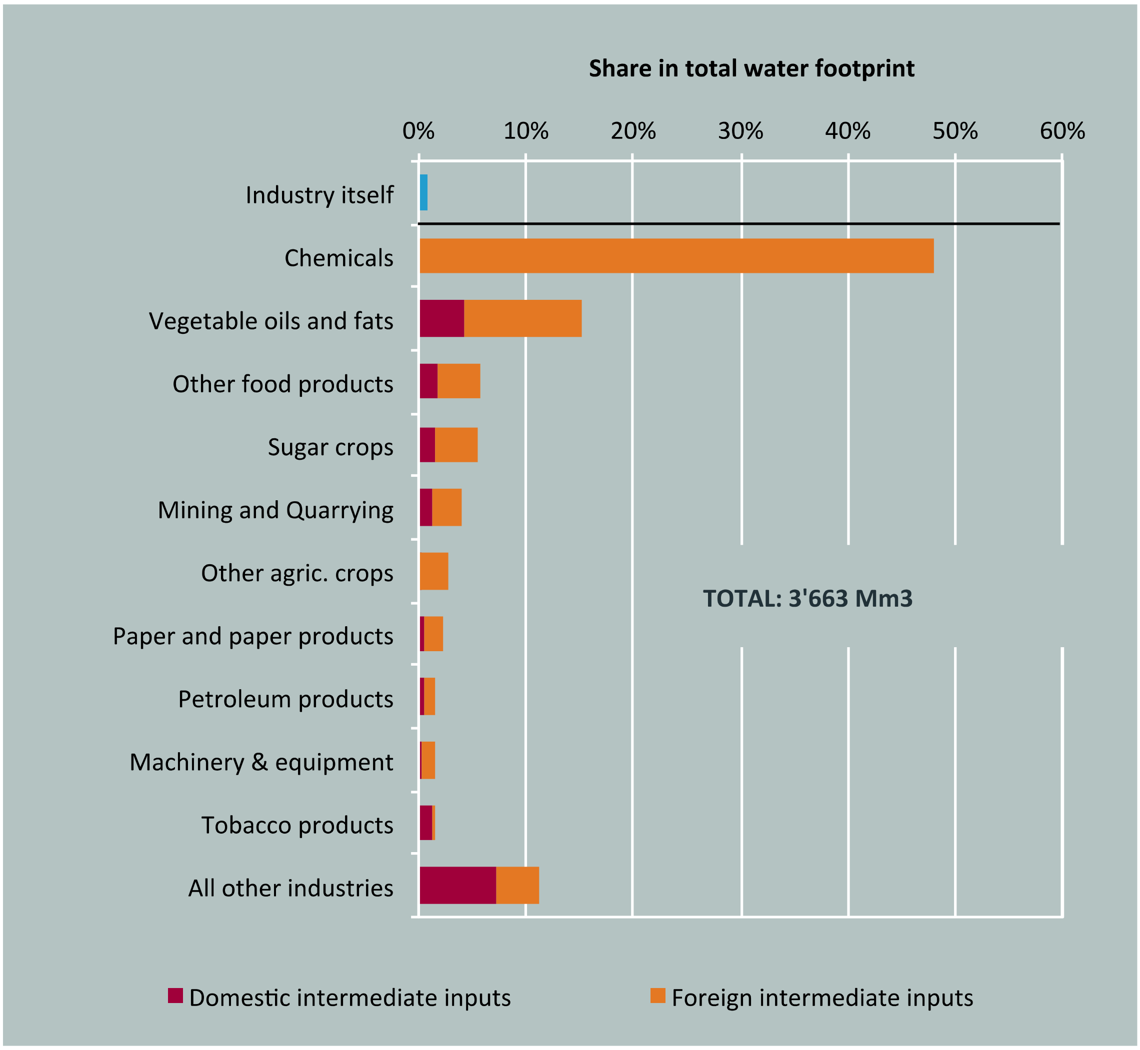

Fig. A.2.2.3: Water footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Production of chemical products' (Source: Calculations Rütter Soceco)

A.2.3 Air pollution footprint

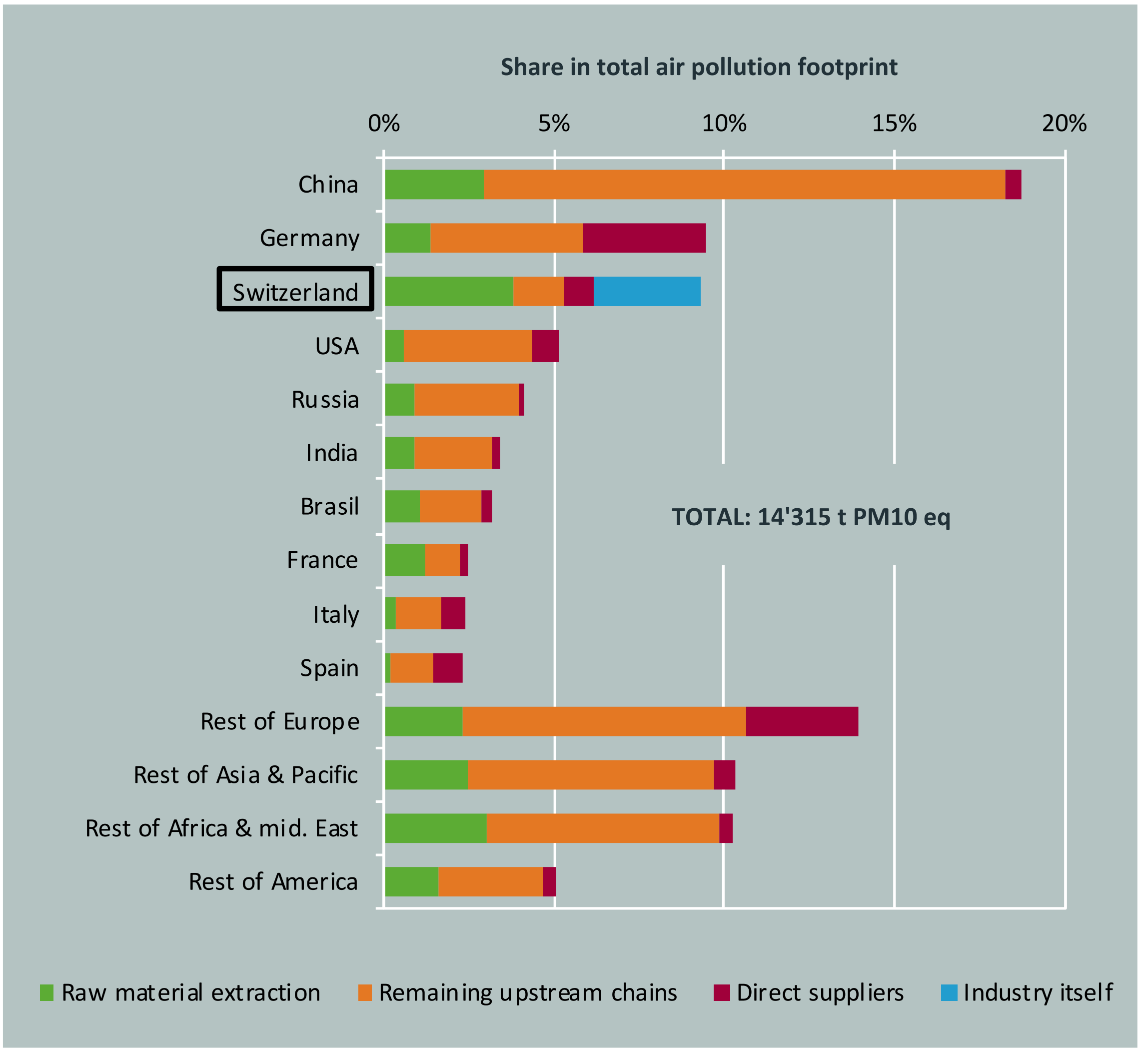

Fig. A.2.3.1: Air pollution footprint caused by the Swiss industry ‘Production of chemical products’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco

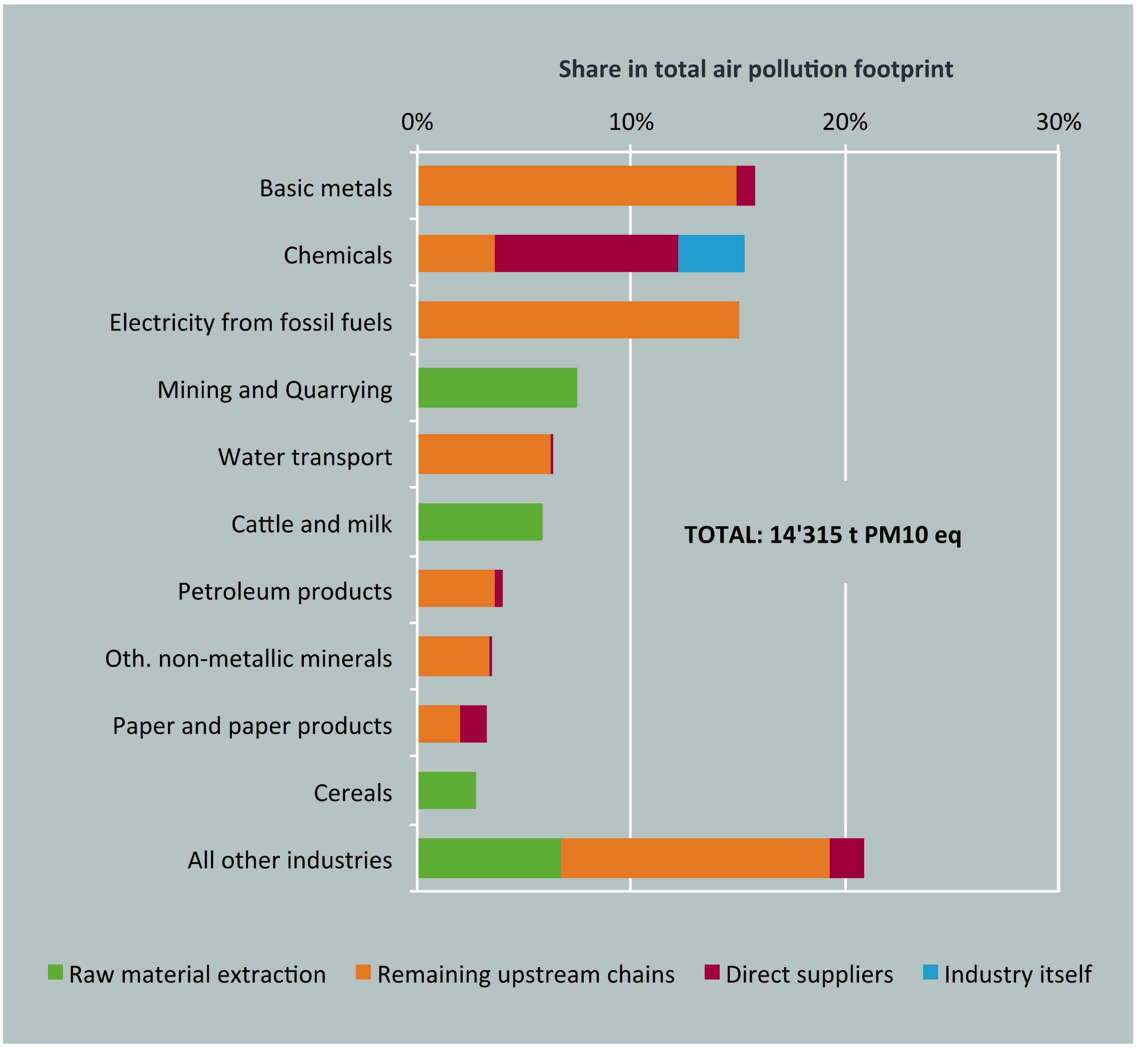

Fig. A.2.3.2: Air pollution footprint caused by the industry ‘Production of chemical products’ by supply chain stage and industry (Source: Calculations Rütter Soceco)

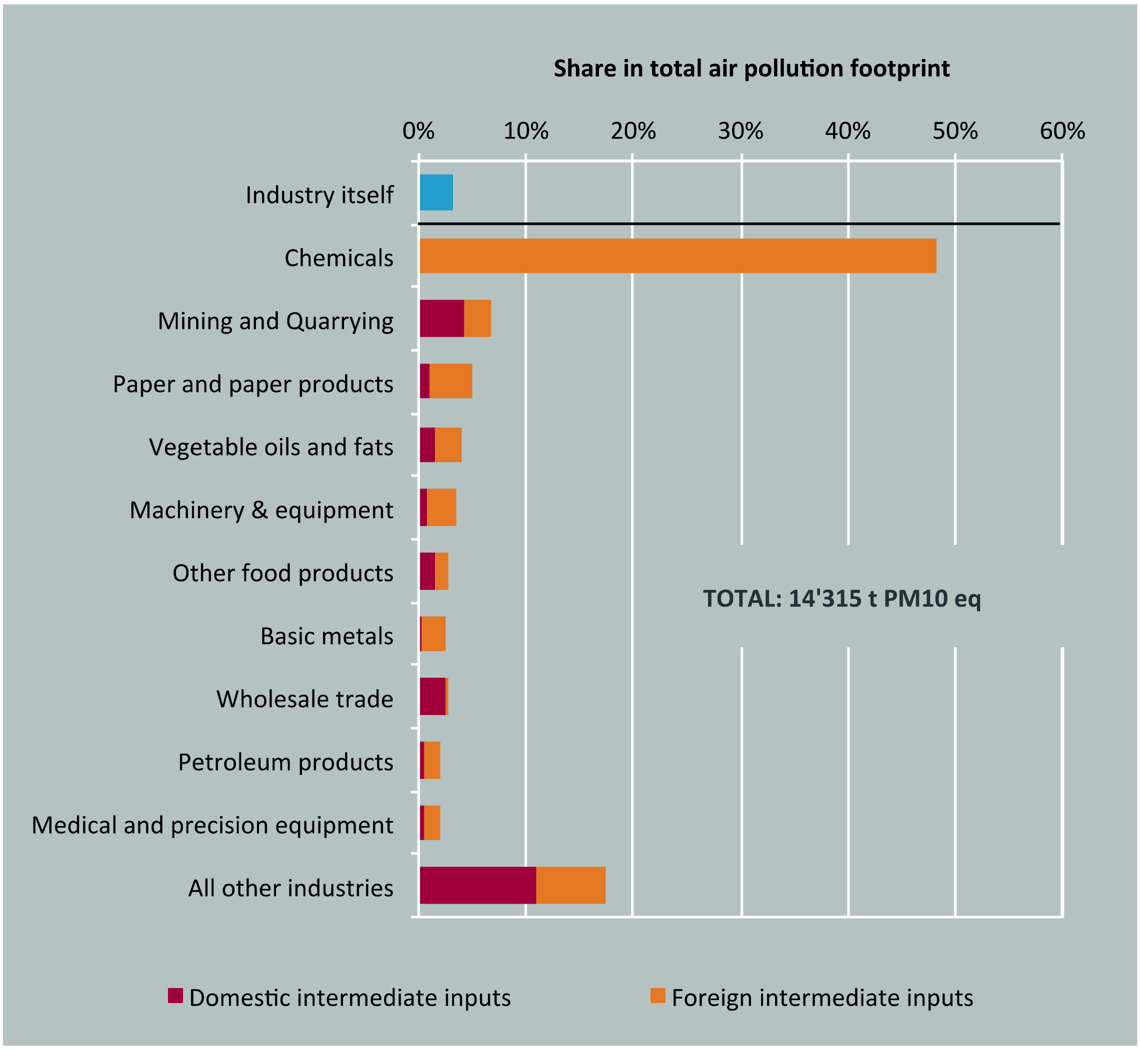

Fig. A.2.3.3: Air pollution footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Production of chemical products' (Source: Calculations Rütter Soceco)

A.2.4 Eutrophication footprint

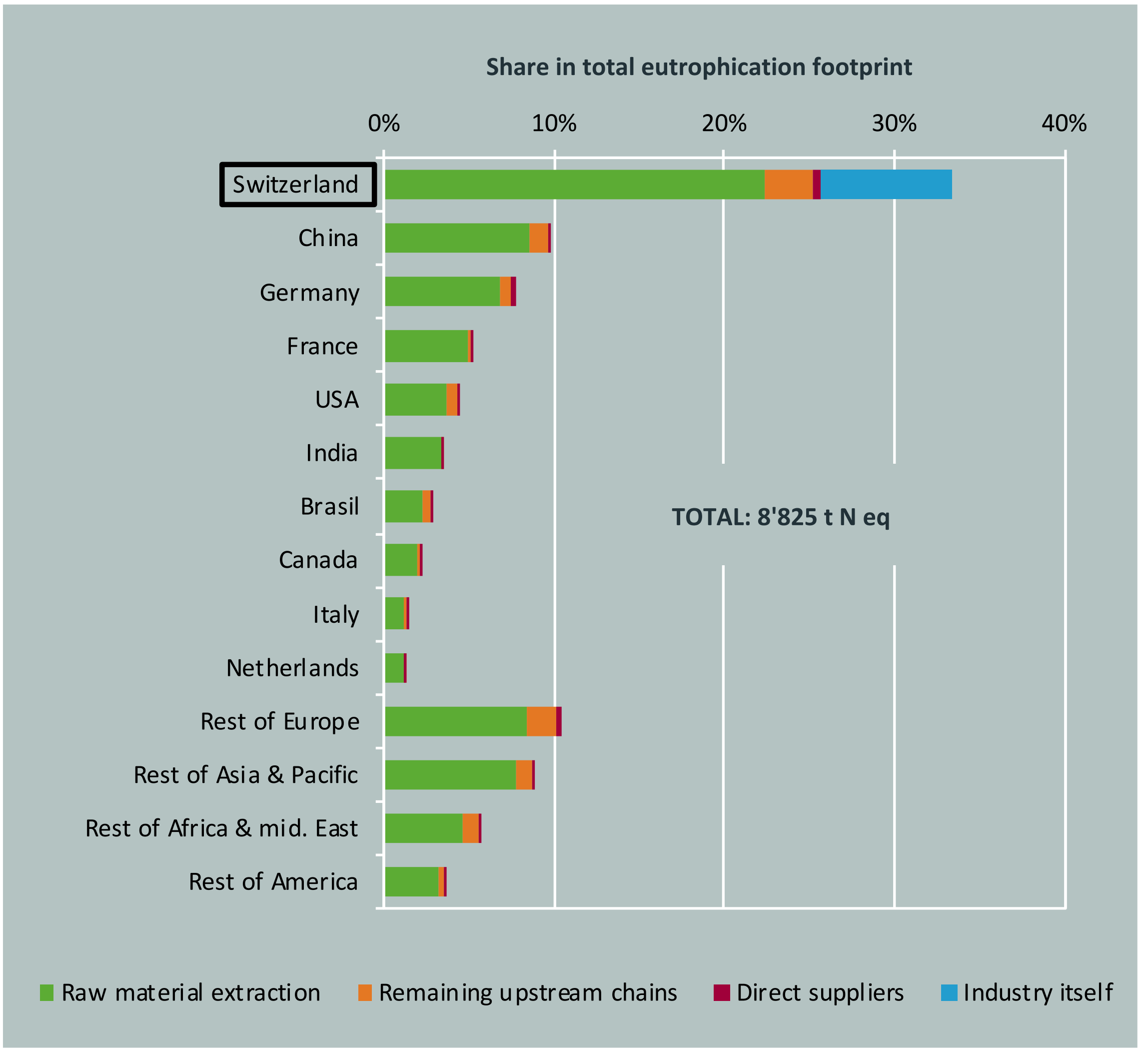

Fig. A.2.4.1: Eutrophication footprint caused by the Swiss industry ‘Production of chemical products’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

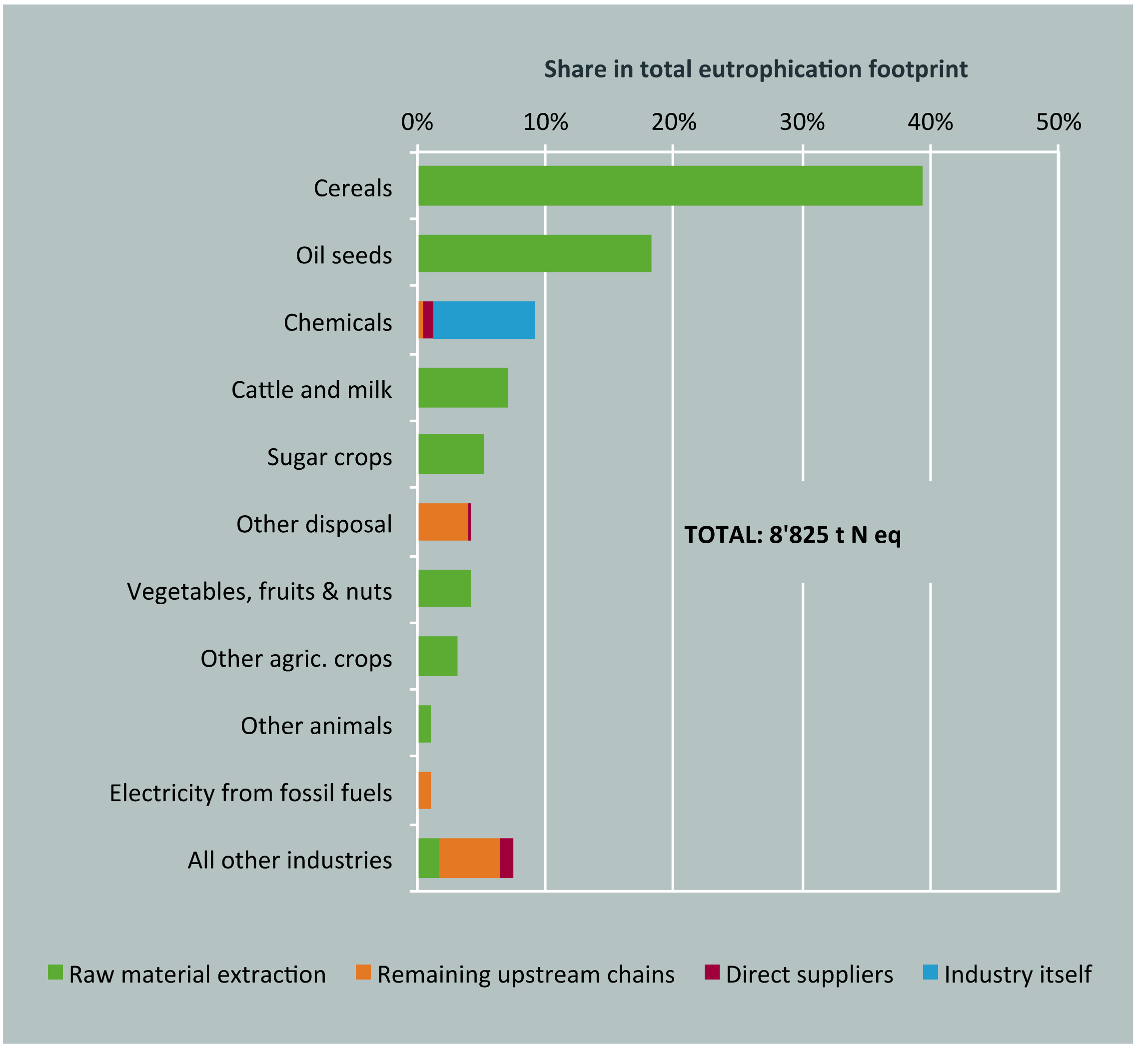

Fig. A.2.4.2: Eutrophication footprint caused by the industry ‘Production of chemical products’ by supply chain stage and industry (Source: Calculations Rütter Soceco)

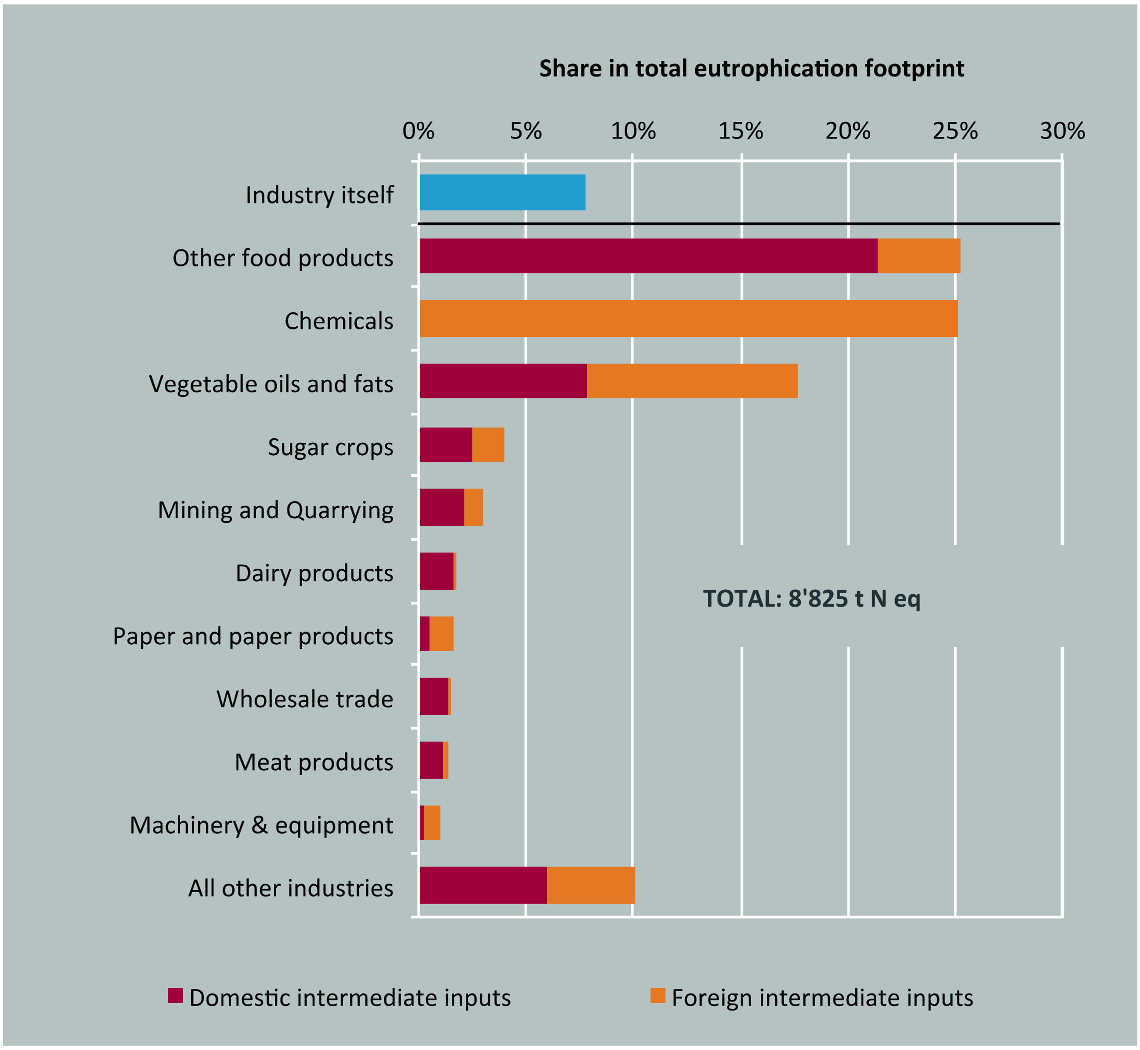

Fig. A.2.4.3: Eutrophication footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Production of chemical products’ (Source: Calculations Rütter Soceco)

A.3 Production of machinery

A.3.1 Greenhouse gas footprint

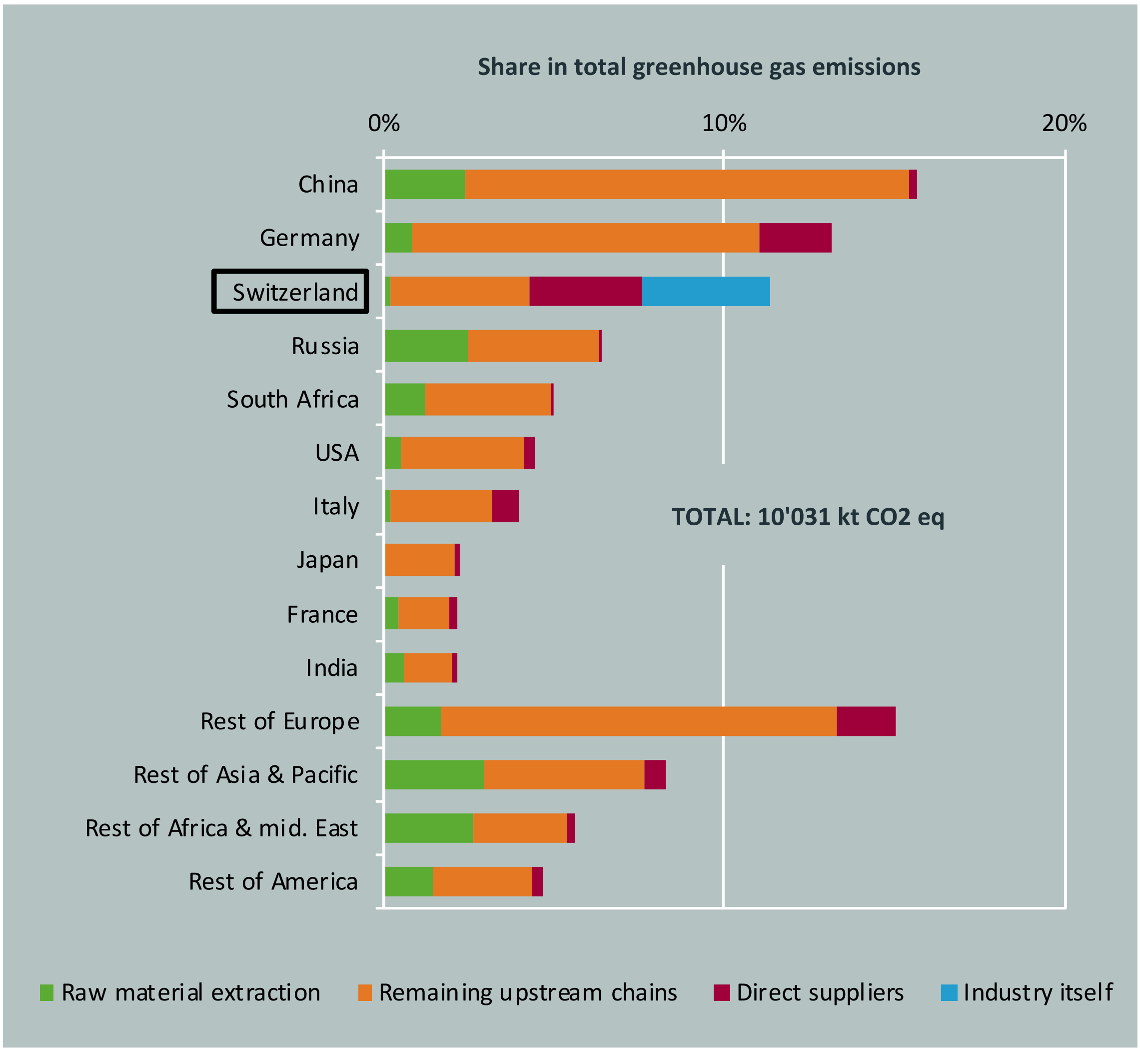

Fig. A.3.1.1: Greenhouse gas footprint caused by the Swiss industry 'Production of machinery', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

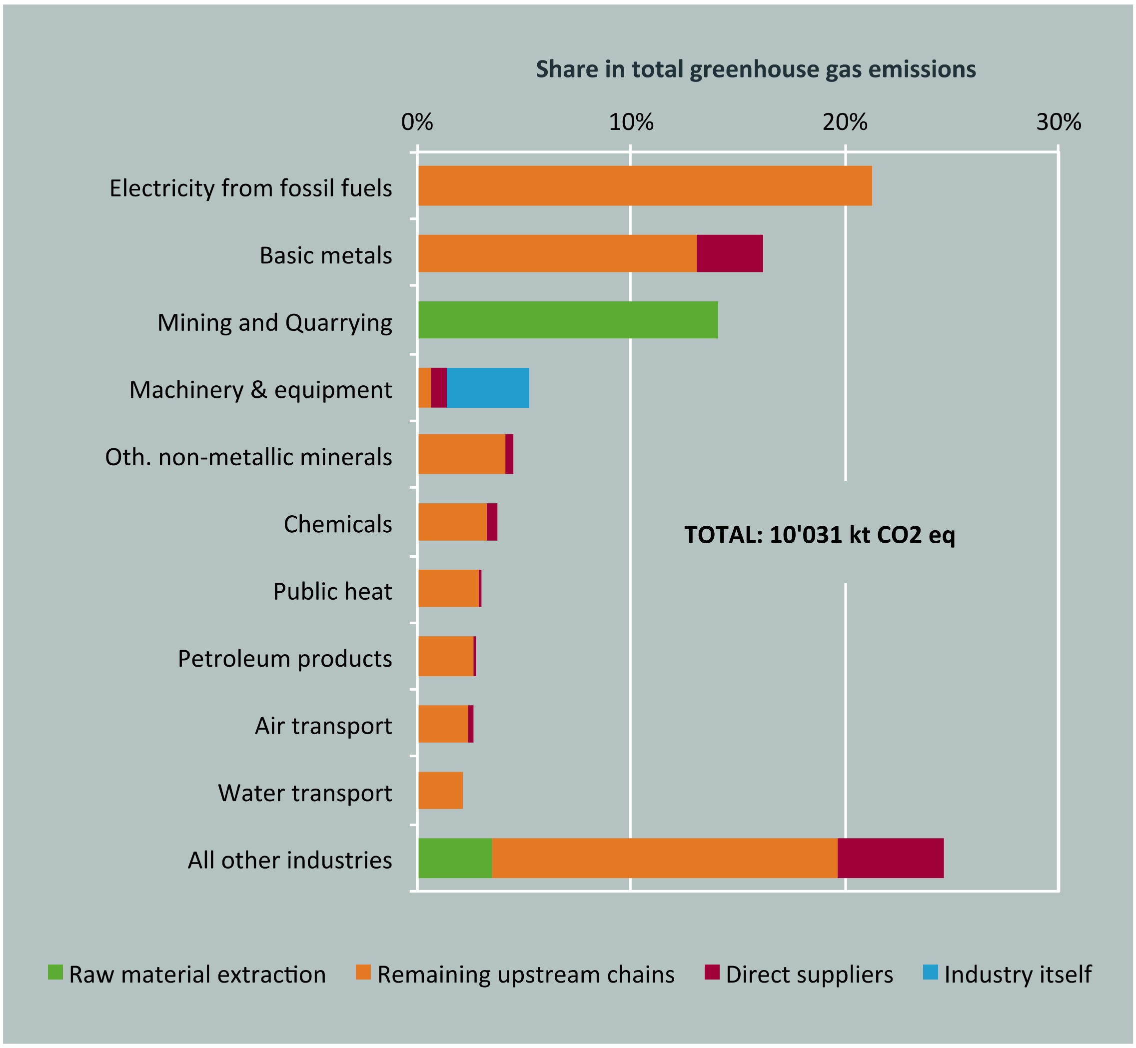

Fig. A.3.1.2: Greenhouse gas footprint caused by the industry 'Production of machinery' by supply chain stage and industry (Source: Calculations Rütter Soceco)

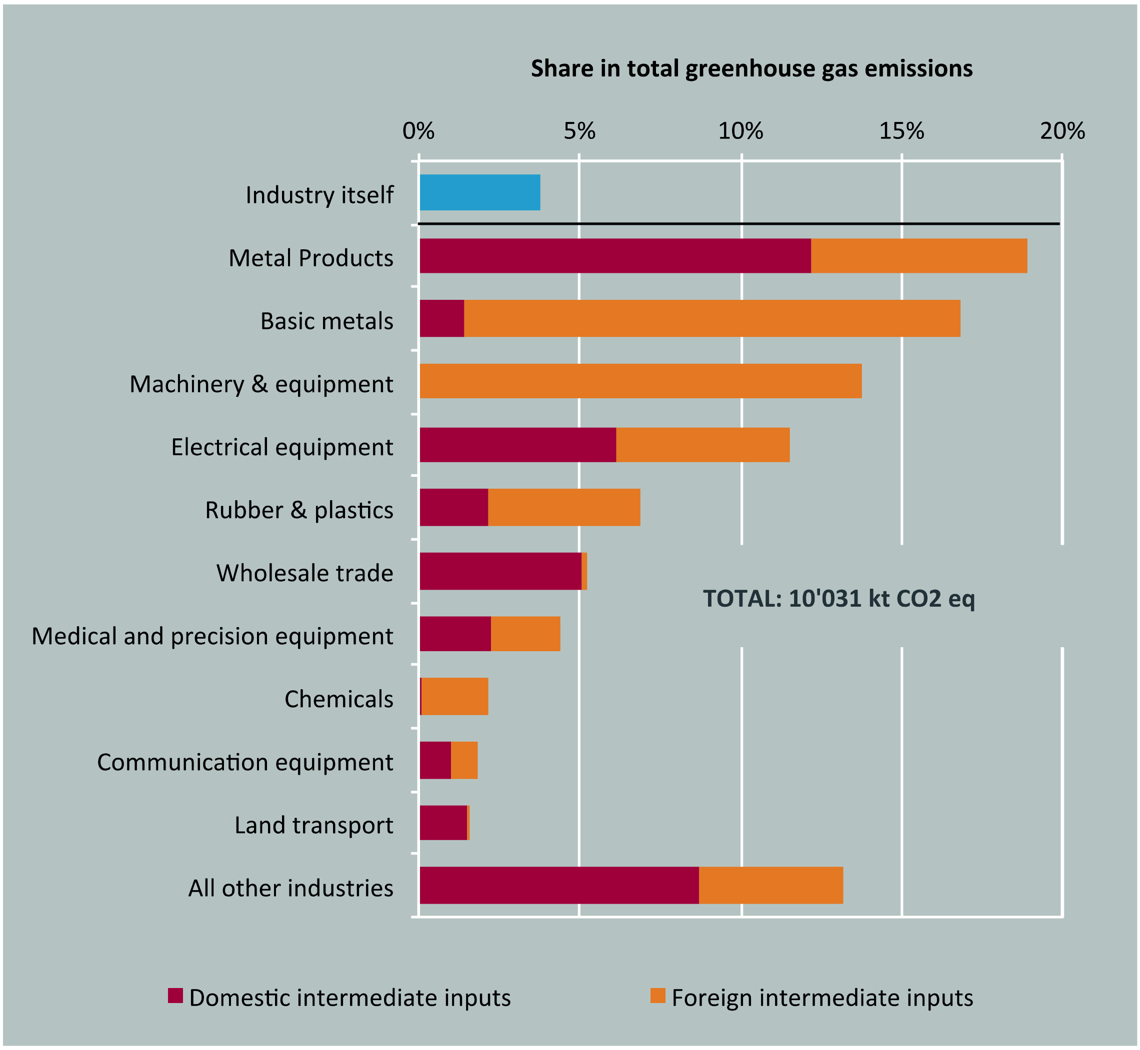

Fig. A.3.1.3: Greenhouse gas footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Production of machinery' (Source: Calculations Rütter Soceco)

A.3.2 Biodiversity loss footprint

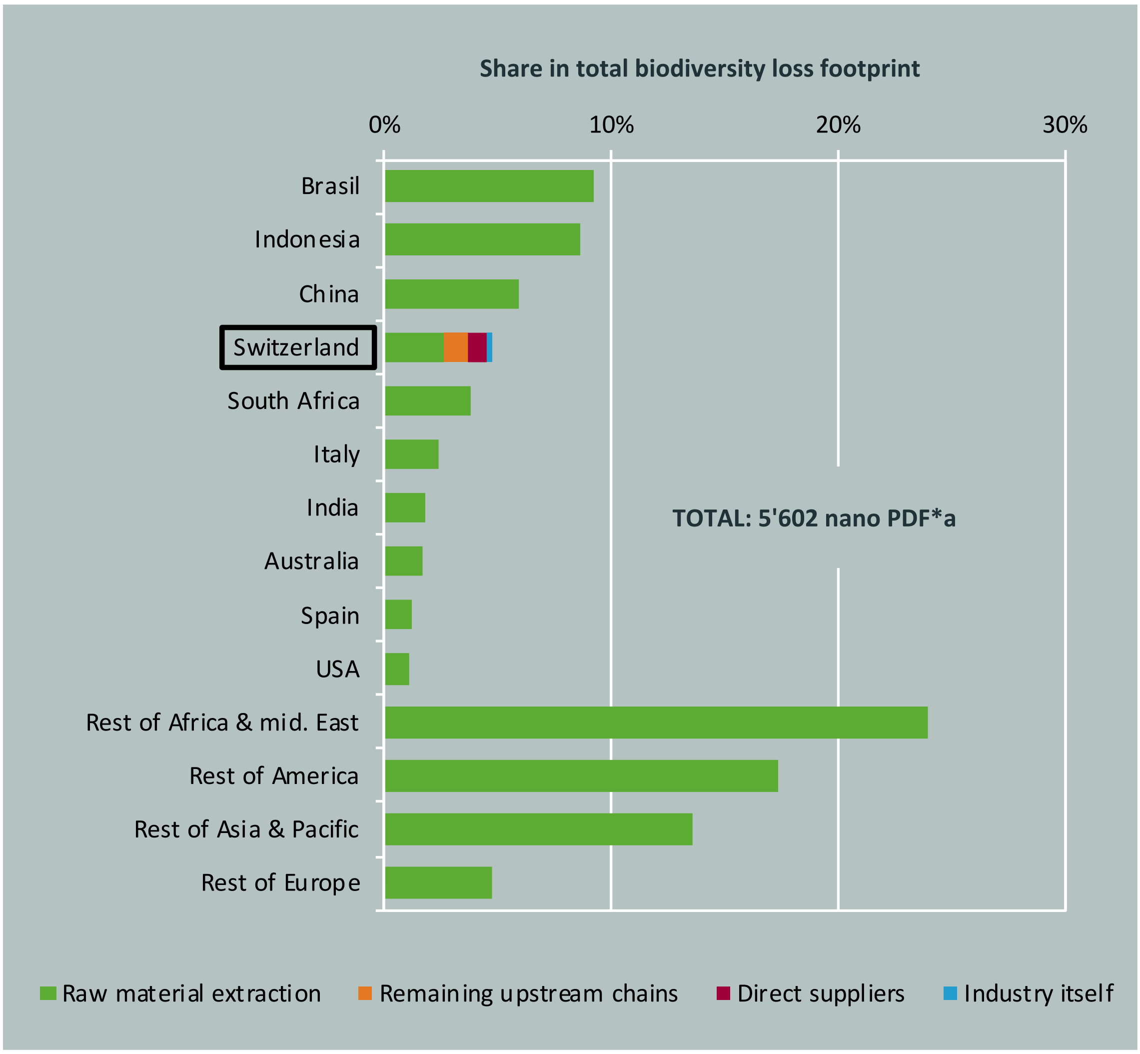

Fig. A.3.2.1: Biodiversity loss footprint caused by the Swiss industry 'Production of machinery', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

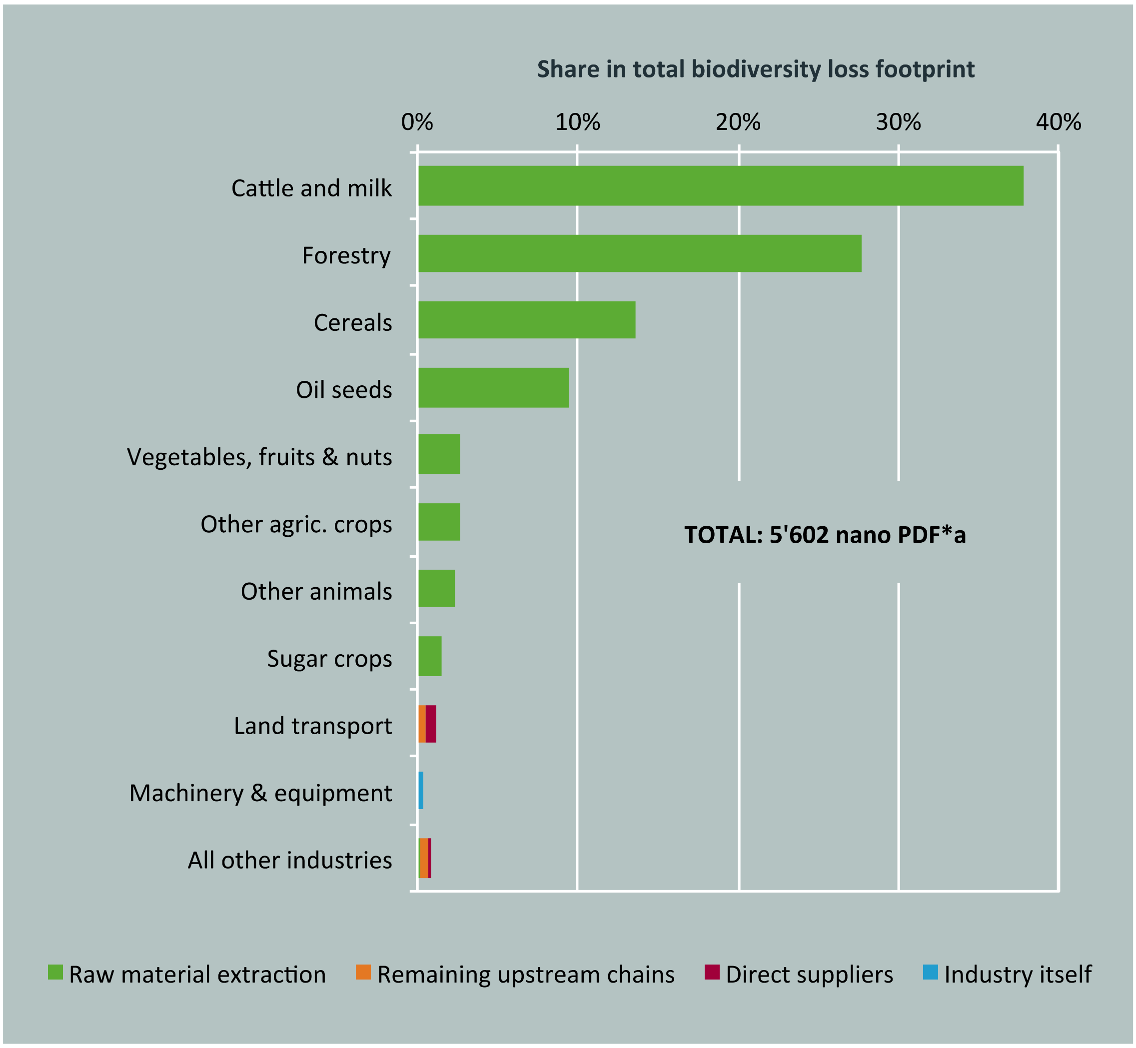

Fig. A.3.2.2: Biodiversity loss footprint caused by the industry 'Production of machinery' by supply chain stage and industry (Source: Calculations Rütter Soceco)

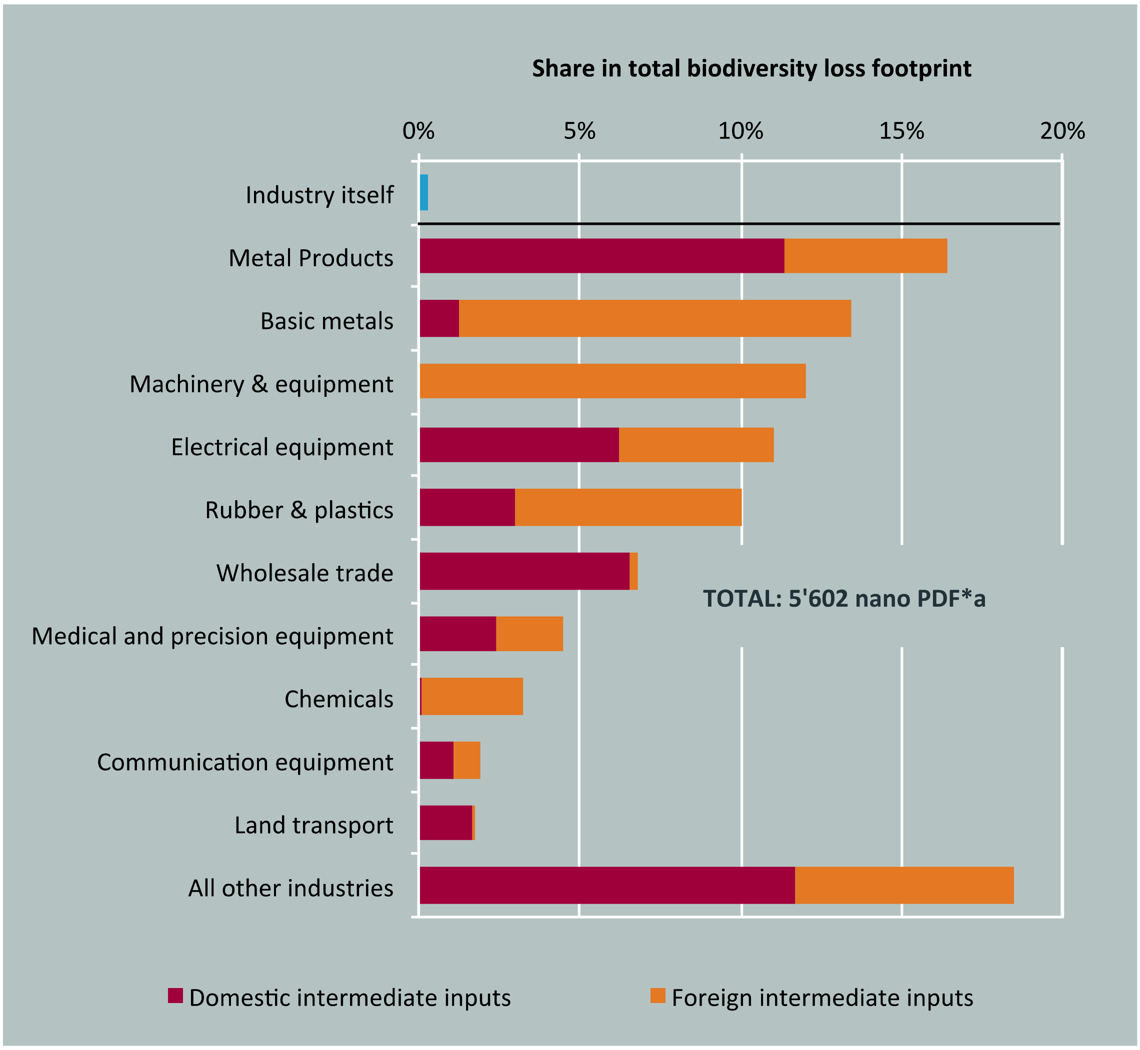

Fig. A.3.2.3: Biodiverstiy loss footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Production of machinery' (Source: Calculations Rütter Soceco)

A.3.3 Water footprint

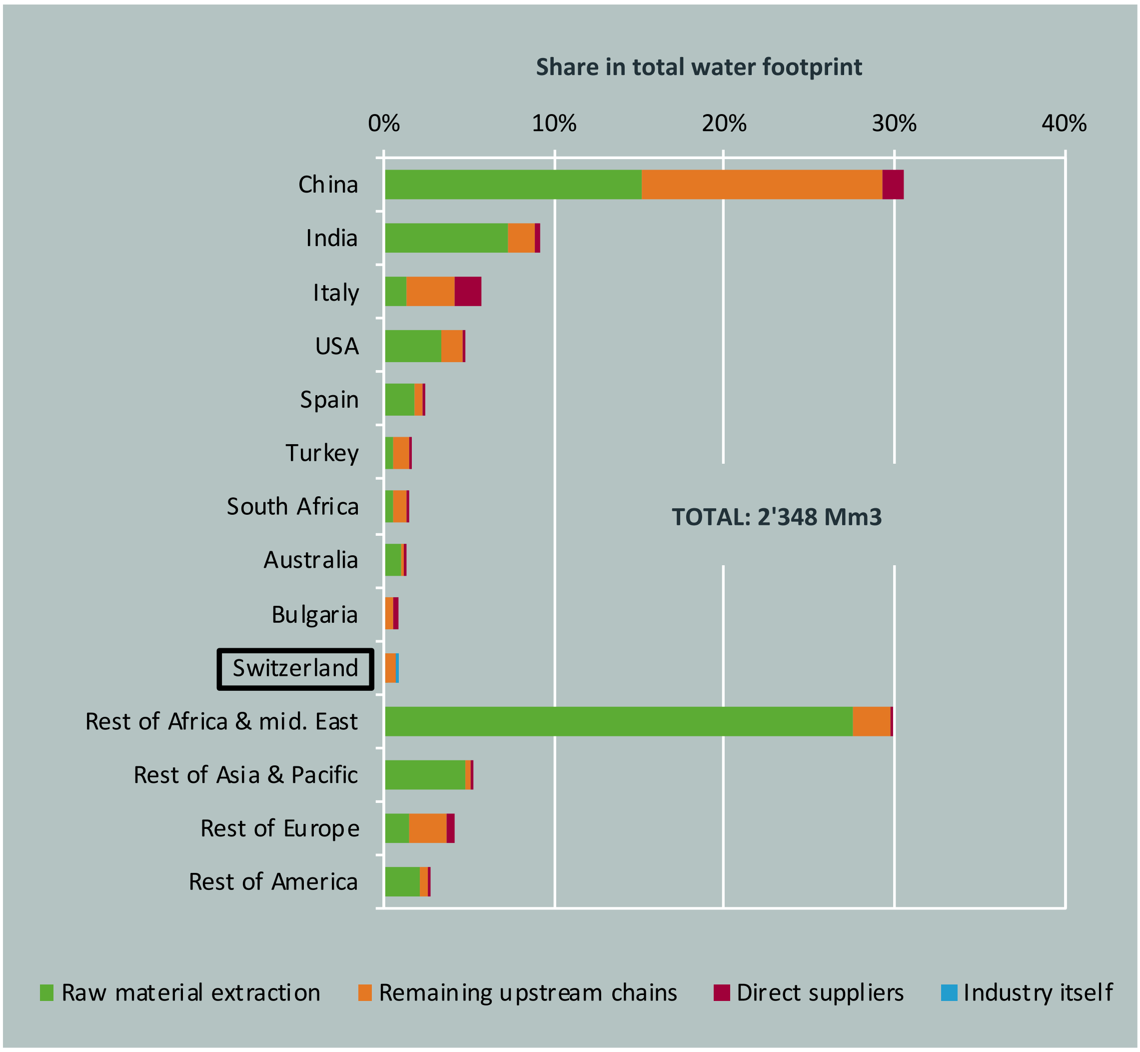

Fig. A.3.3.1: Water footprint caused by the Swiss industry ‘Production of machinery’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

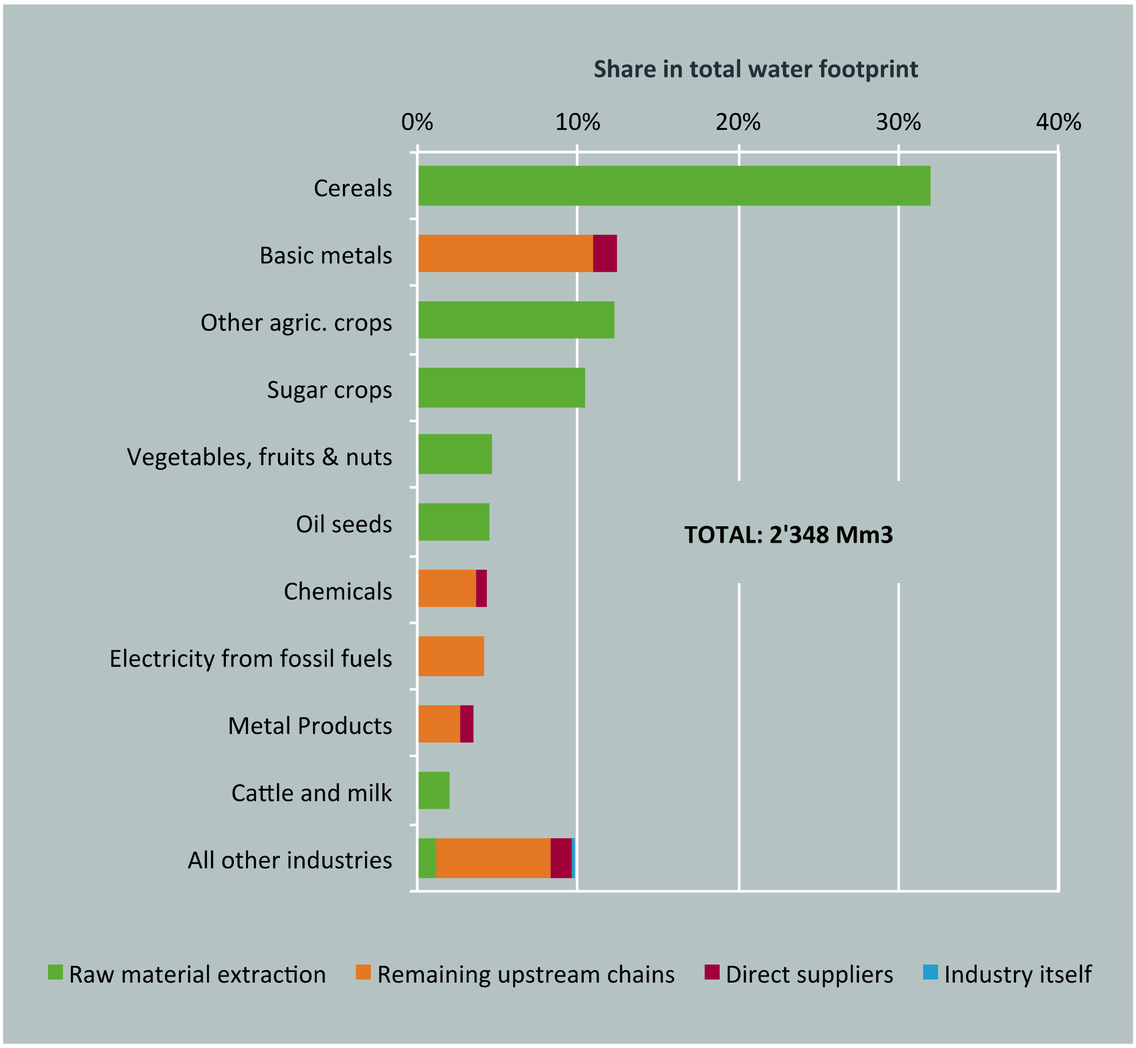

Fig. A.3.3.2: Water footprint caused by the industry 'Production of machinery' by supply chain stage and supplying industries (Source: Calculations Rütter Soceco)

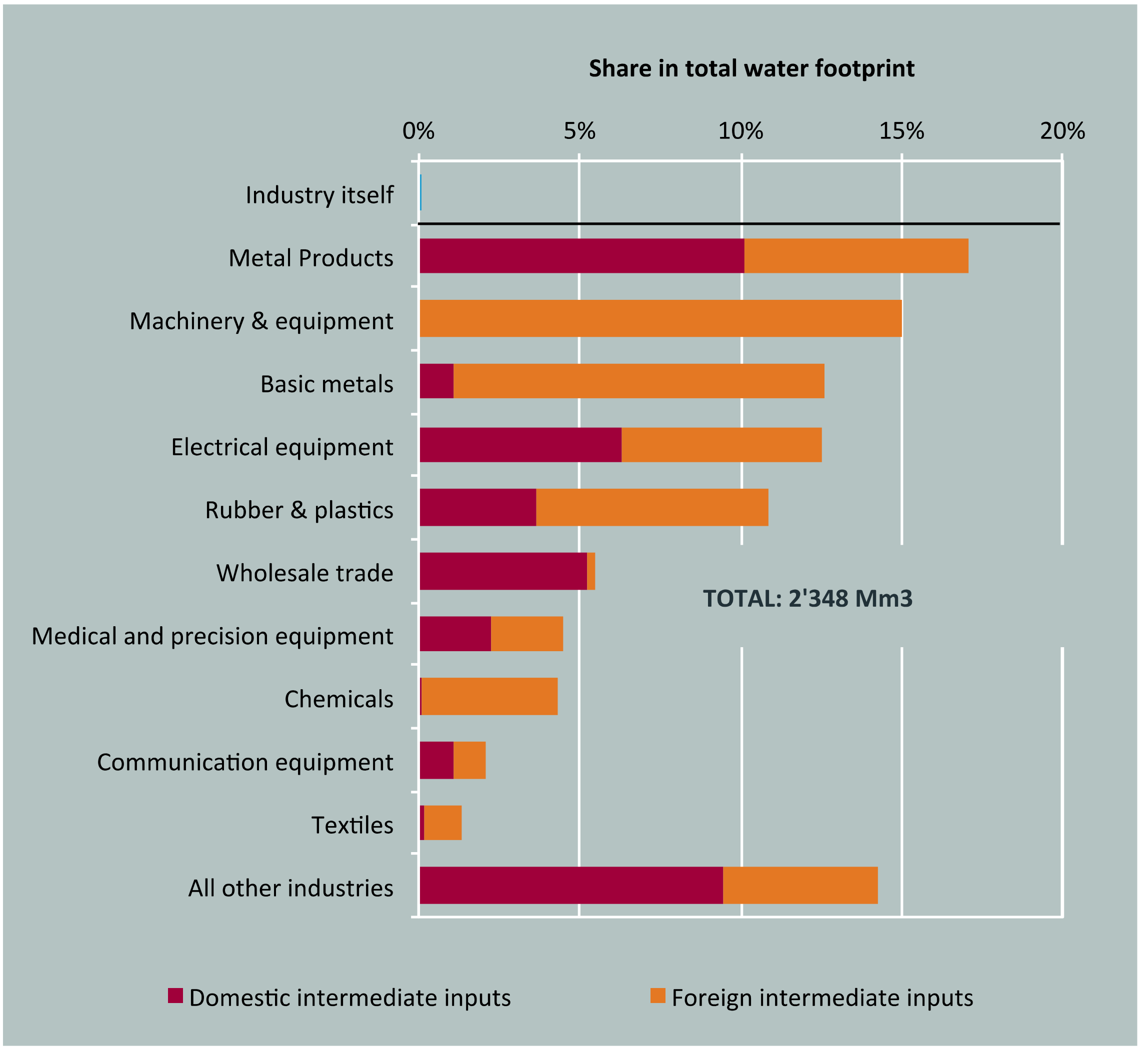

Fig. A.3.3.3: Water footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Production of machinery' (Source: Calculations Rütter Soceco)

A.3.4 Eutrophication footprint

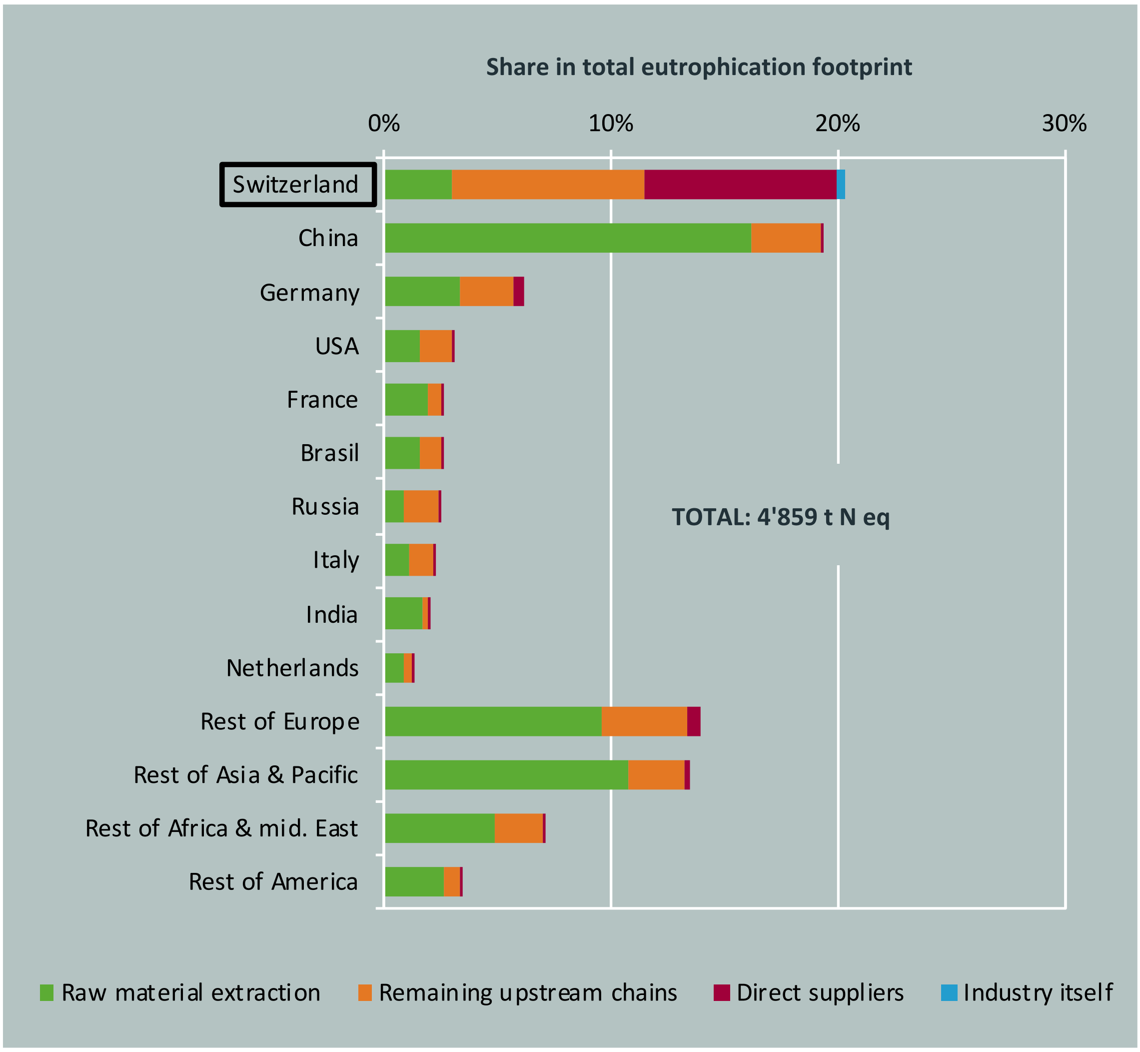

Fig. A.3.4.1: Eutrophication footprint caused by the Swiss industry 'Production of machinery', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

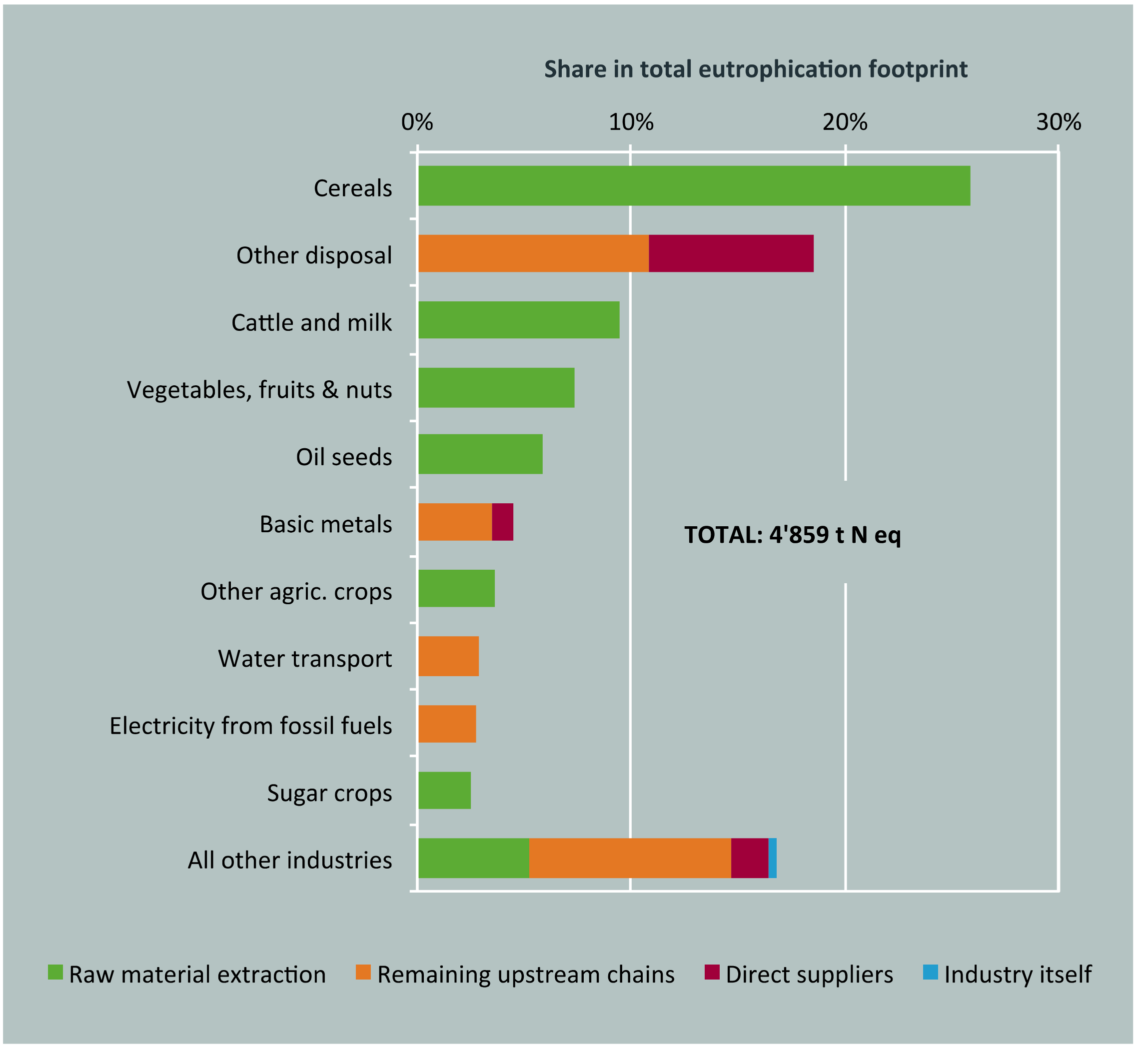

Fig. A.3.4.2: Eutrophication footprint caused by the industry 'Production of machinery' by supply chain stage and industry (Source: Calculations Rütter Soceco)

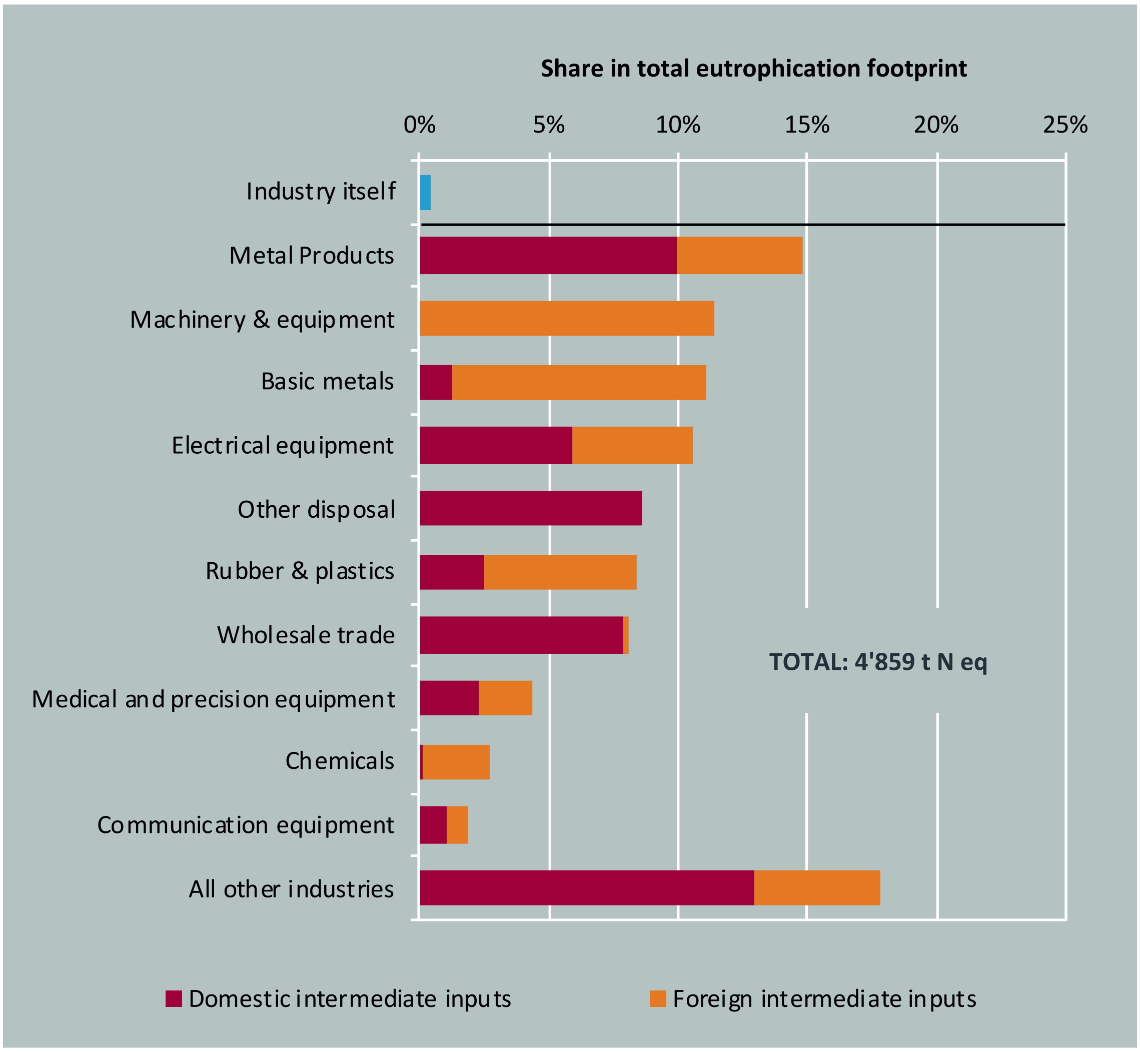

Fig. A.3.4.3: Eutrophication footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Production of machinery' (Source: Calculations Rütter Soceco)

A.4 Real estate services

A.4.1 Biodiversity loss footprint

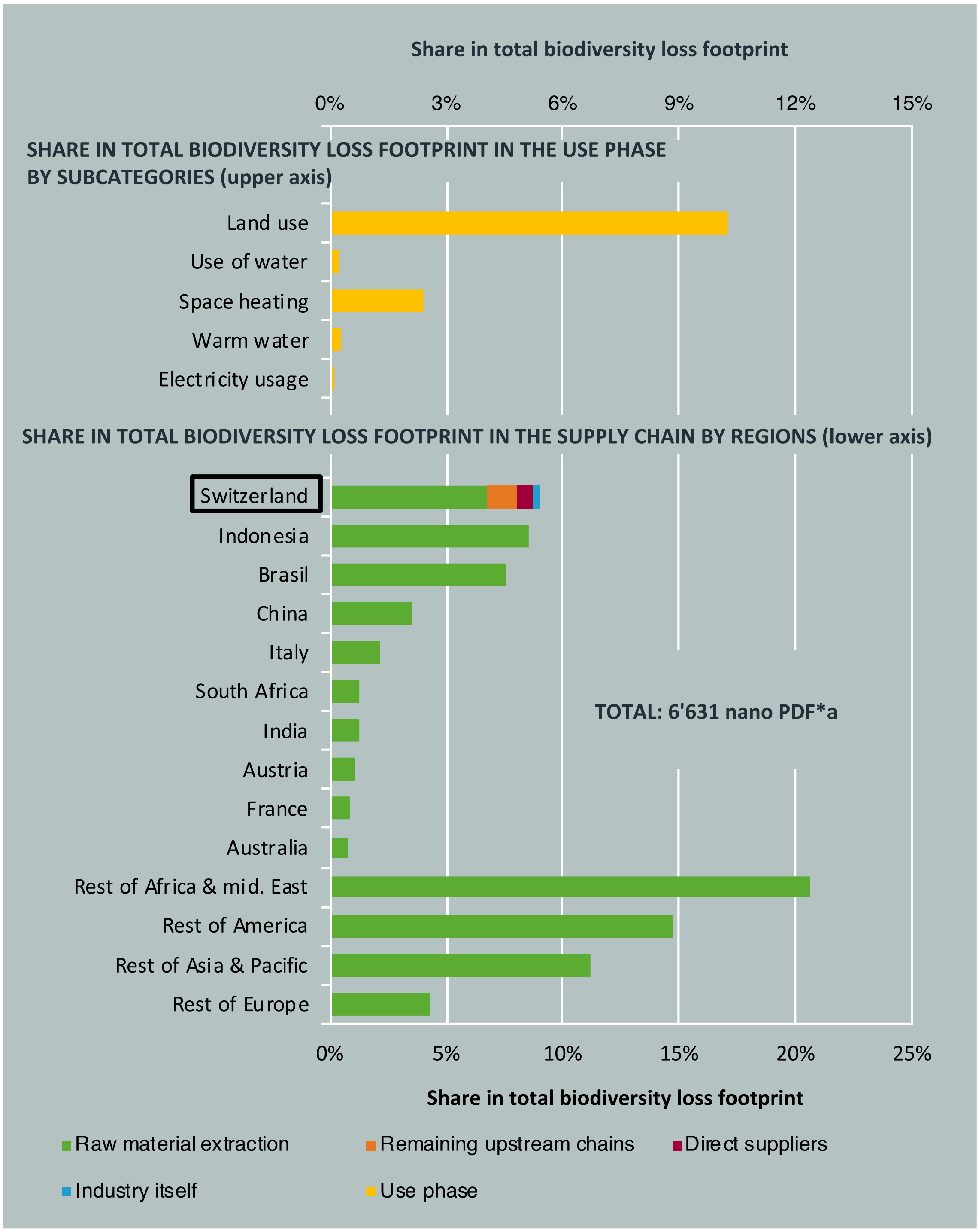

Fig. A.4.1.1: Biodiversity loss footprint caused by the Swiss industry ‘Real estate services’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

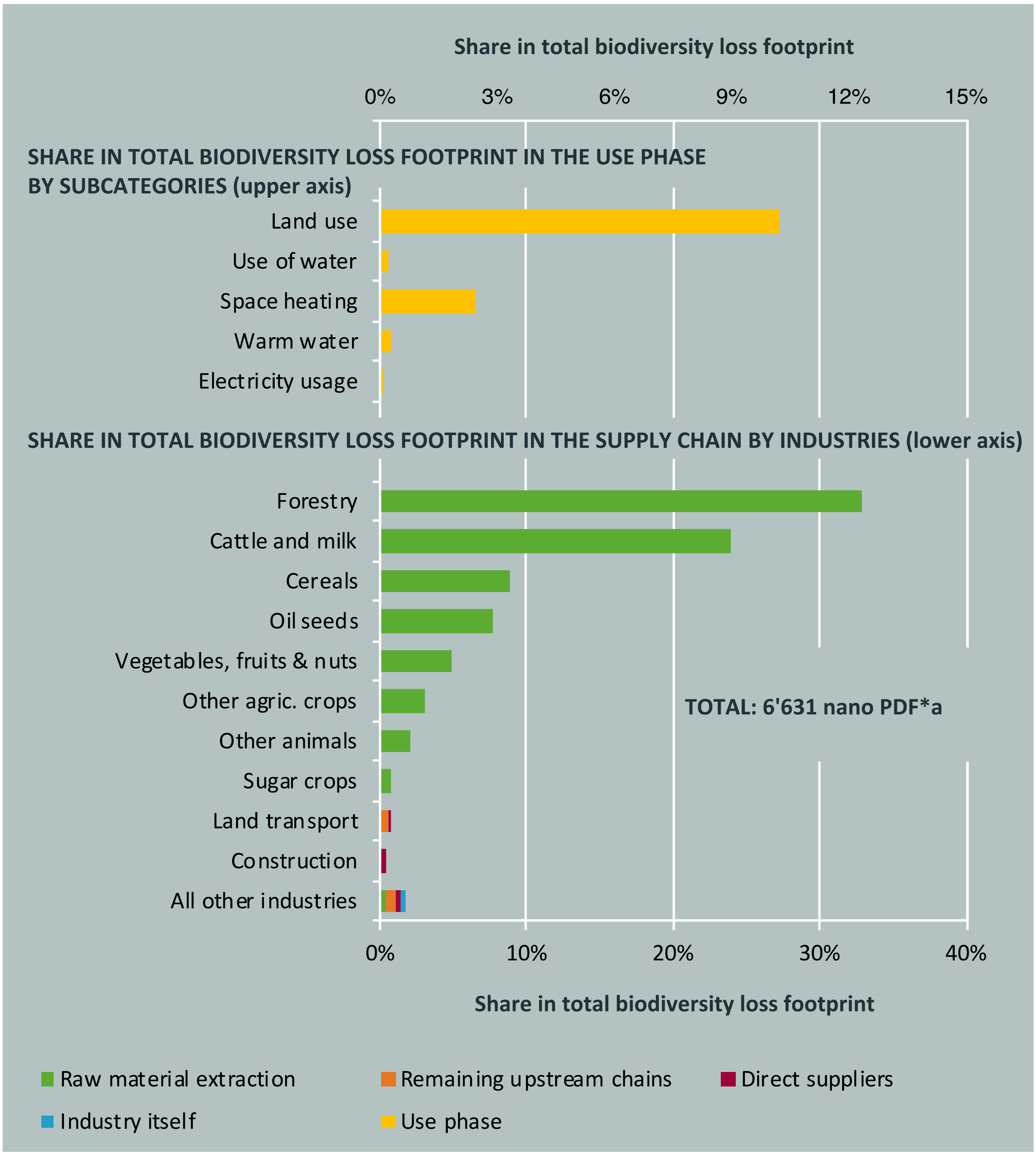

Fig. A.4.1.2: Biodiversity loss footprint caused by the industry ‘Real estate services’ by supply chain stage and industys (Source: Calculations Rütter Soceco)

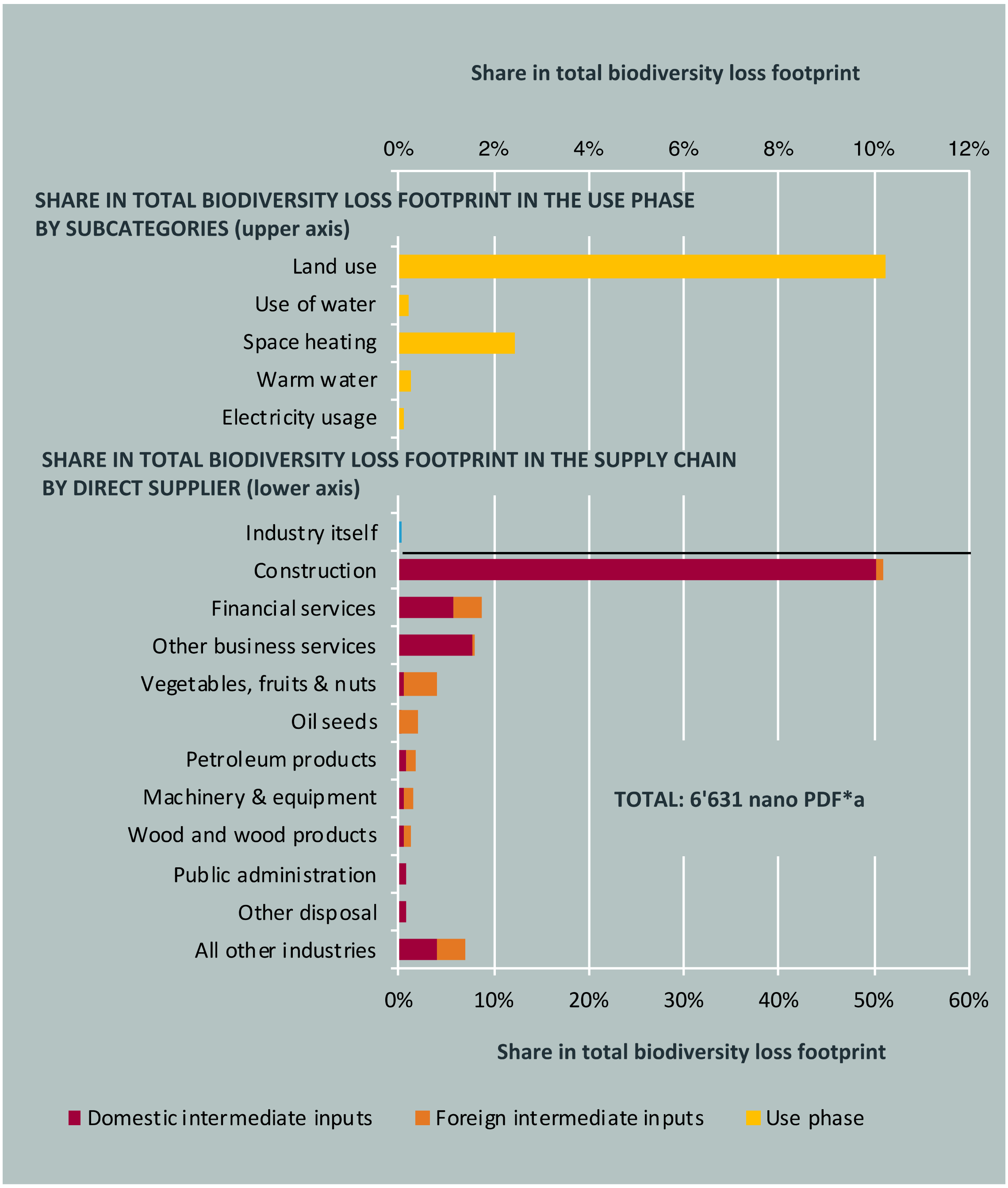

Fig. A.4.1.3: Biodiverstiy loss footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Real estate services', the industry itself and the use phase (Source: Calculations Rütter Soceco)

A.4.2 Water footprint

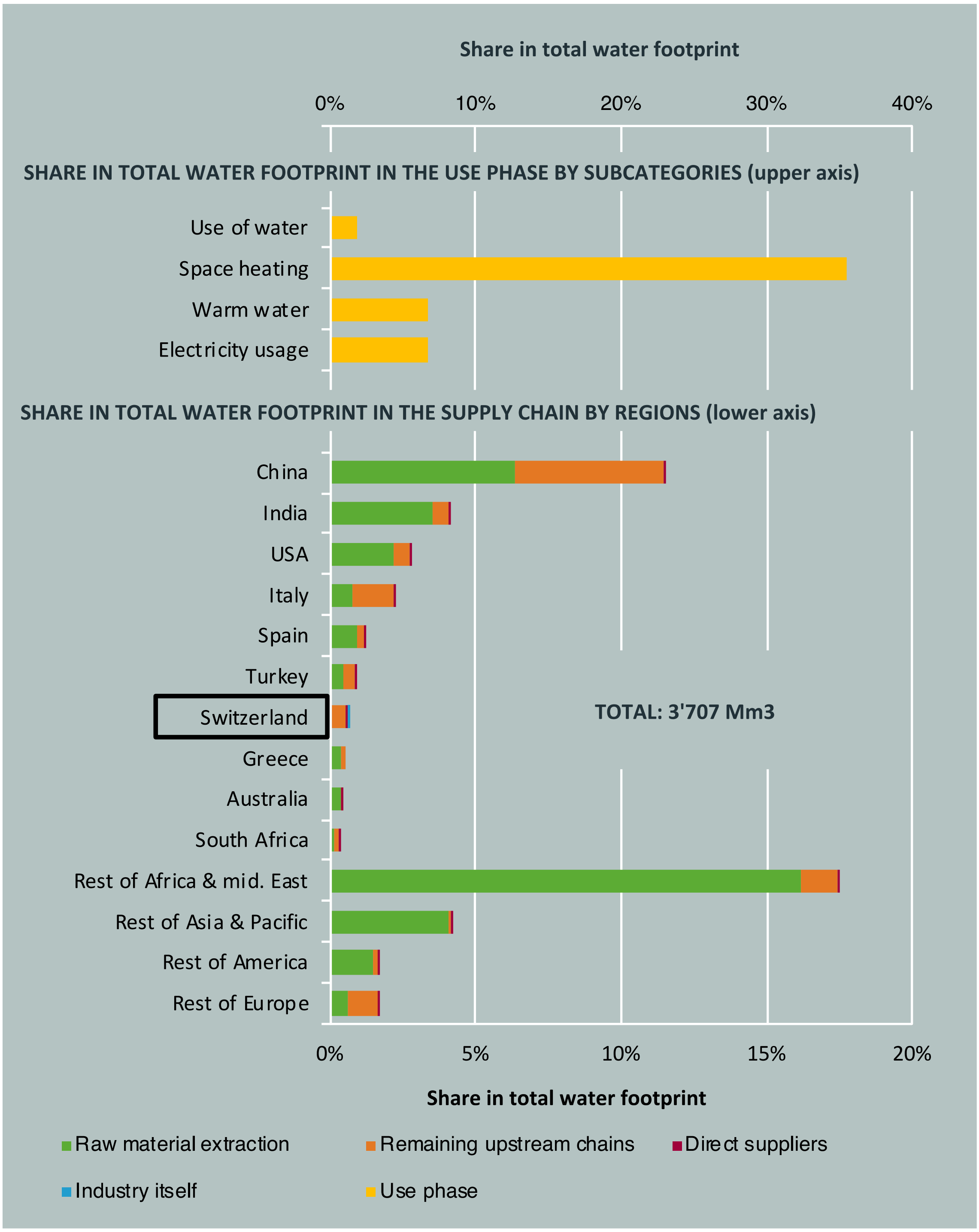

Fig. A.4.2.1: Water footprint caused by the Swiss industry 'Real estate services', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

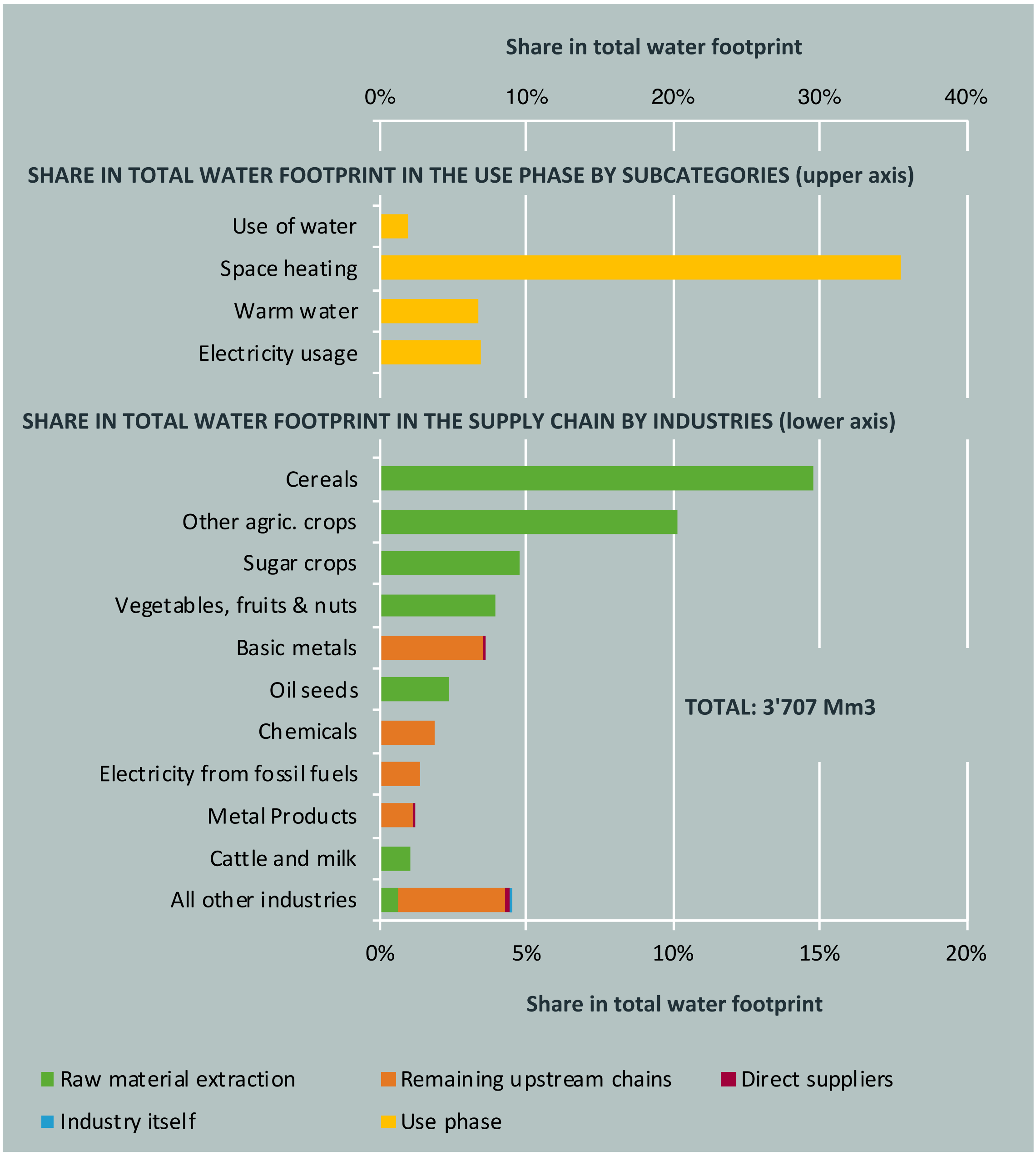

Fig. A.4.2.2: Water footprint caused by the industry 'Real estate services' by supply chain stage and industry (Source: Calculations Rütter Soceco)

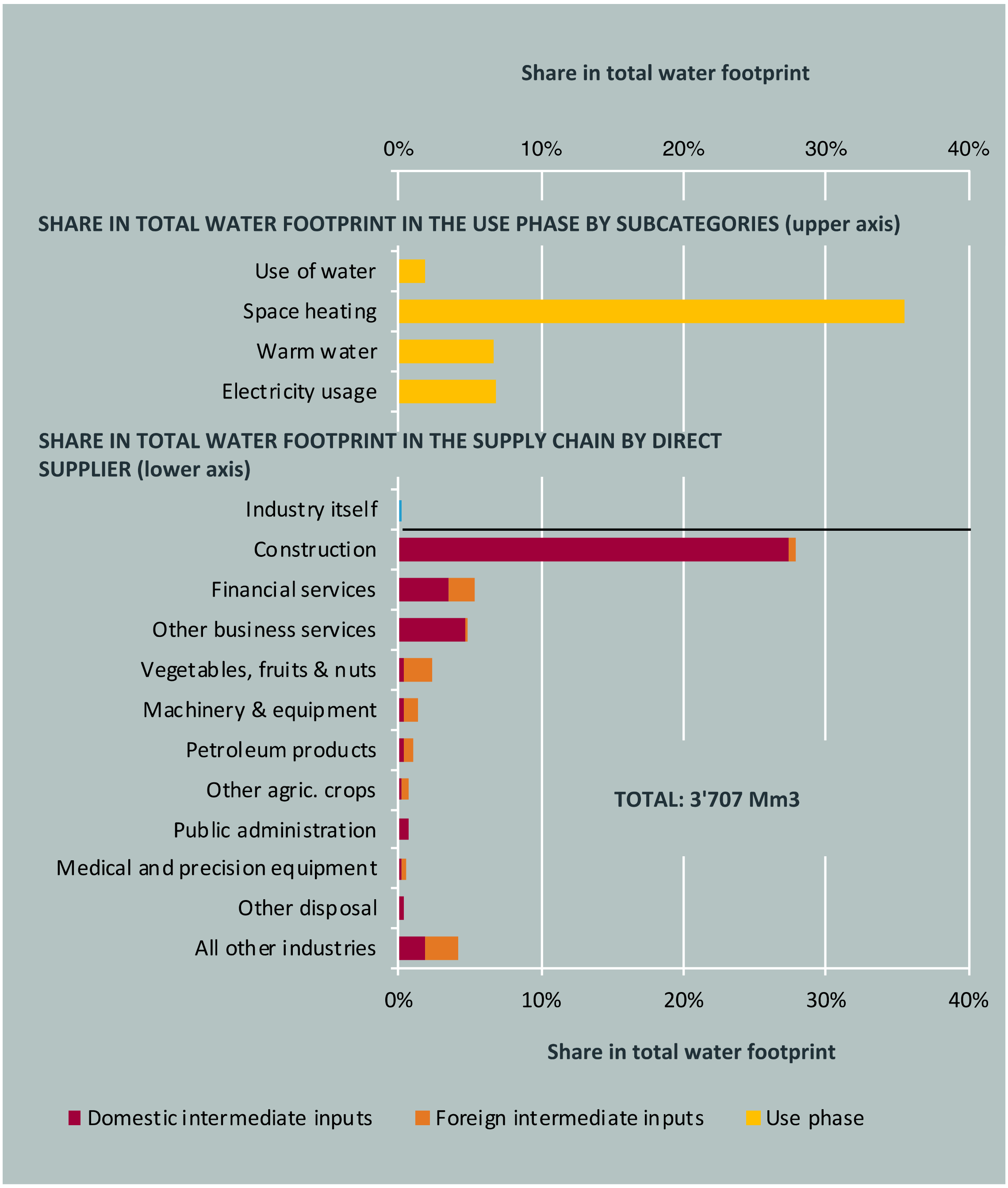

Fig. A.4.2.3: Water footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Real estate services', the industry itself and the use phase (Source: Calculations Rütter Soceco)

A.4.3 Air pollution footprint

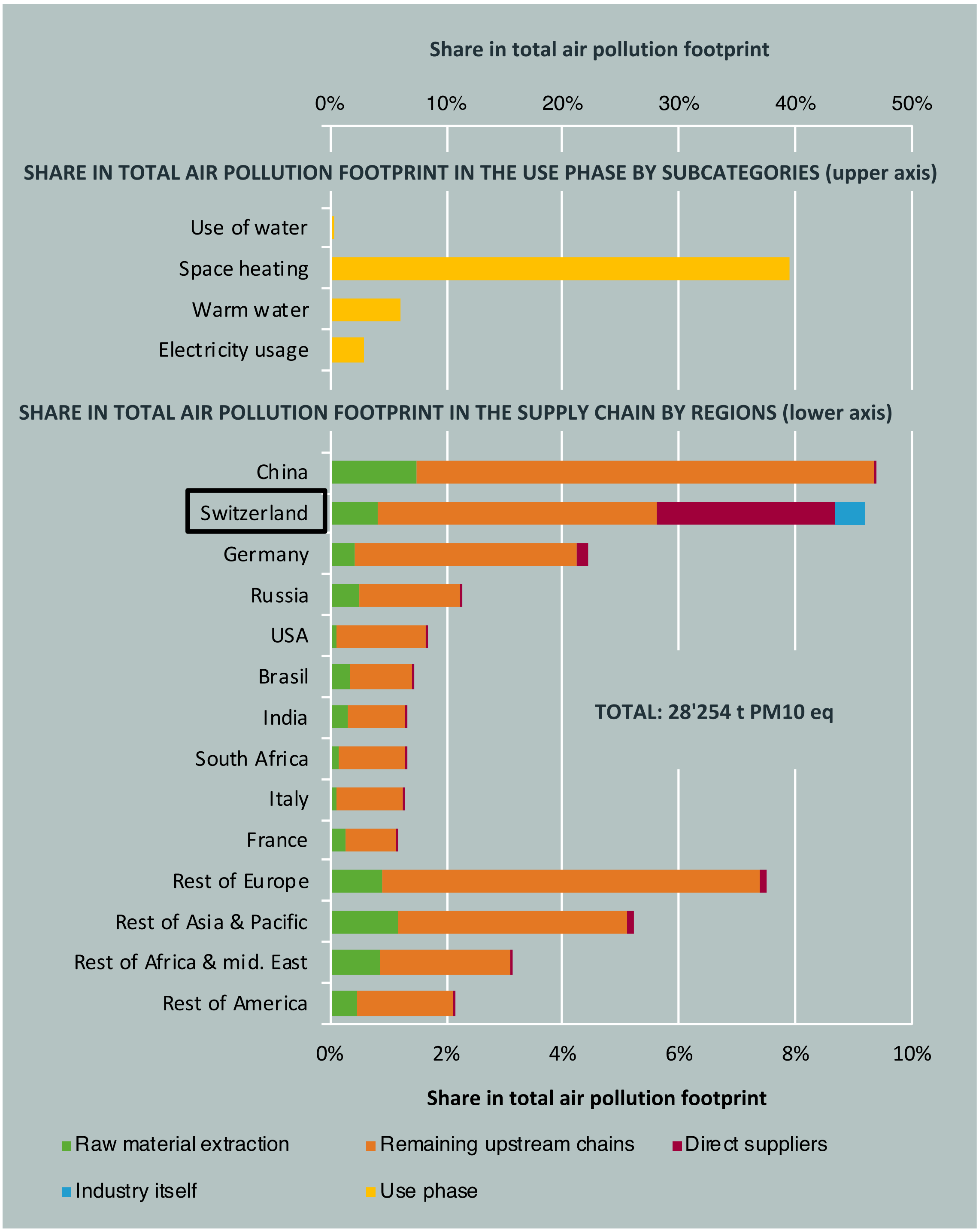

Fig. A.4.3.1: Air pollution footprint caused by the Swiss industry 'Real estate services', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

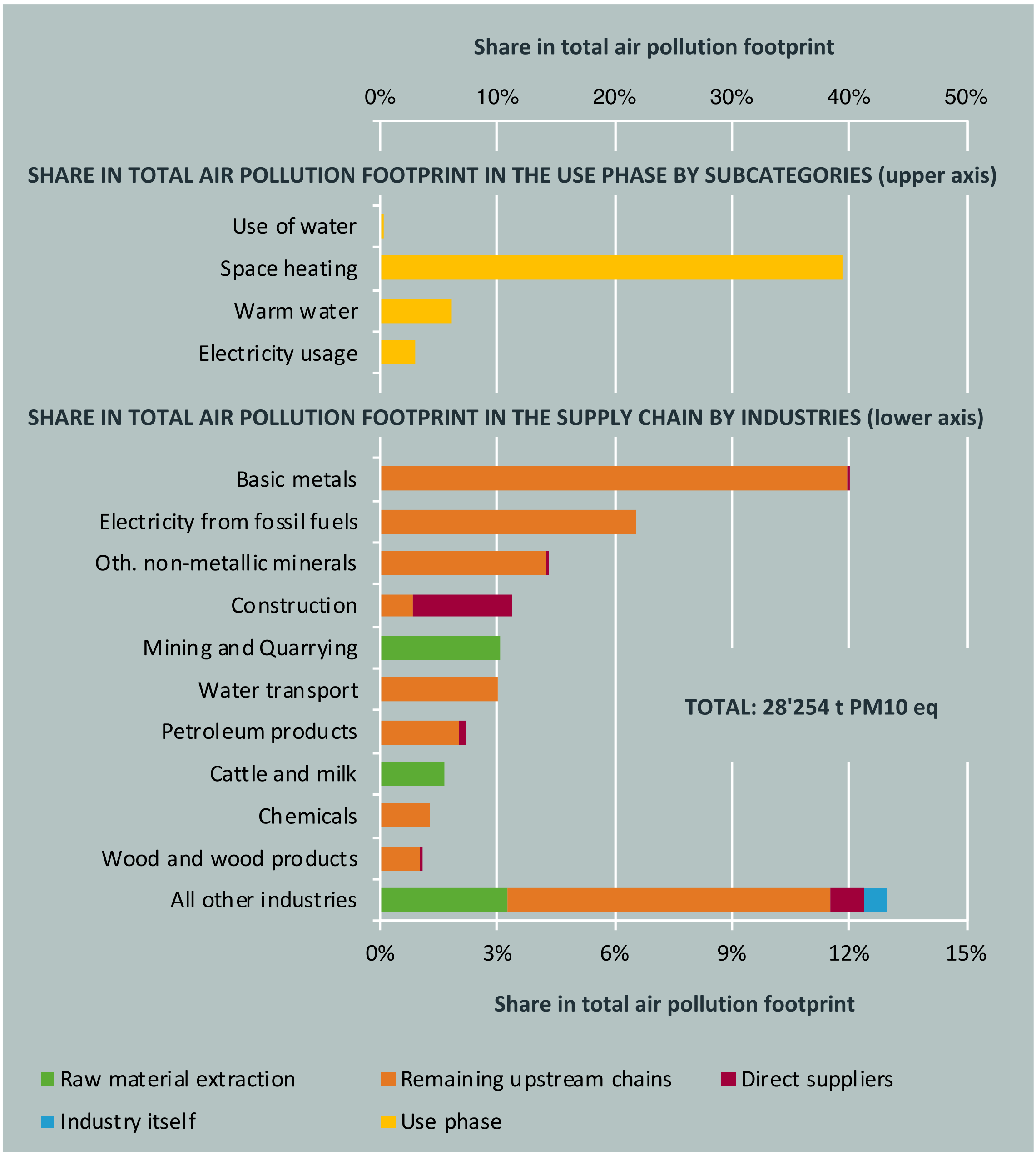

Fig. A.4.3.2: Air pollution footprint caused by the industry 'Real estate services' by supply chain stage and industry (Source: Calculations Rütter Soceco)

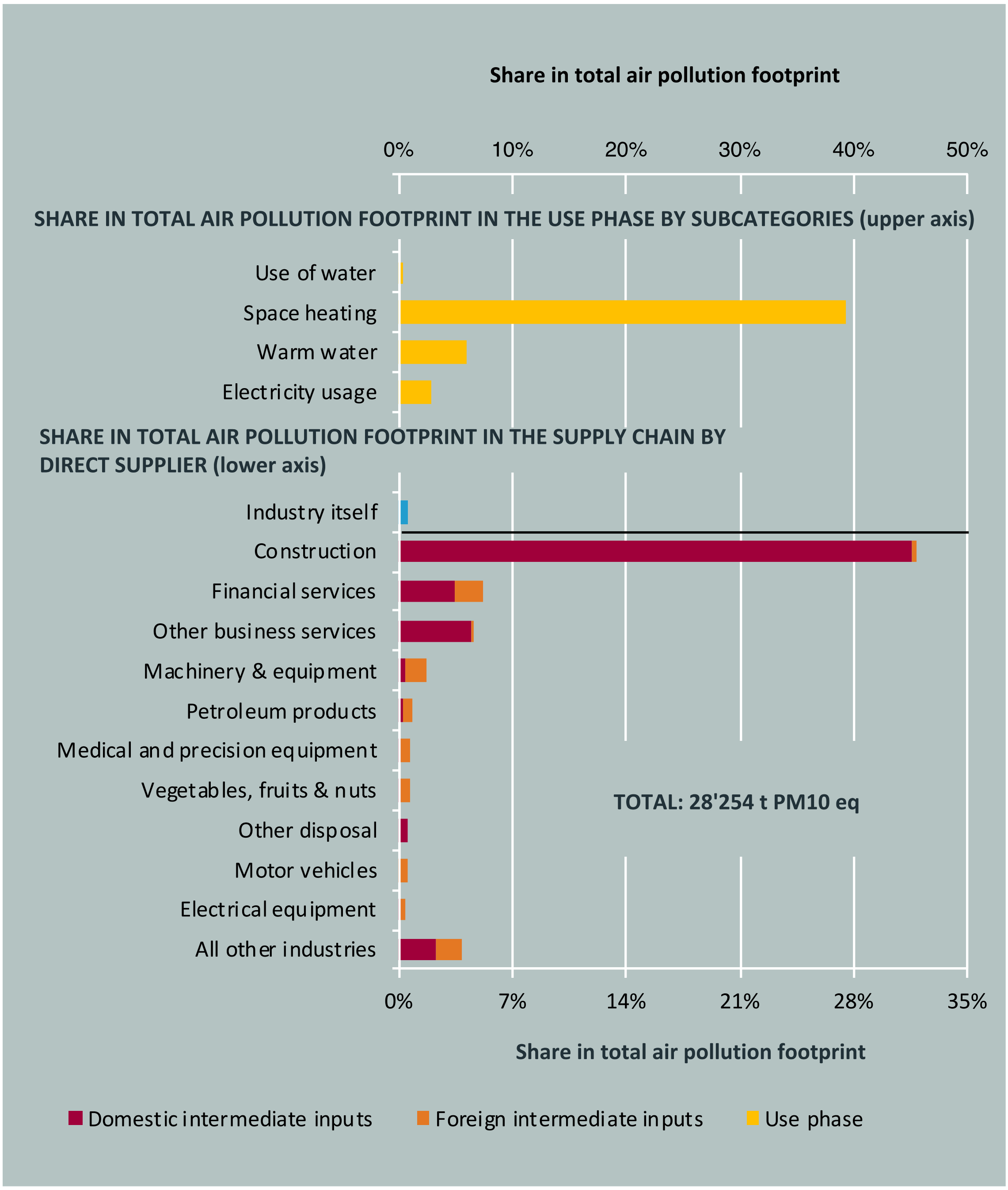

Fig. A.4.3.3: Air pollution footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Real estate services', the industry itself and the use phase (Source: Calculations Rütter Soceco)

A.4.4 Eutrophication footprint

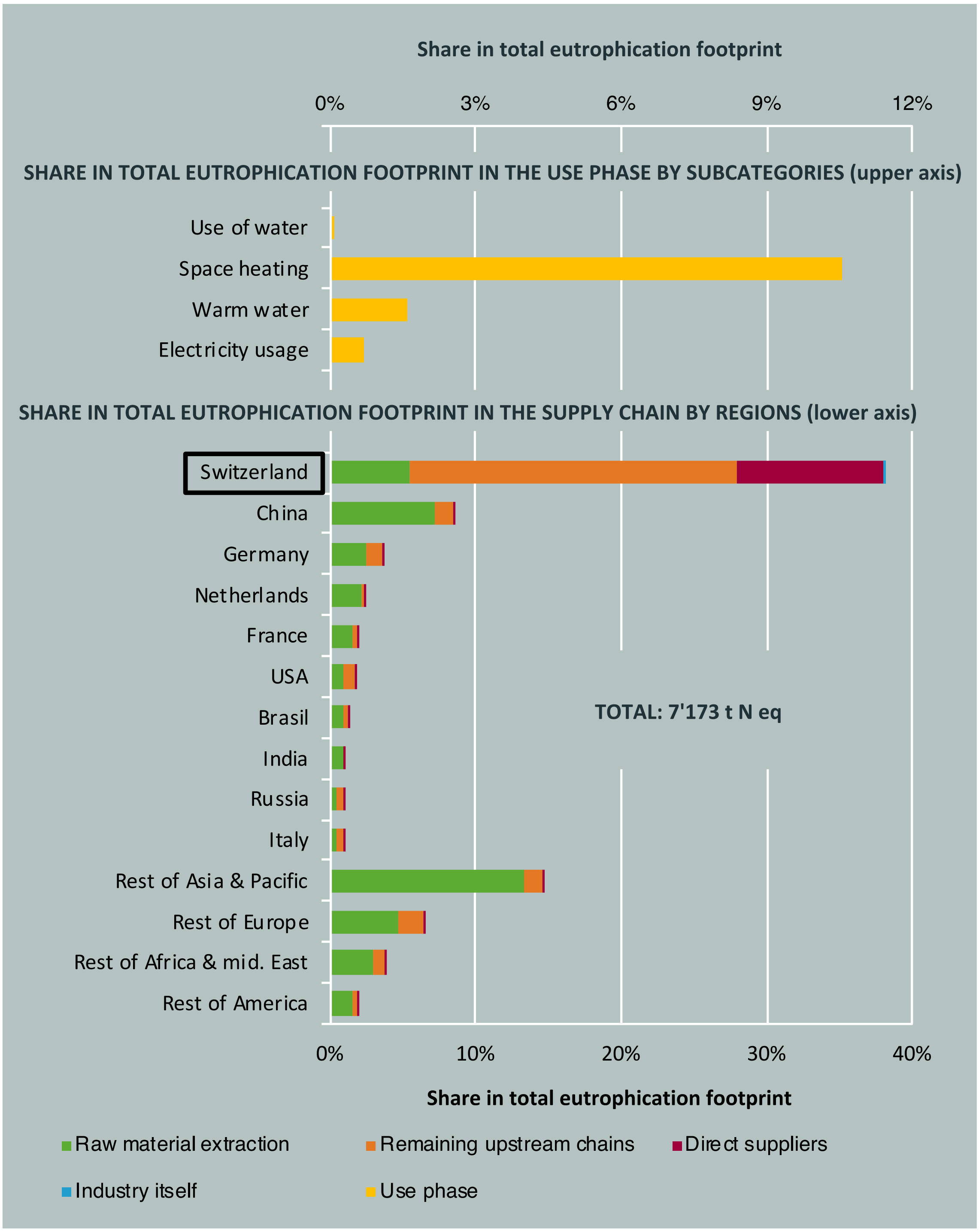

Fig. A.4.4.1: Eutrophication footprint caused by the Swiss industry 'Real estate services', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

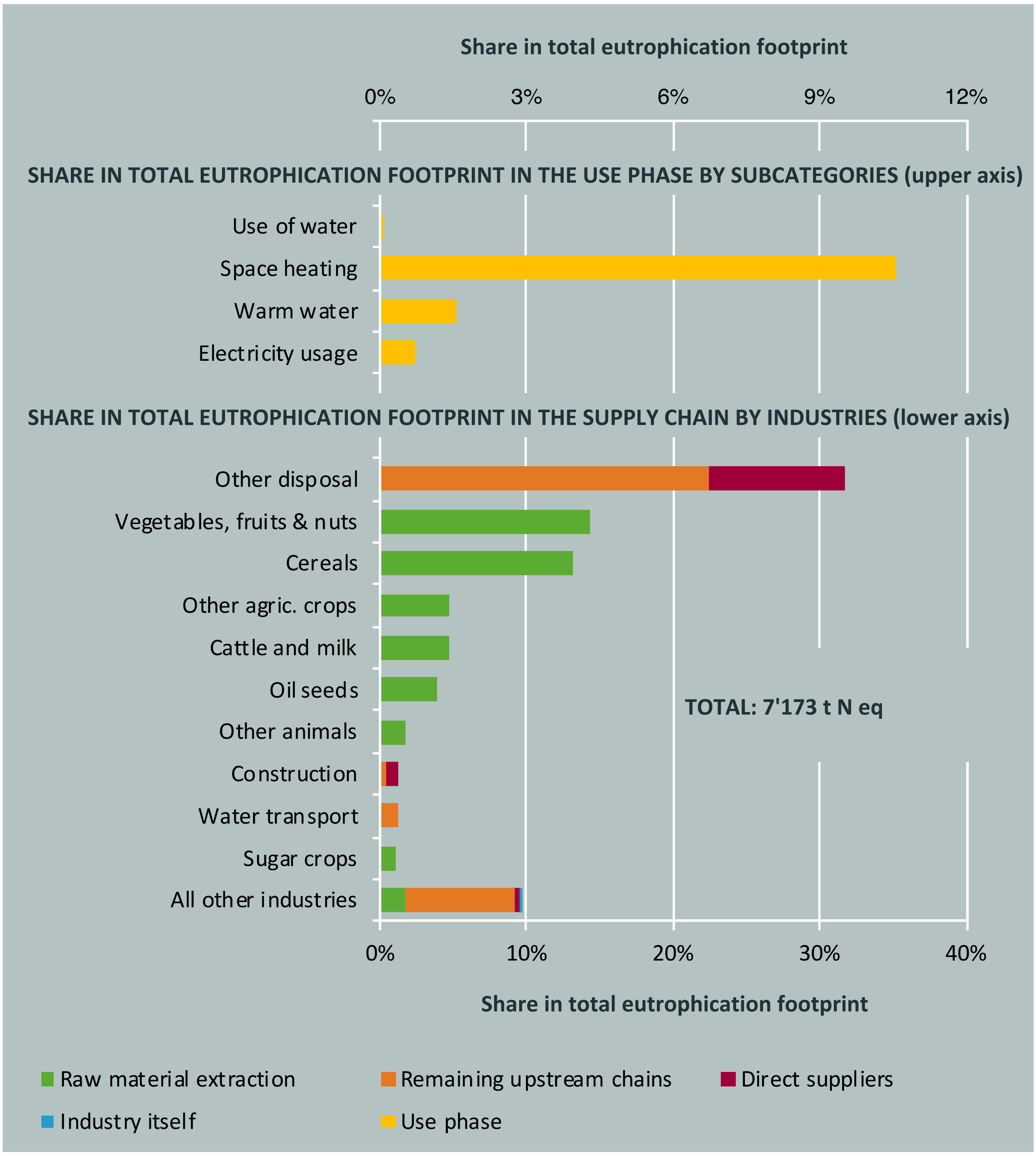

Fig. A.4.4.2: Eutrophication footprint caused by the industry 'Real estate services' by supply chain stage and industry (Source: Calculations Rütter Soceco)

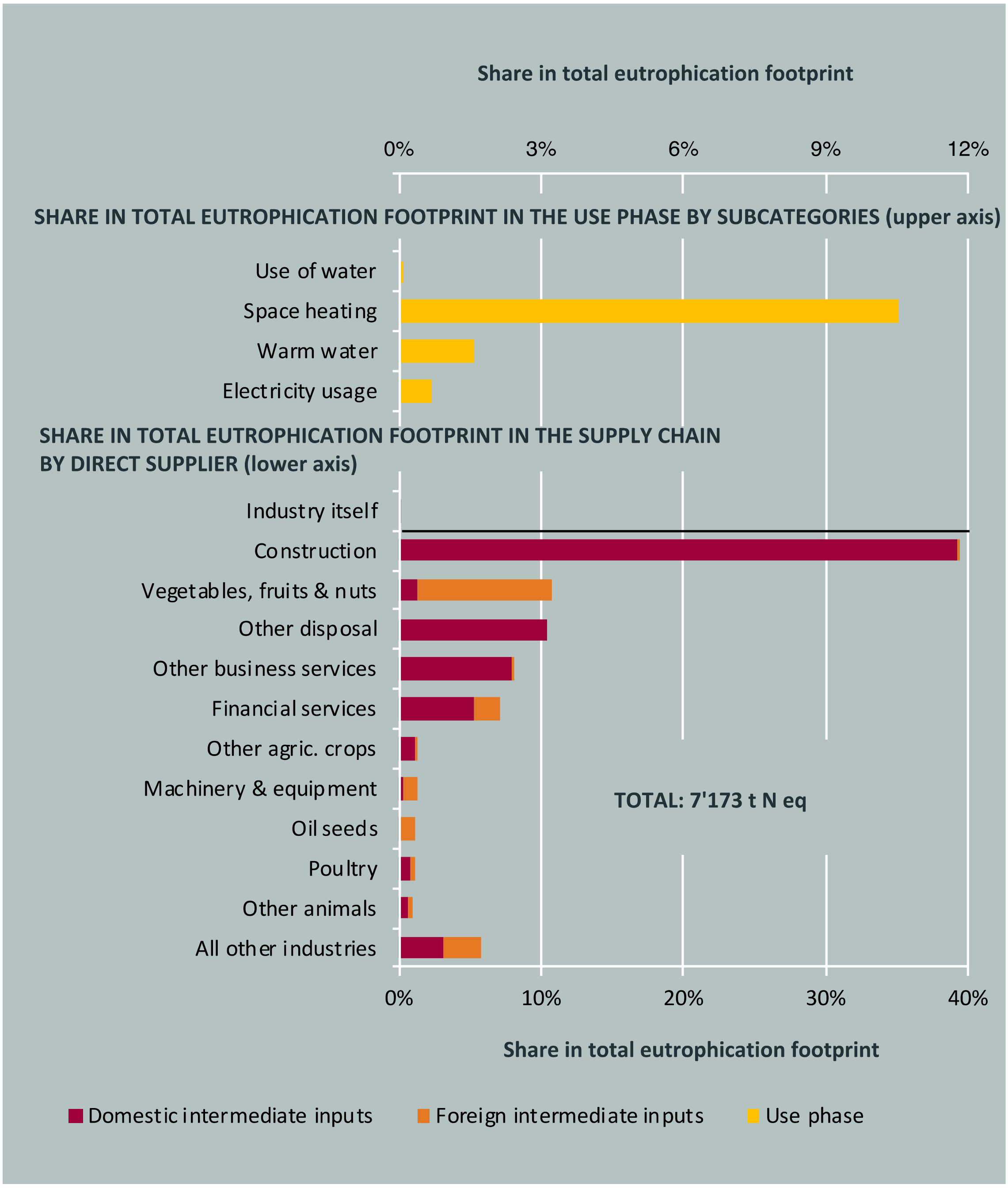

Fig. A.4.4.3: Eutrophication footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Real estate services', the industry itself and the use phase (Source: Calculations Rütter Soceco)

A.5 Health and social work

A.5.1 Biodiversity loss footprint

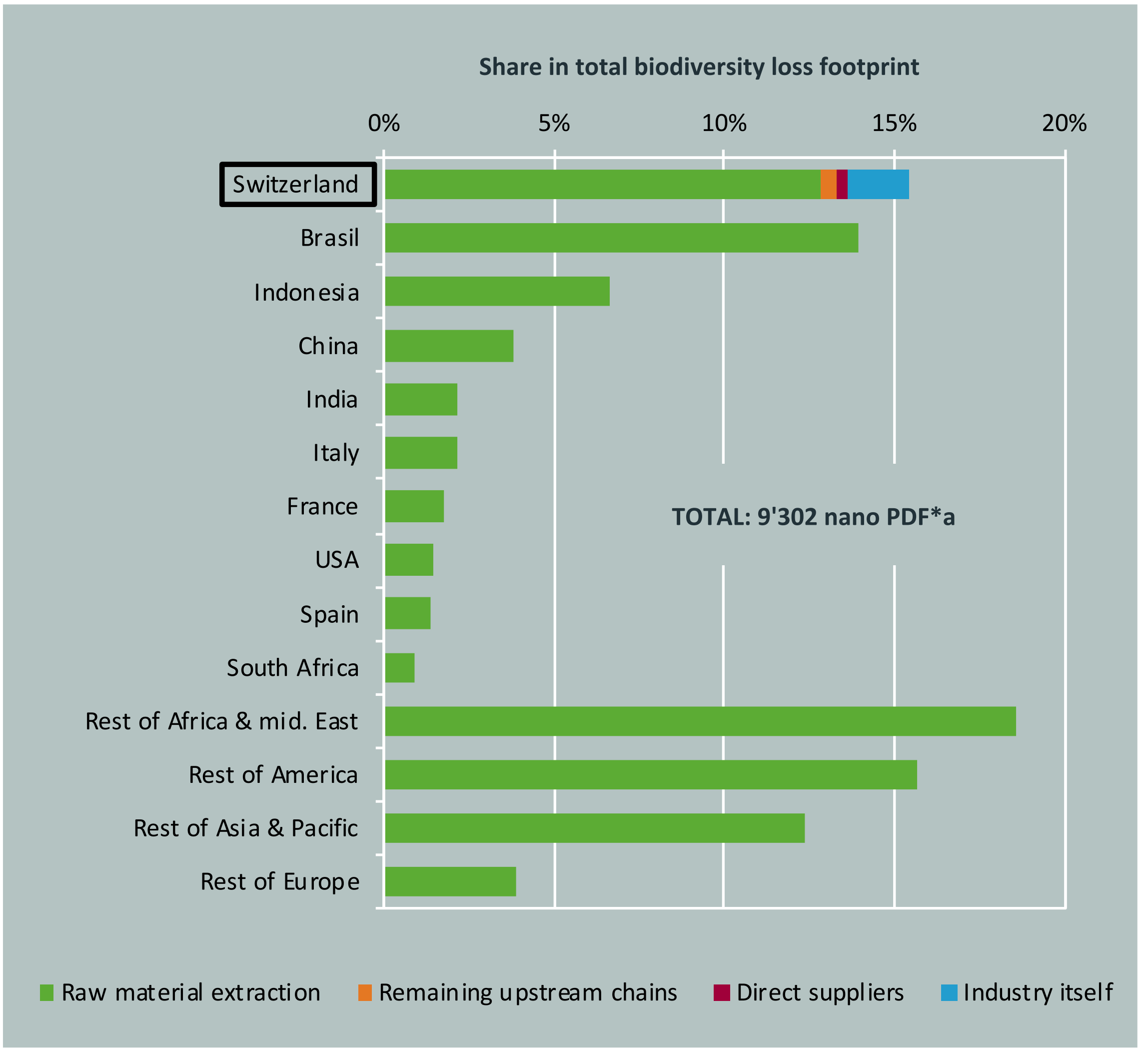

Fig. A.5.1.1: Biodiversity loss footprint caused by the Swiss industry 'Human health and social work', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

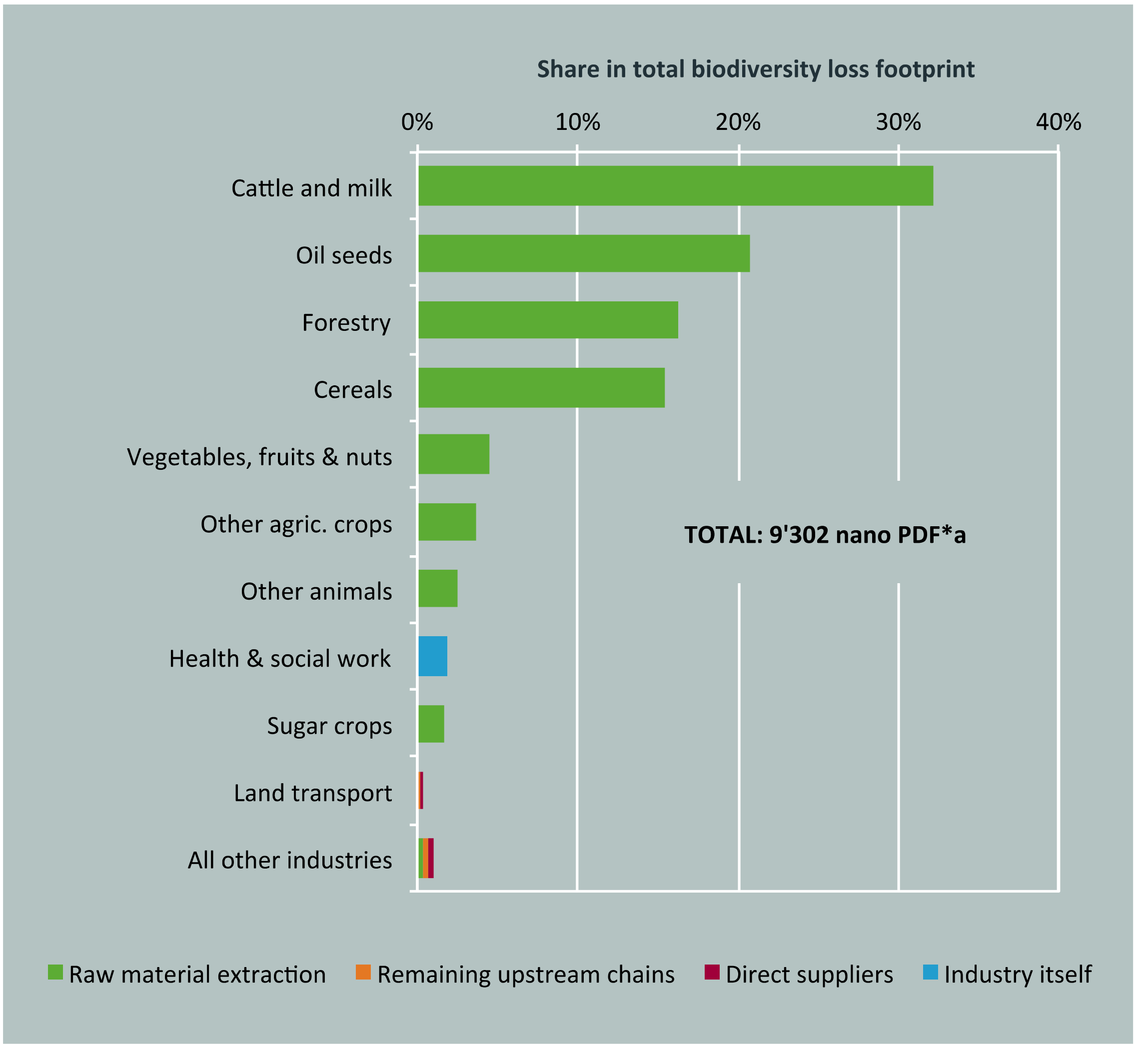

Fig. A.5.1.2: Biodiversity loss footprint caused by the industry 'Human health and social work' by supply chain stage and industry (Source: Calculations Rütter Soceco)

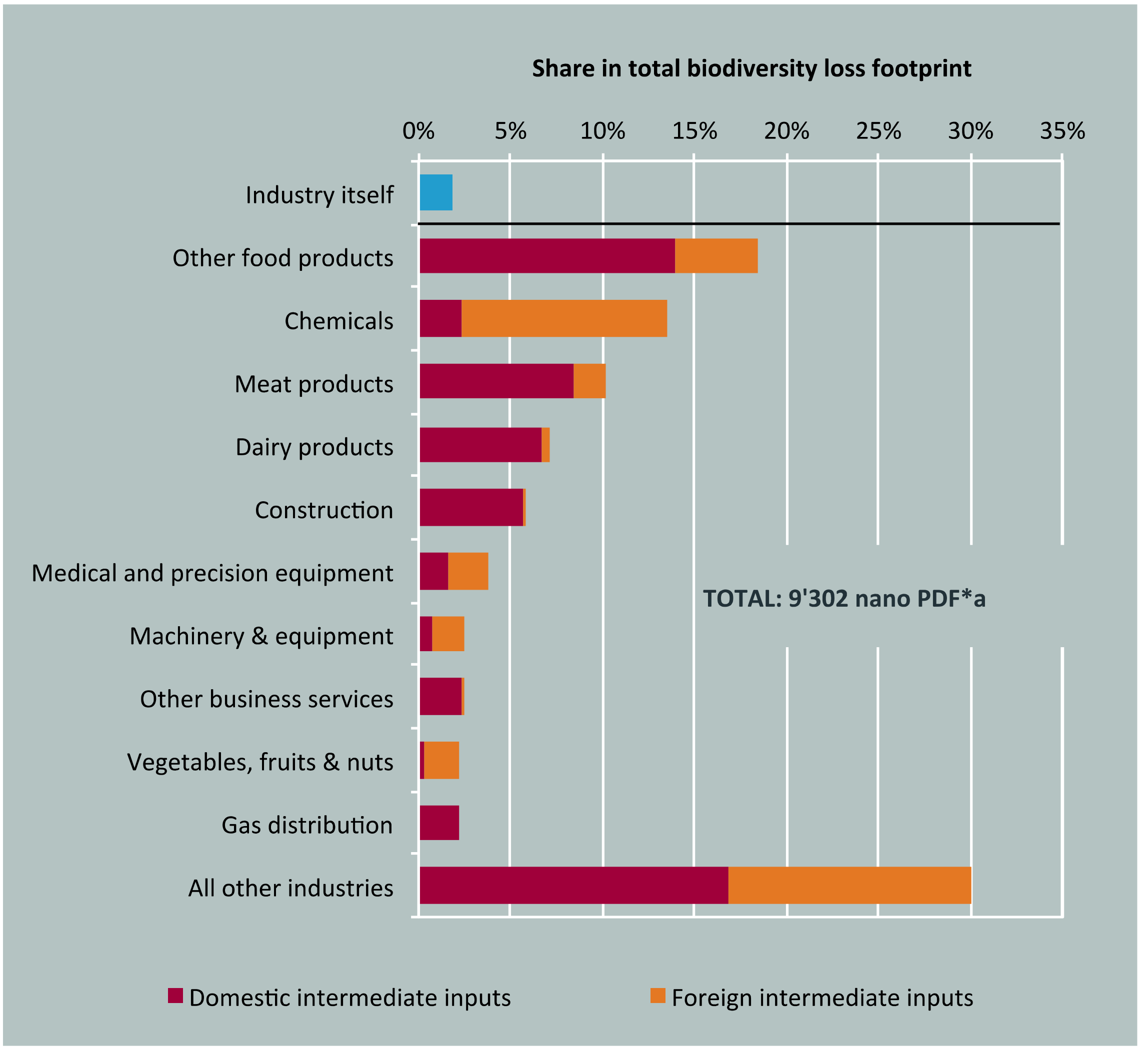

Fig. A.5.1.3: Biodiverstiy loss footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Human health and social work' (Source: Calculations Rütter Soceco)

A.5.2 Water footprint

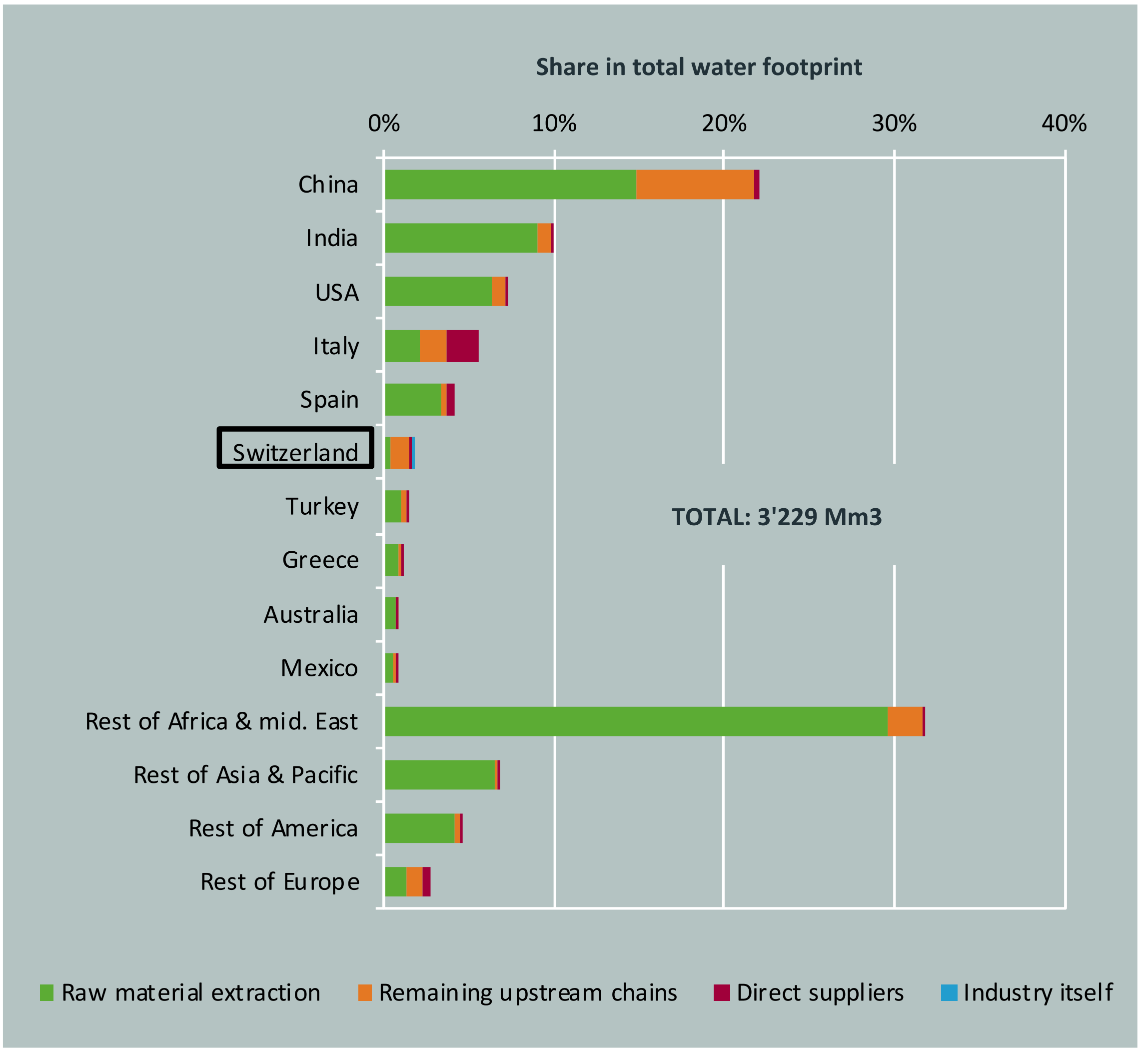

Fig. A.5.2.1: Water footprint caused by the Swiss industry 'Human health and social work', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

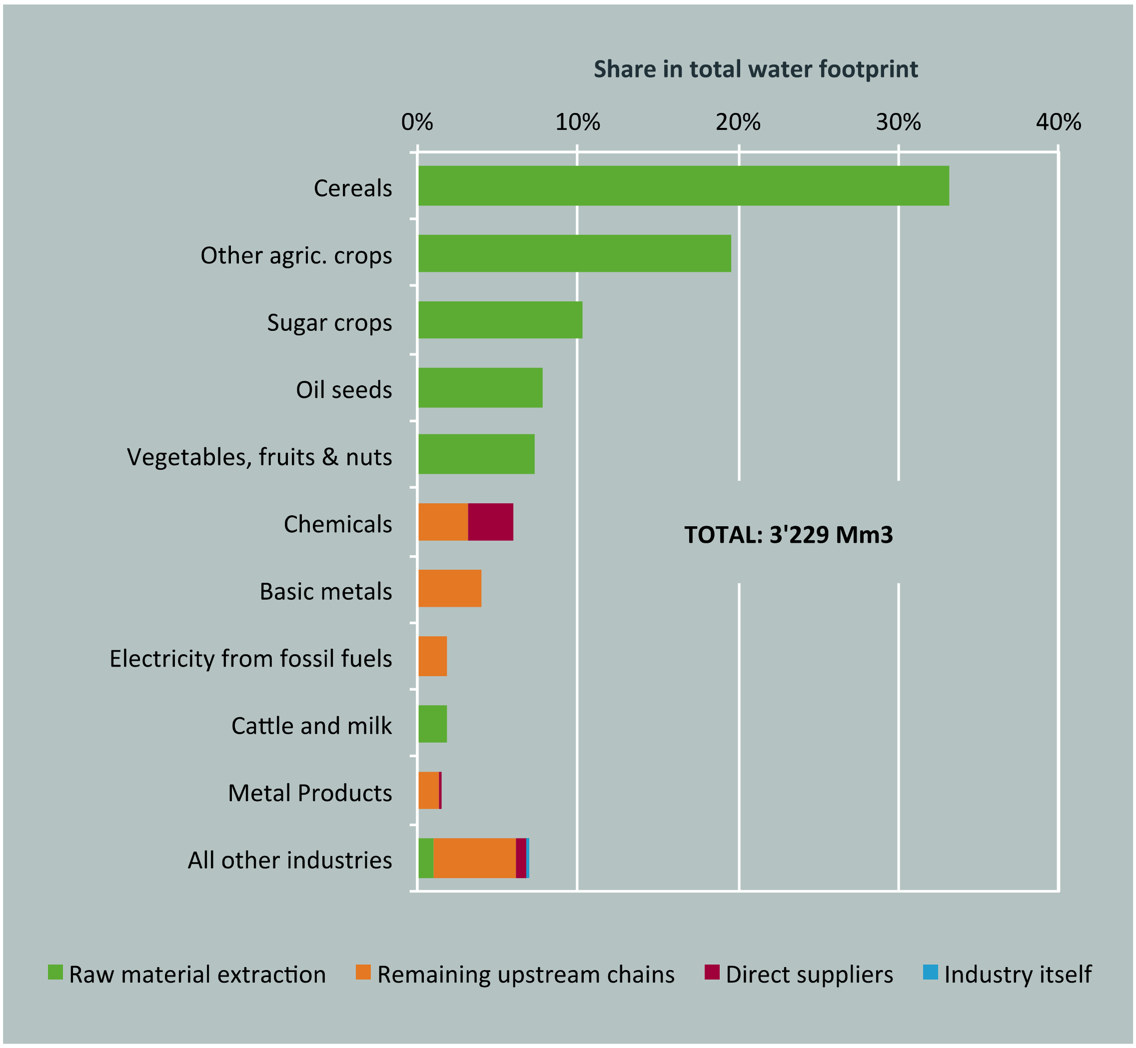

Fig. A.5.2.2: Water footprint caused by the industry 'Human health and social work' by supply chain stage and industry (Source: Calculations Rütter Soceco)

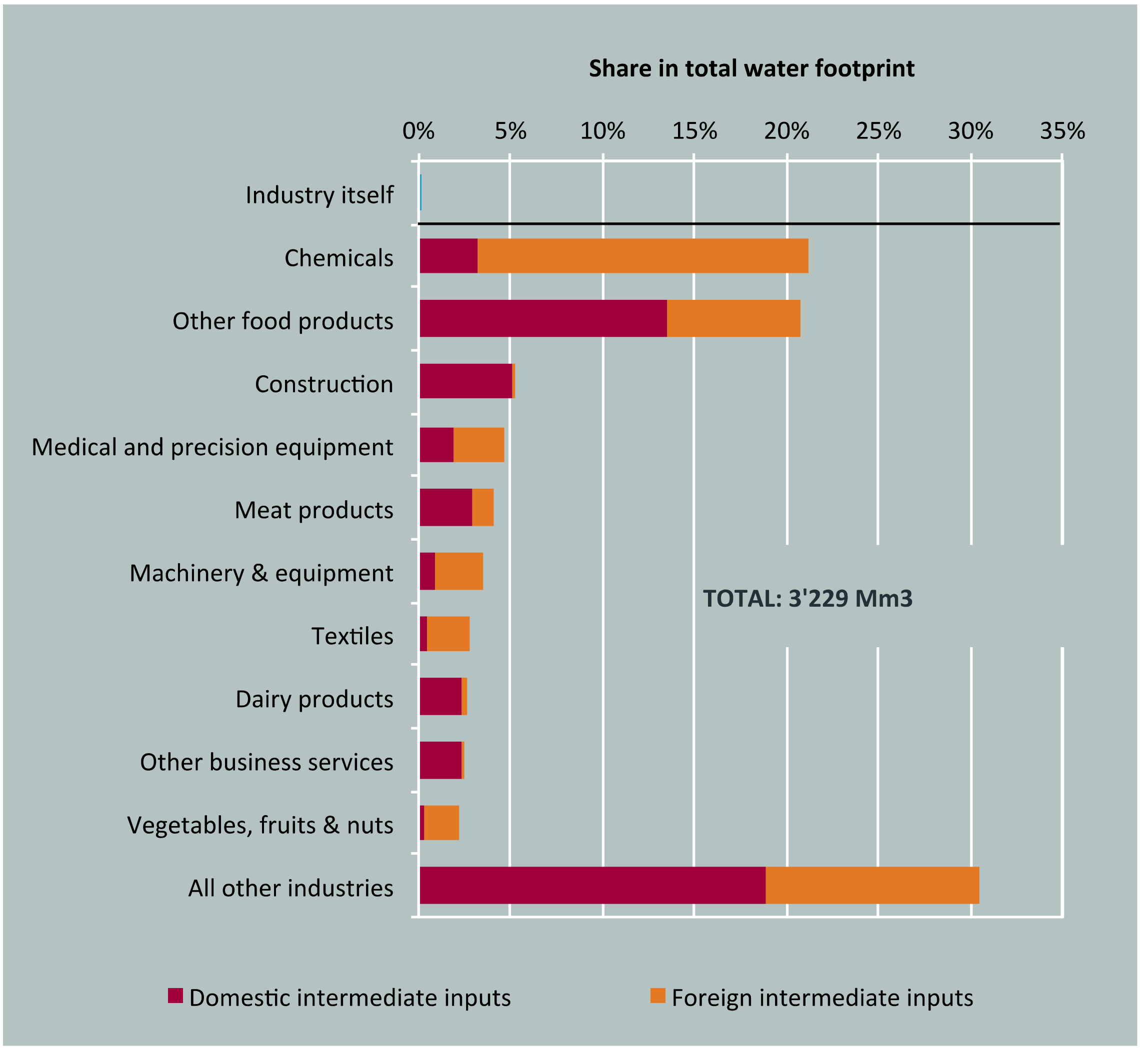

Fig. A.5.2.3: Water footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Human health and social work' (Source: Calculations Rütter Soceco)

A.5.3 Air pollution footprint

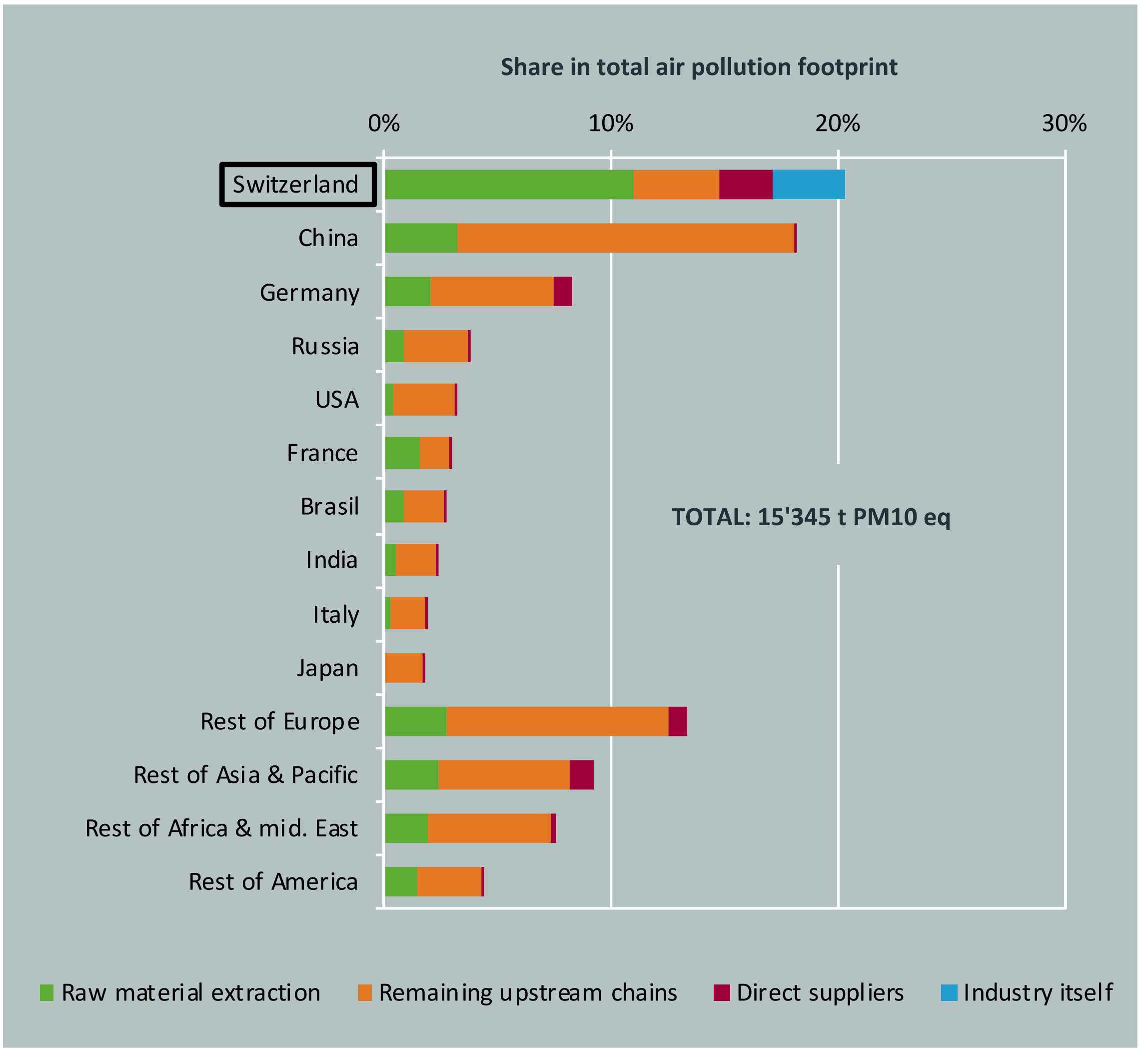

Fig. A.5.3.1: Air pollution footprint caused by the Swiss industry ‘Human health and social work’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

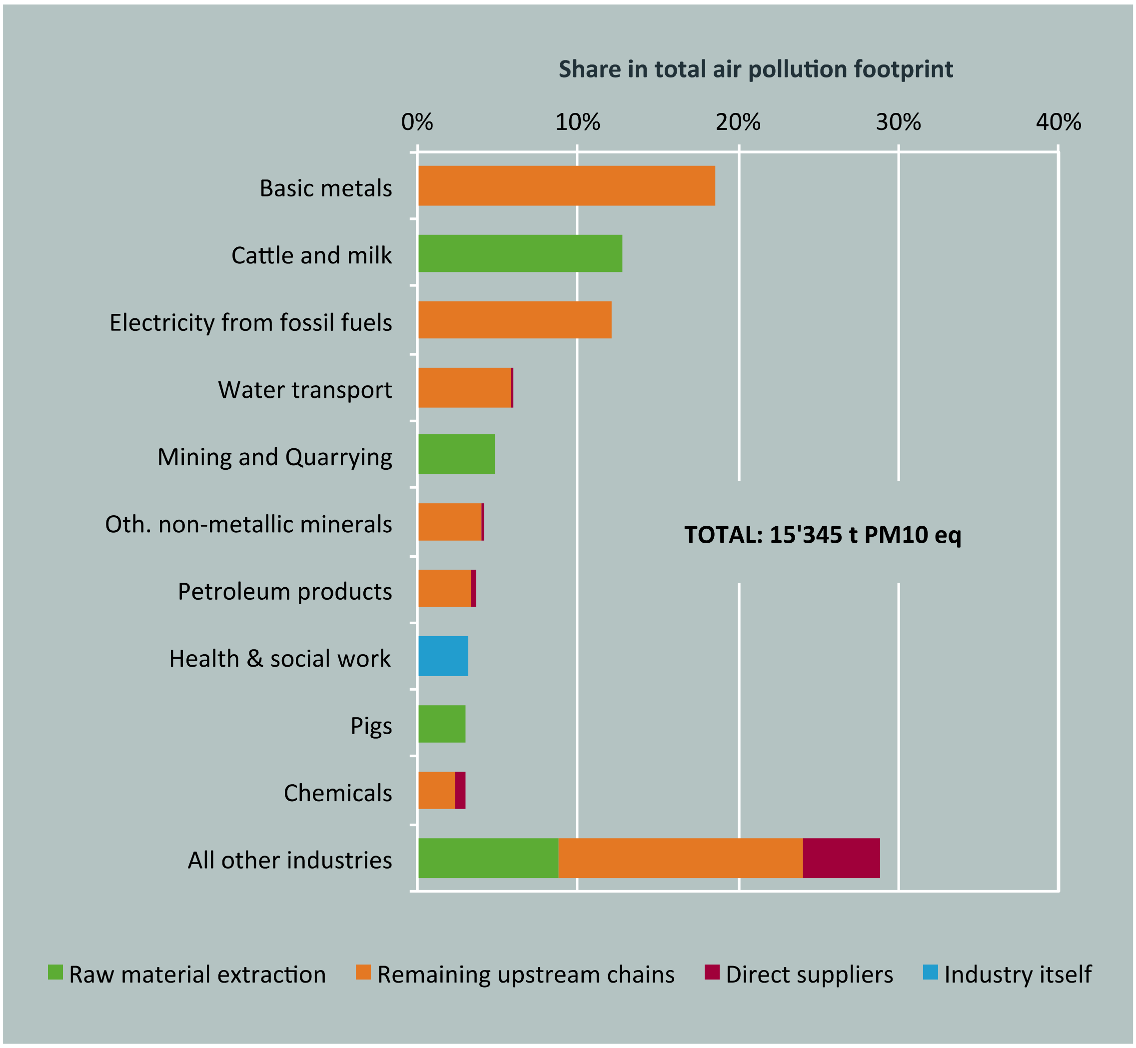

Fig. A.5.3.2: Air pollution footprint caused by the industry ‘Human health and social work’ by supply chain stage and industry (Source: Calculations Rütter Soceco)

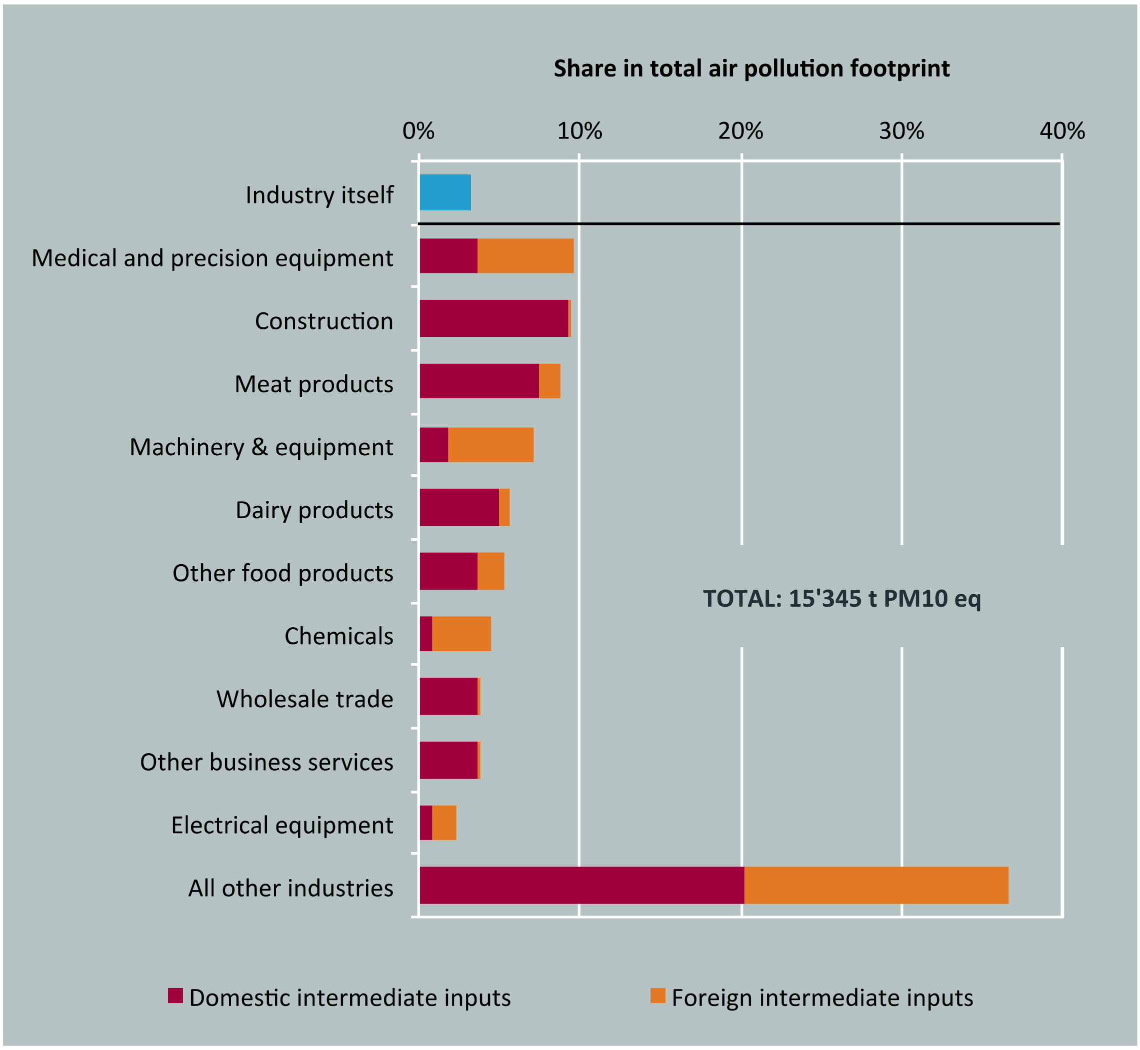

Fig. A.5.3.3: Air pollution footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Human health and social work’ (Source: Calculations Rütter Soceco)

A.5.4 Eutrophication footprint

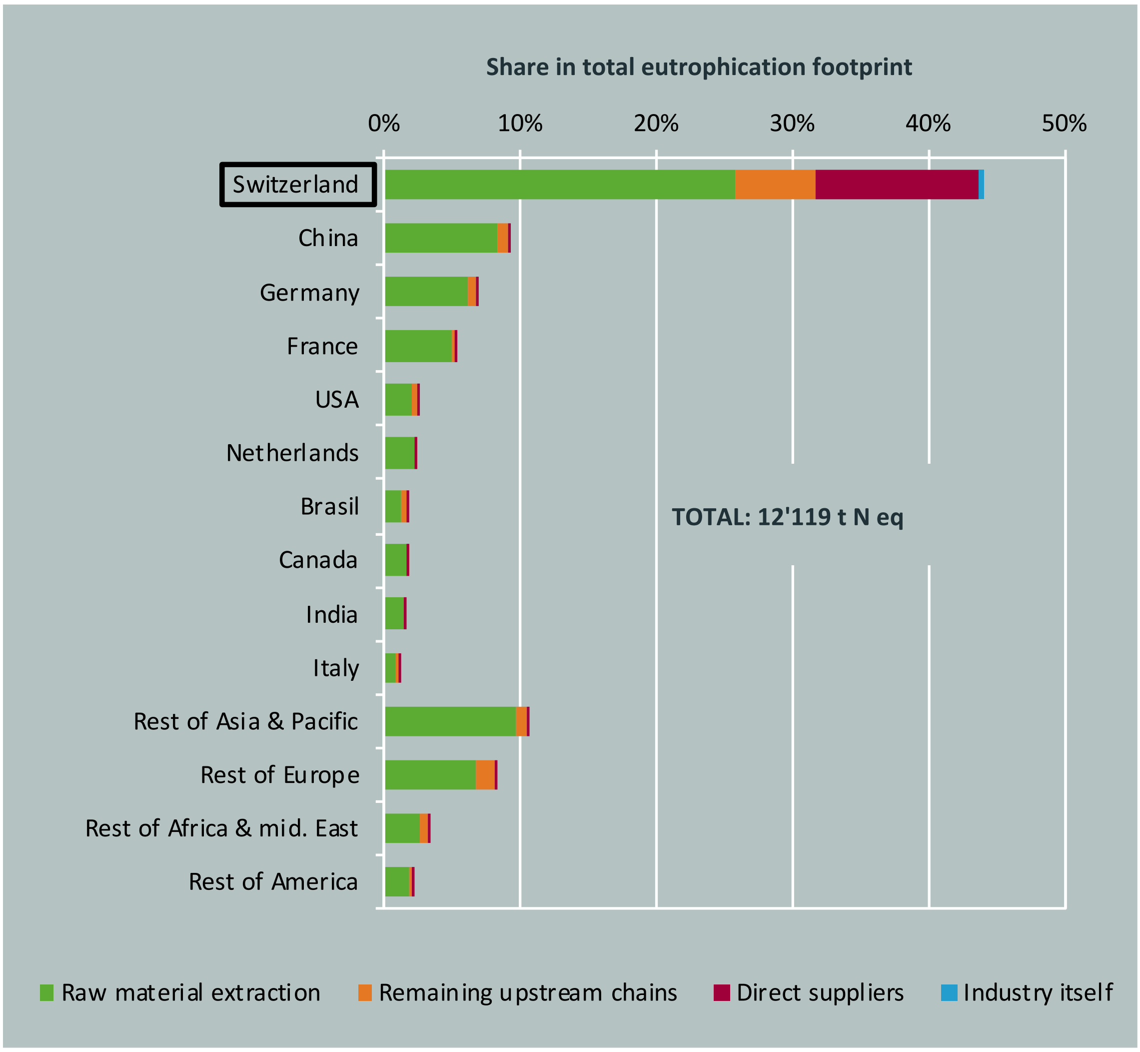

Fig. A.5.4.1: Eutrophication footprint caused by the Swiss industry 'Human health and social work', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

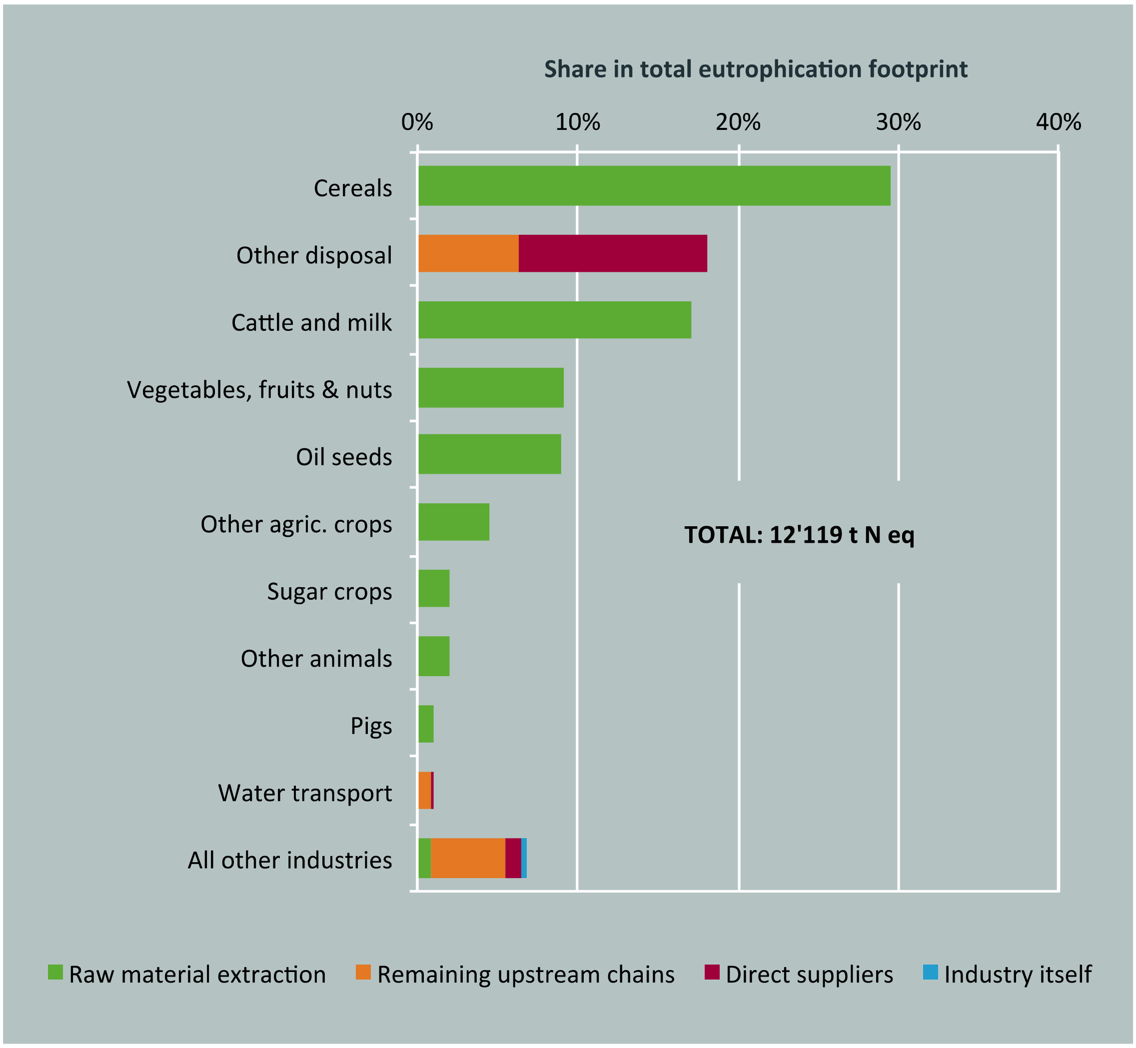

Fig. A.5.4.2: Eutrophication footprint caused by the industry 'Human health and social work' by supply chain stage and industry (Source: Calculations Rütter Soceco)

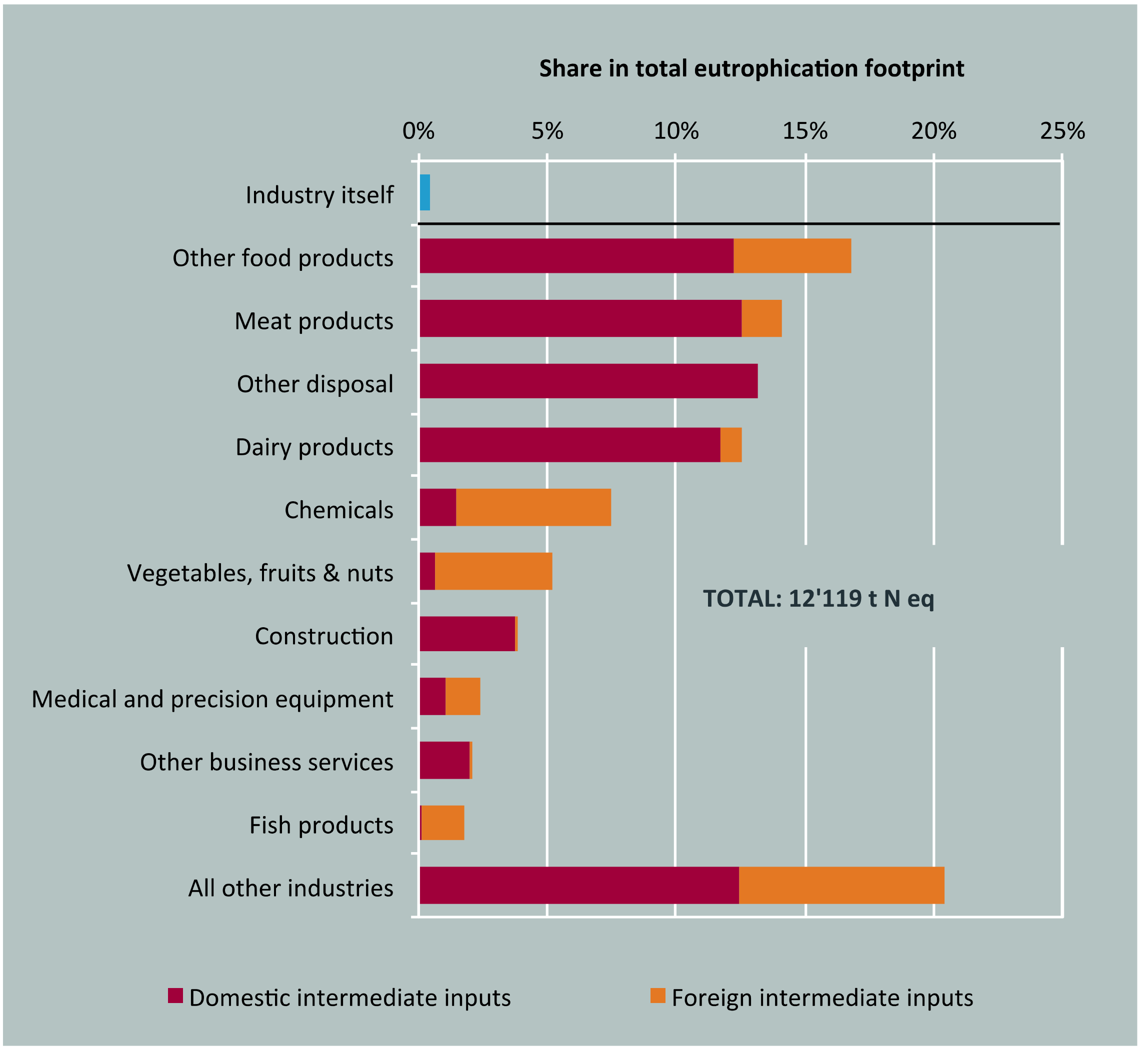

Fig. A.5.4.3: Eutrophication footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Human health and social work' (Source: Calculations Rütter Soceco)

A.6 Food trade

A.6.1 Greenhouse gas footprint

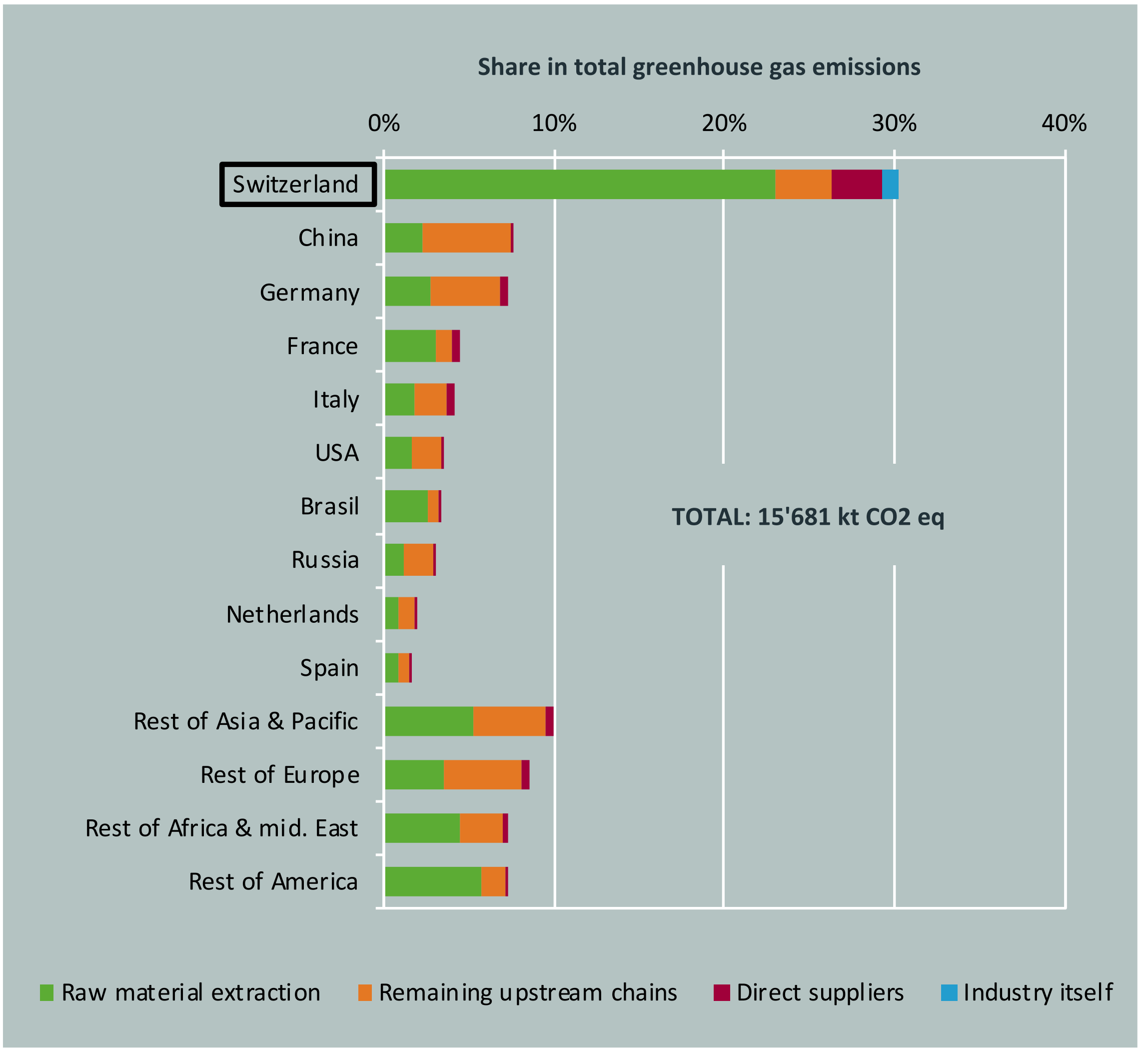

Fig. A.6.1.1: Greenhouse gas footprint caused by the Swiss industry 'Food trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

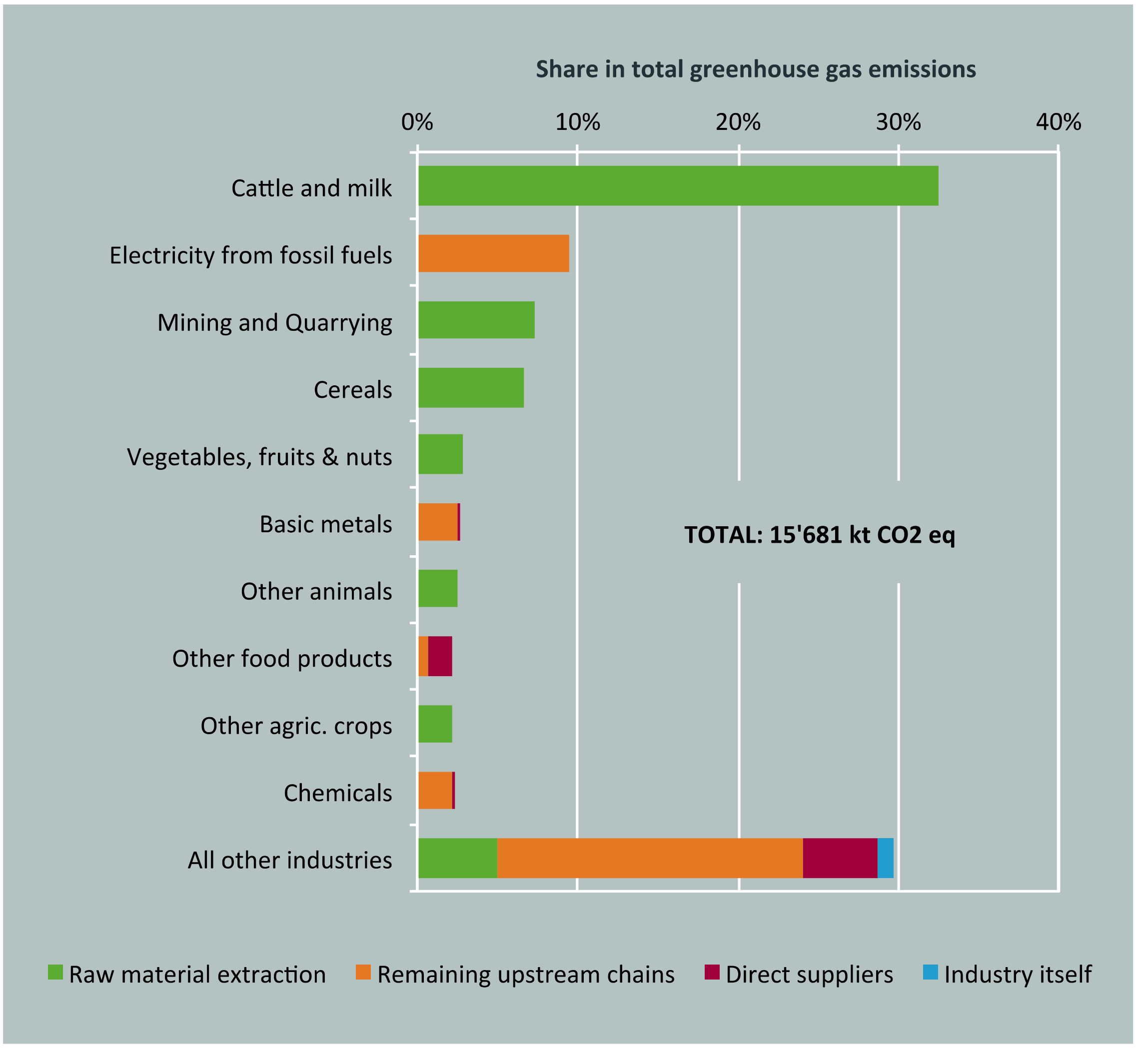

Fig. A.6.1.2: Greenhouse gas footprint caused by the industry 'Food trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

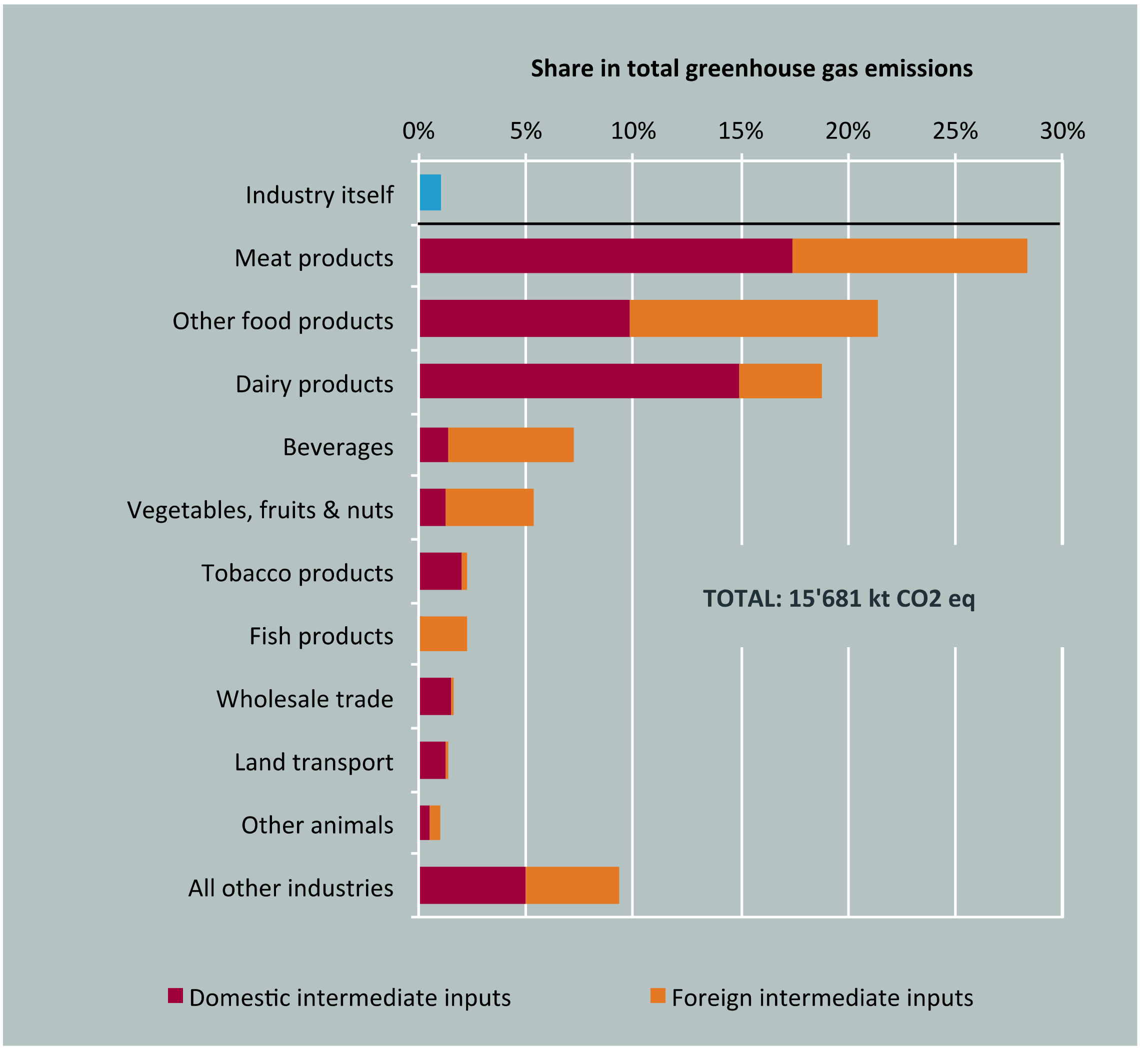

Fig. A.6.1.3: Greenhouse gas footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Food trade' (Source: Calculations Rütter Soceco)

A.6.2 Water footprint

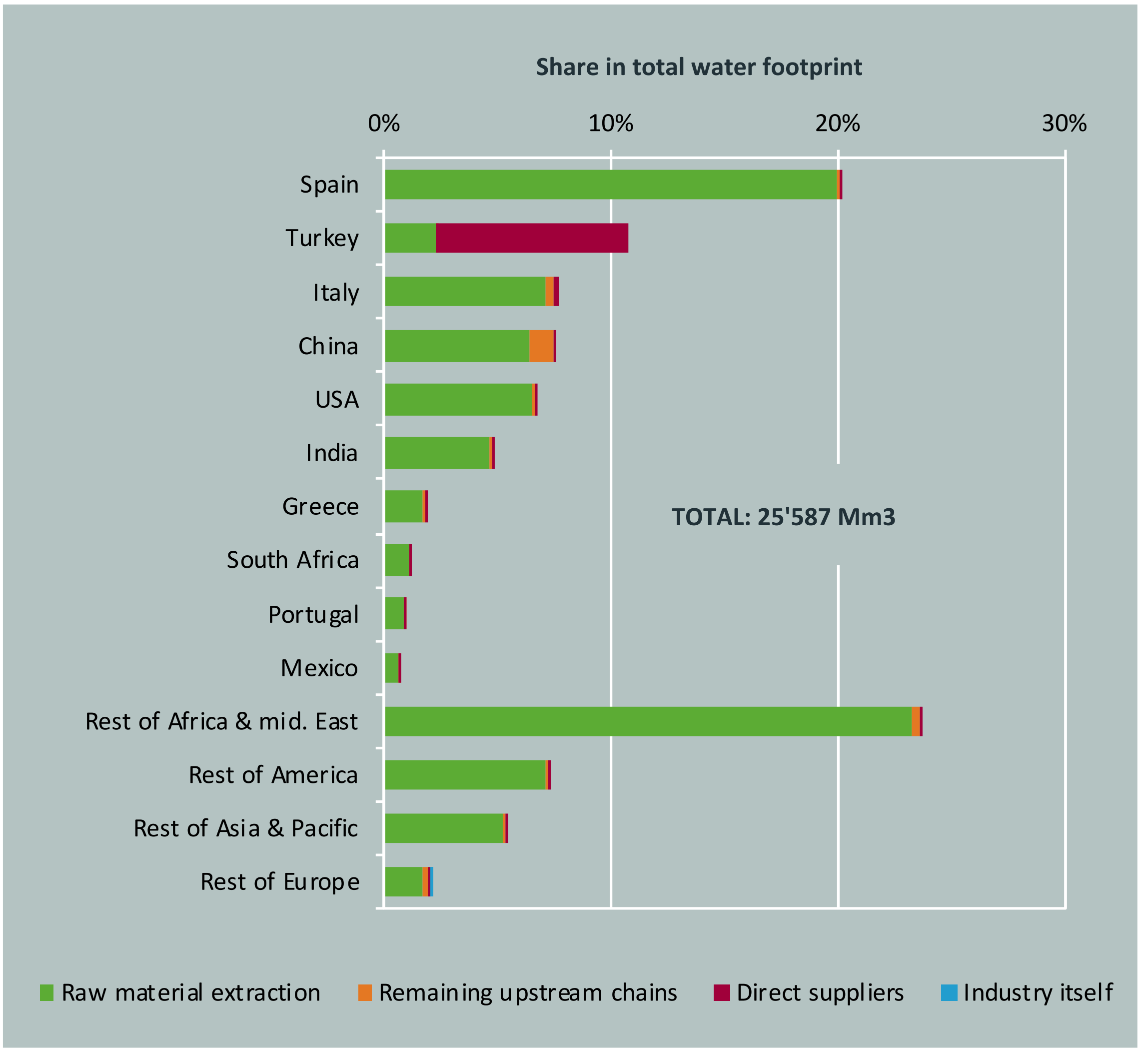

Fig. A.6.2.1: Water footprint caused by the Swiss industry 'Food trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

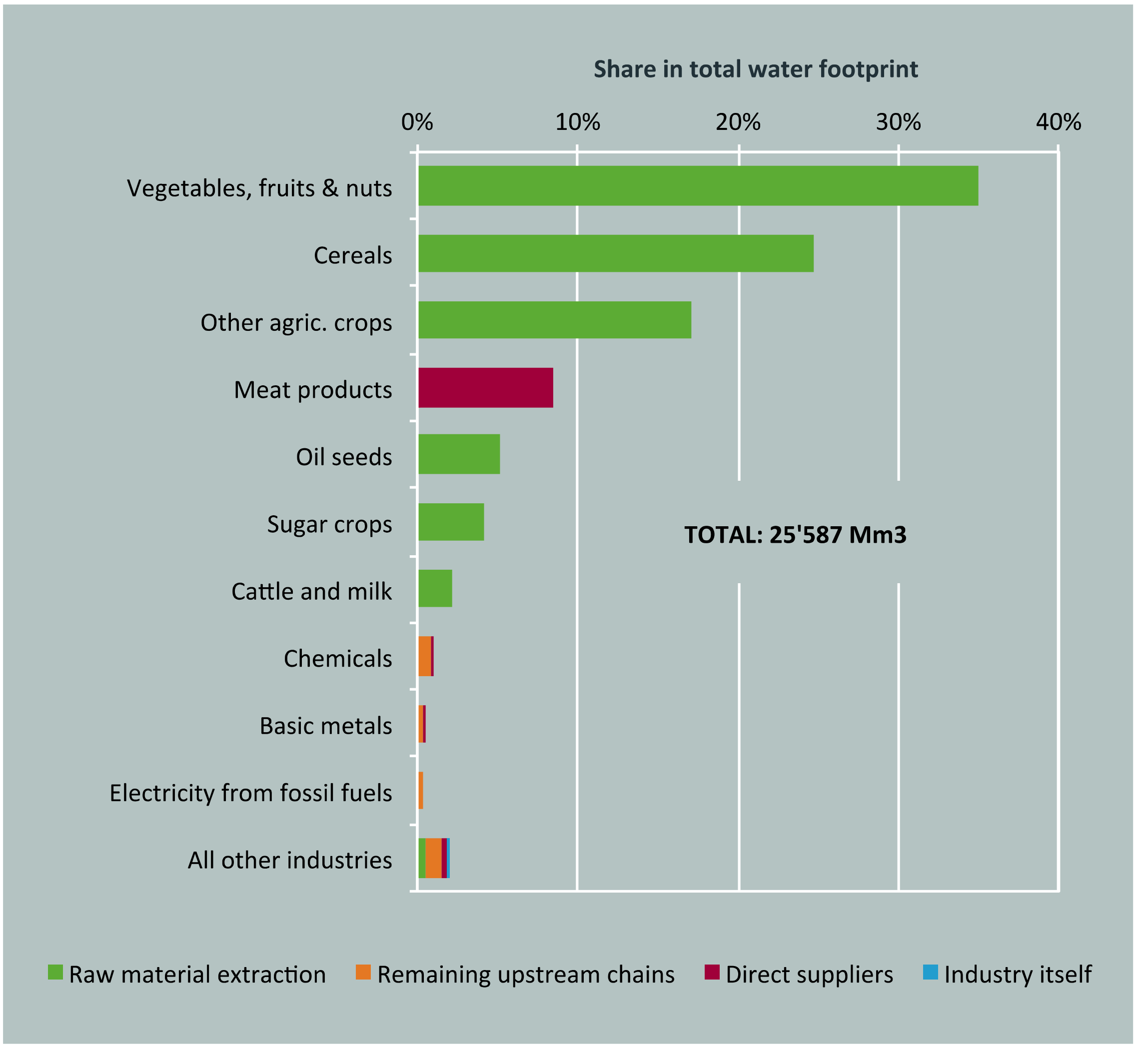

Fig. A.6.2.2: Water footprint caused by the industry 'Food trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

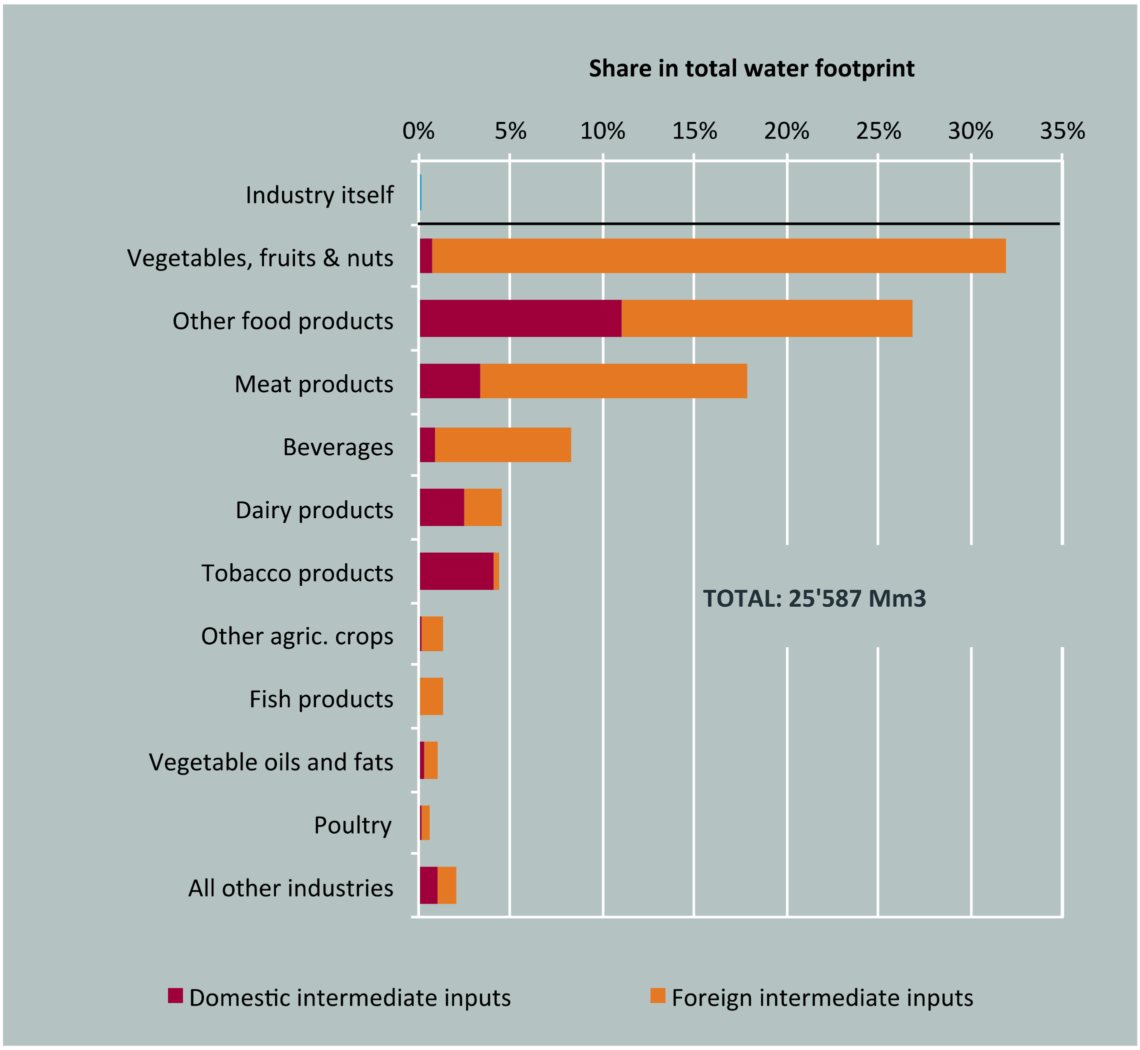

Fig. A.6.2.3: Water footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Food trade' (Source: Calculations Rütter Soceco)

A.6.3 Air pollution footprint

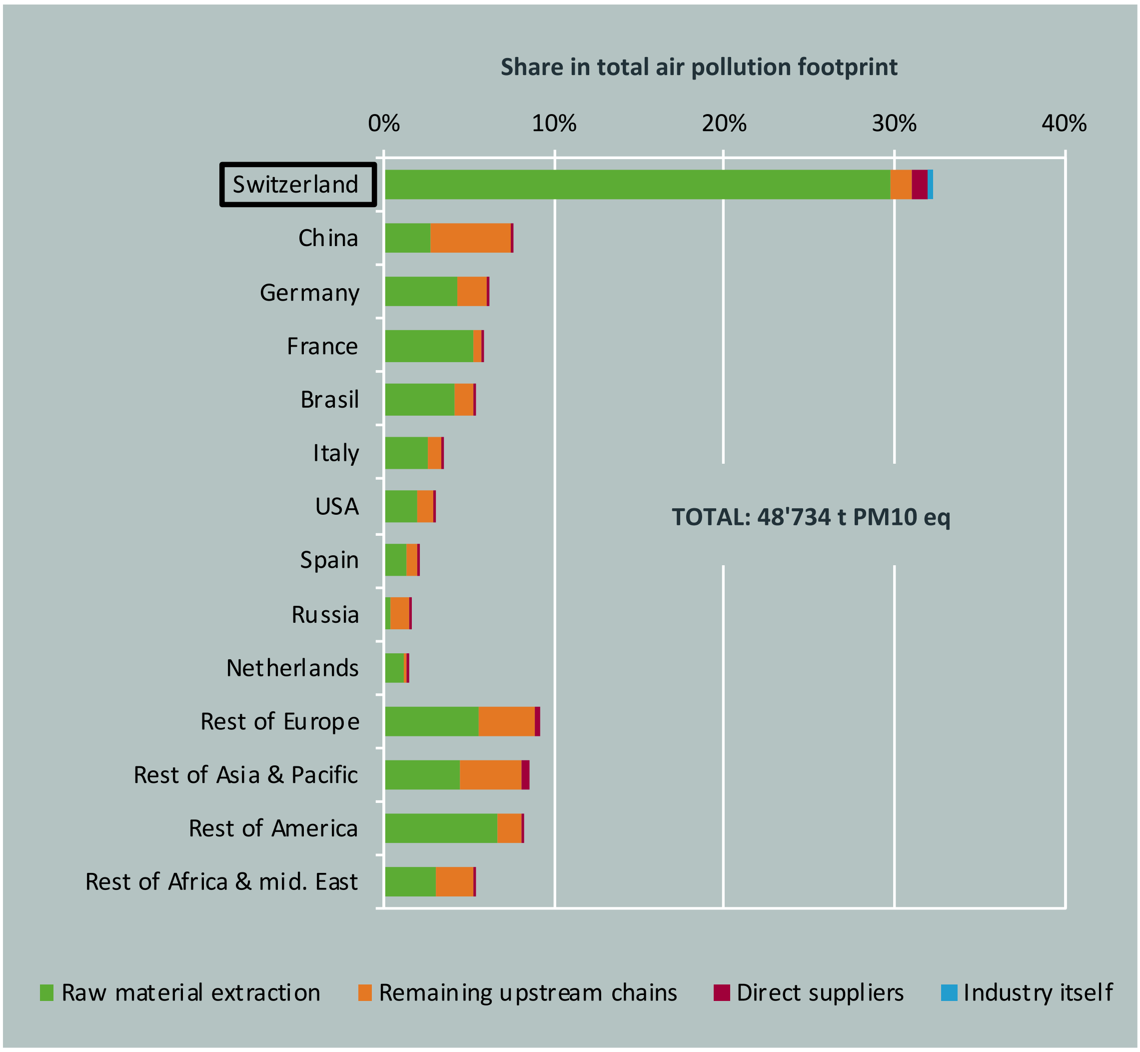

Fig. A.6.3.1: Air pollution footprint caused by the Swiss industry 'Food trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

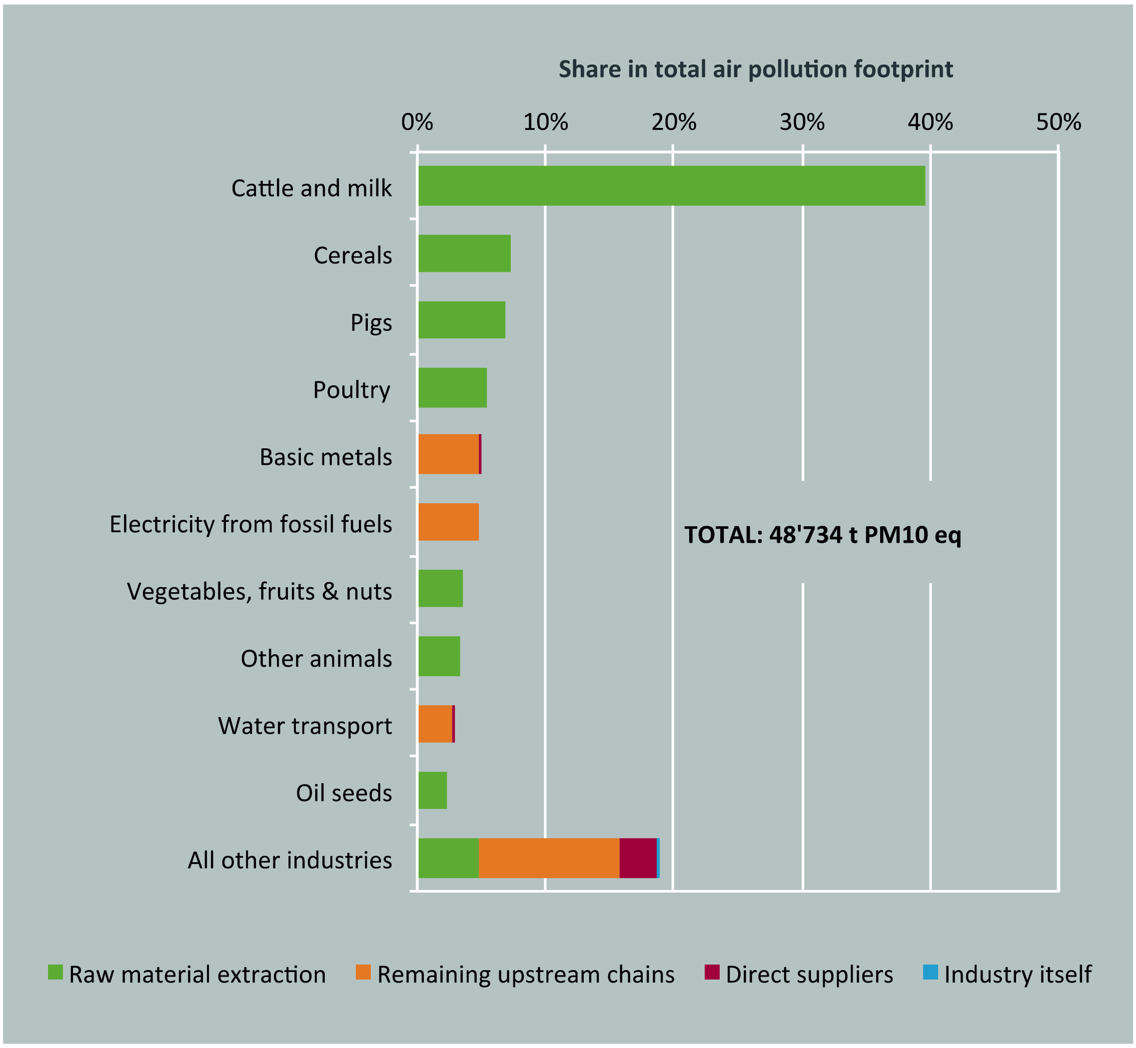

Fig. A.6.3.2: Air pollution footprint caused by the industry 'Food trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

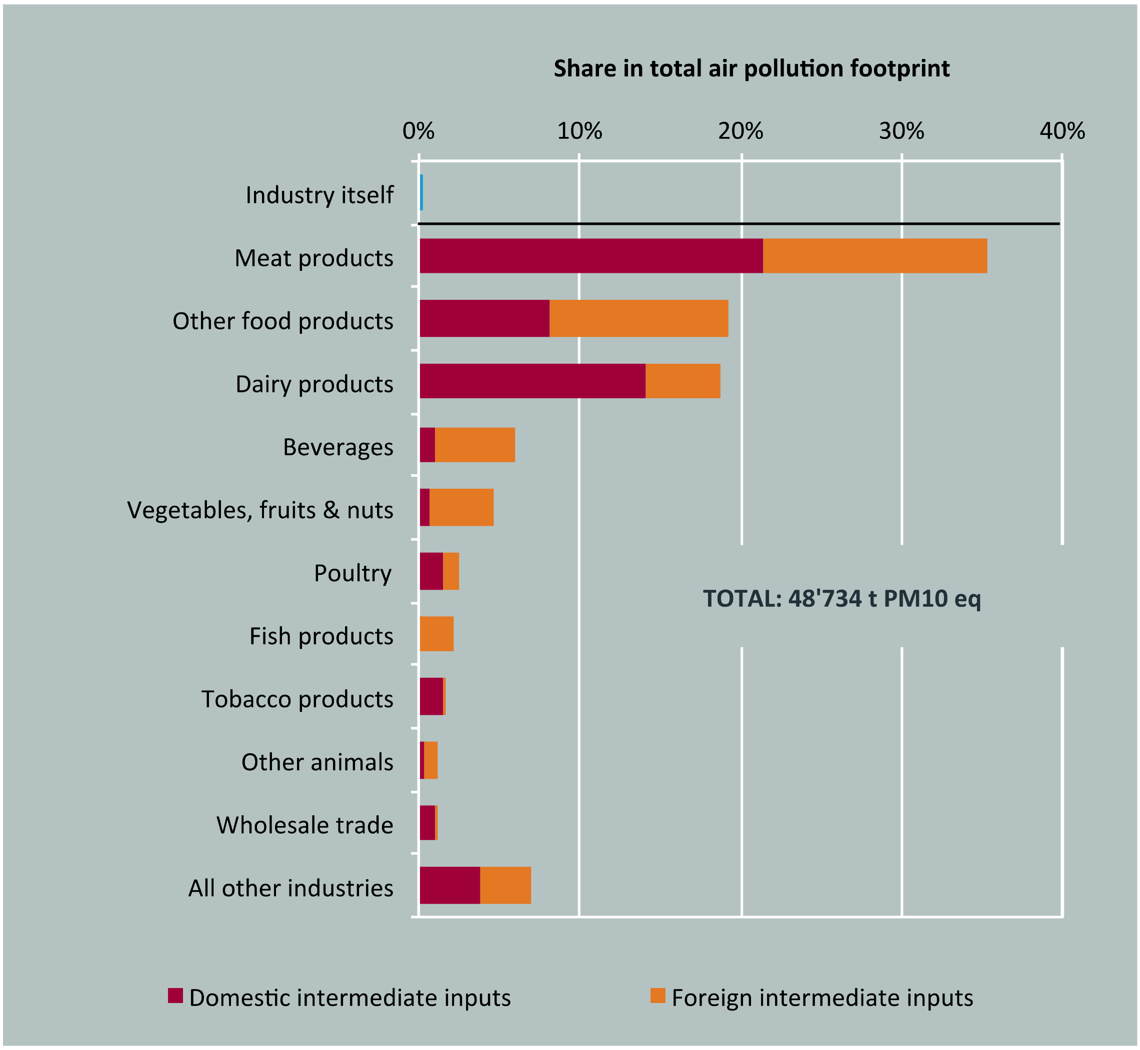

Fig. A.6.3.3: Air pollution footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Food trade' (Source: Calculations Rütter Soceco)

A.6.4 Eutrophication footprint

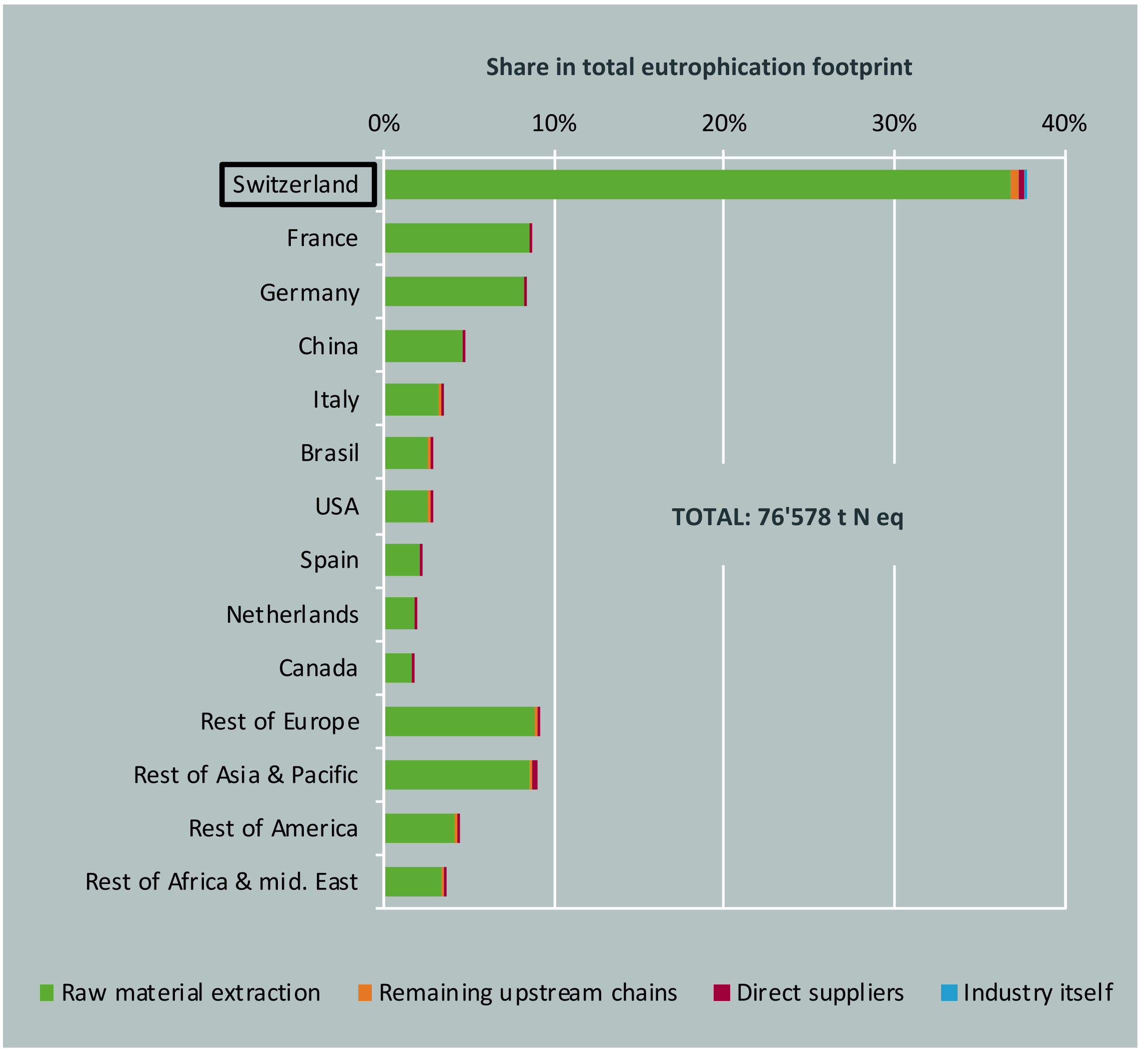

Fig. A.6.4.1: Eutrophication footprint caused by the Swiss industry ‘Food trade’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

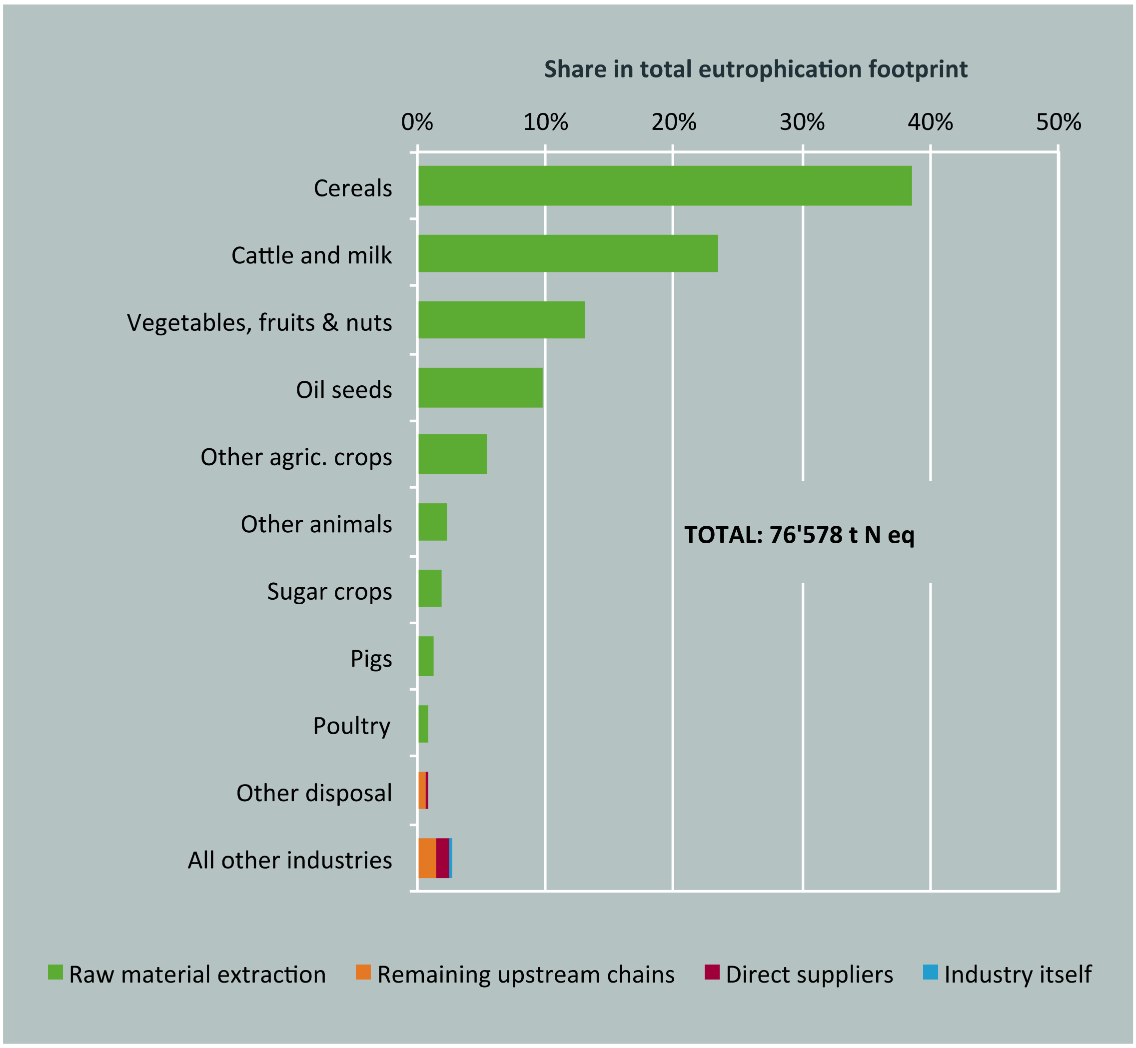

Fig. A.6.4.2: Eutrophication footprint caused by the industry 'Food trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

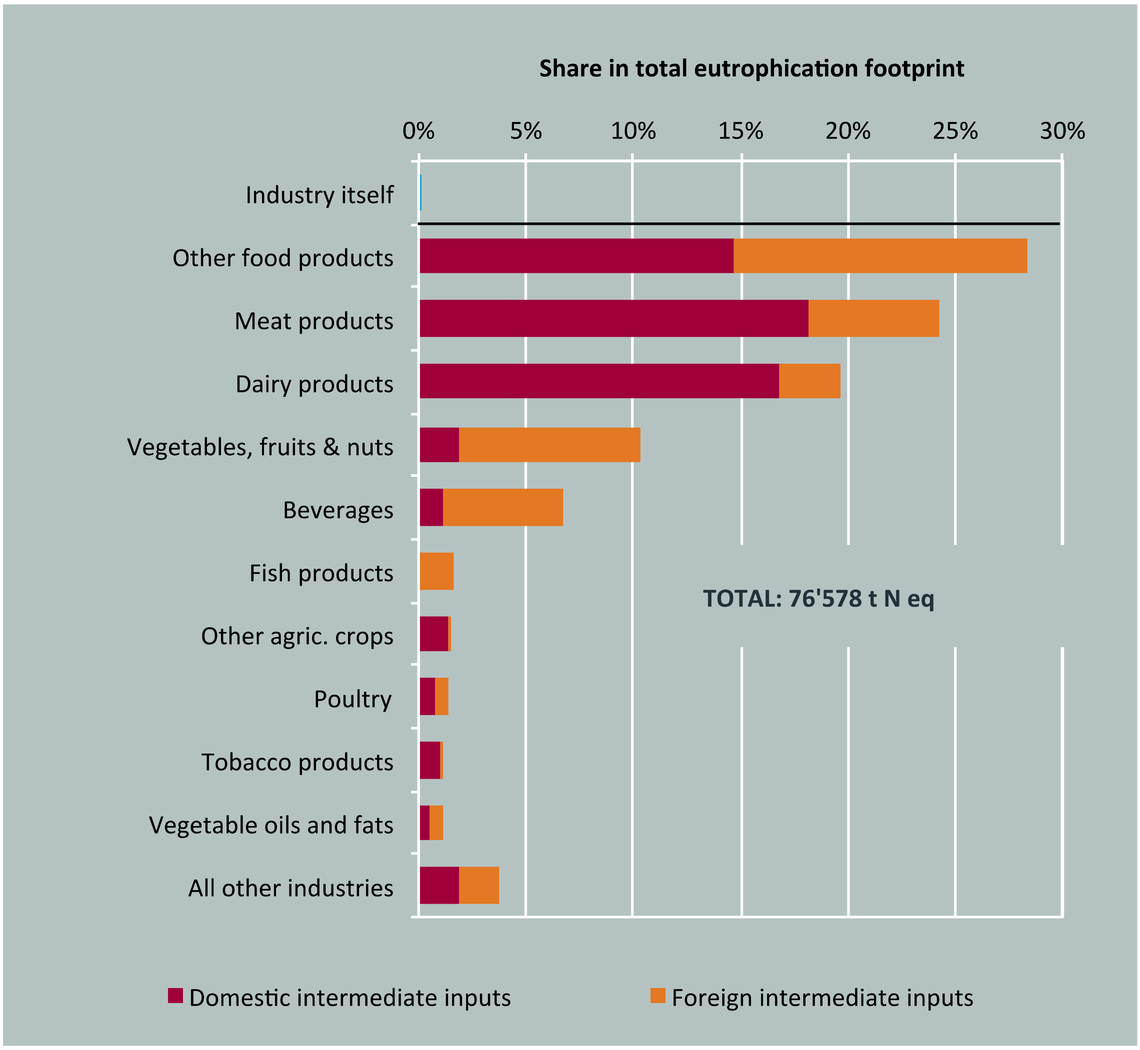

Fig. A.6.4.3: Eutrophication footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Food trade’ (Source: Calculations Rütter Soceco)

A.7 Trade with clothing, textiles and footwear

A.7.1 Greenhouse gas footprint

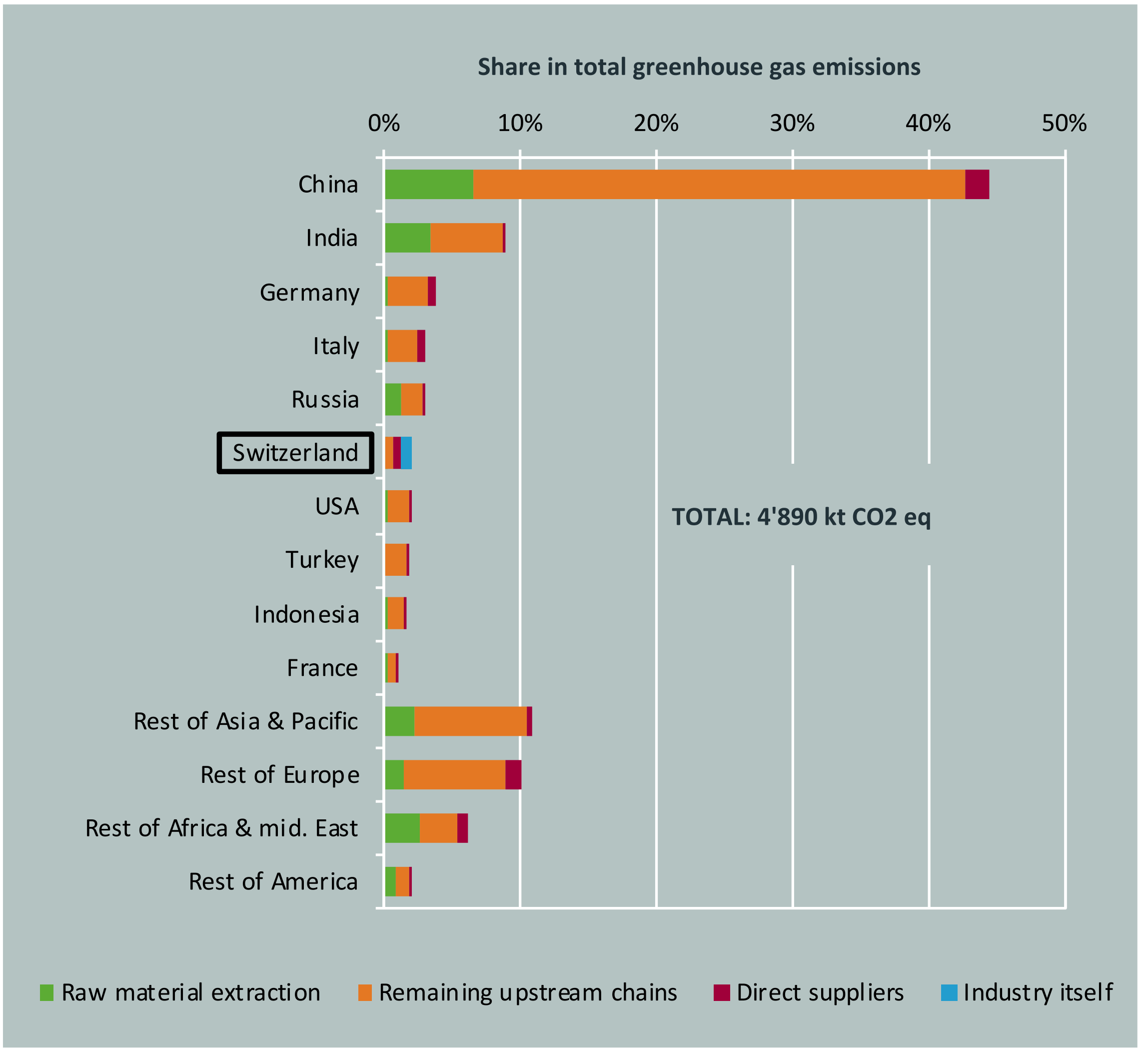

Fig. A.7.1.1: Greenhouse gas footprint caused by the Swiss industry 'textile trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

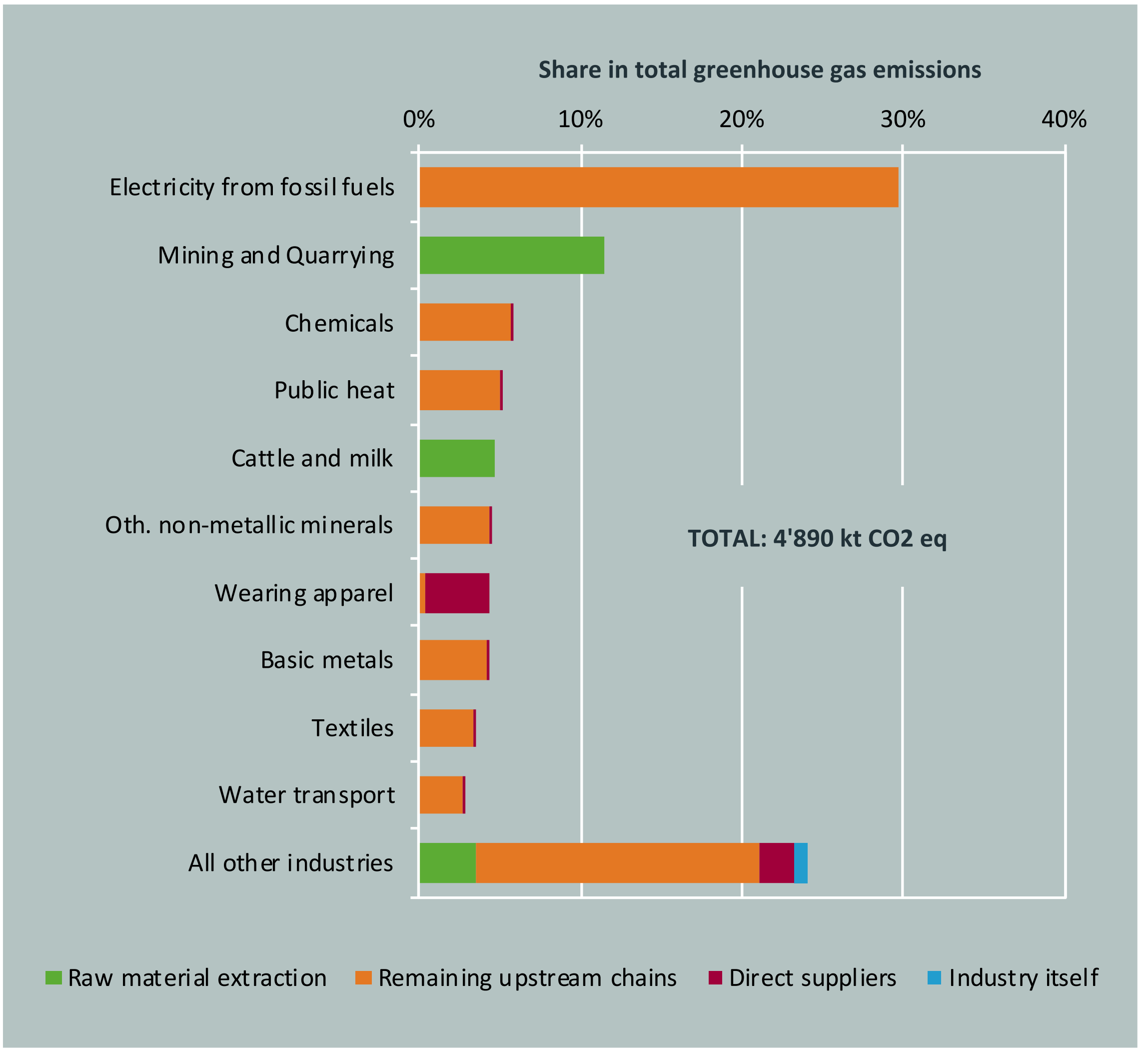

Fig. A.7.1.2: Greenhouse gas footprint caused by the industry 'textile trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

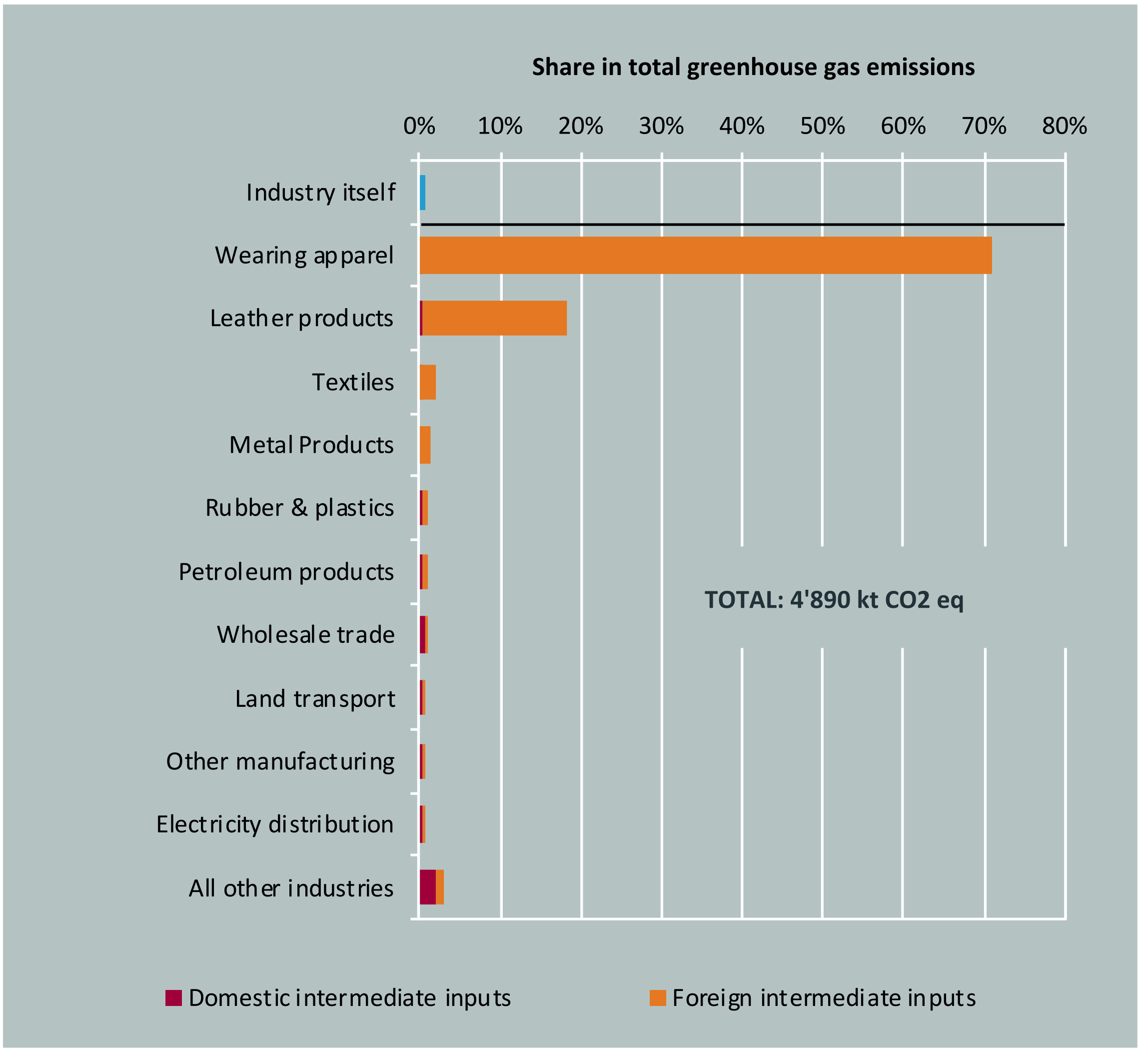

Fig. A.7.1.3: Greenhouse gas footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'textile trade' (Source: Calculations Rütter Soceco)

A.7.2 Biodiversity loss footprint

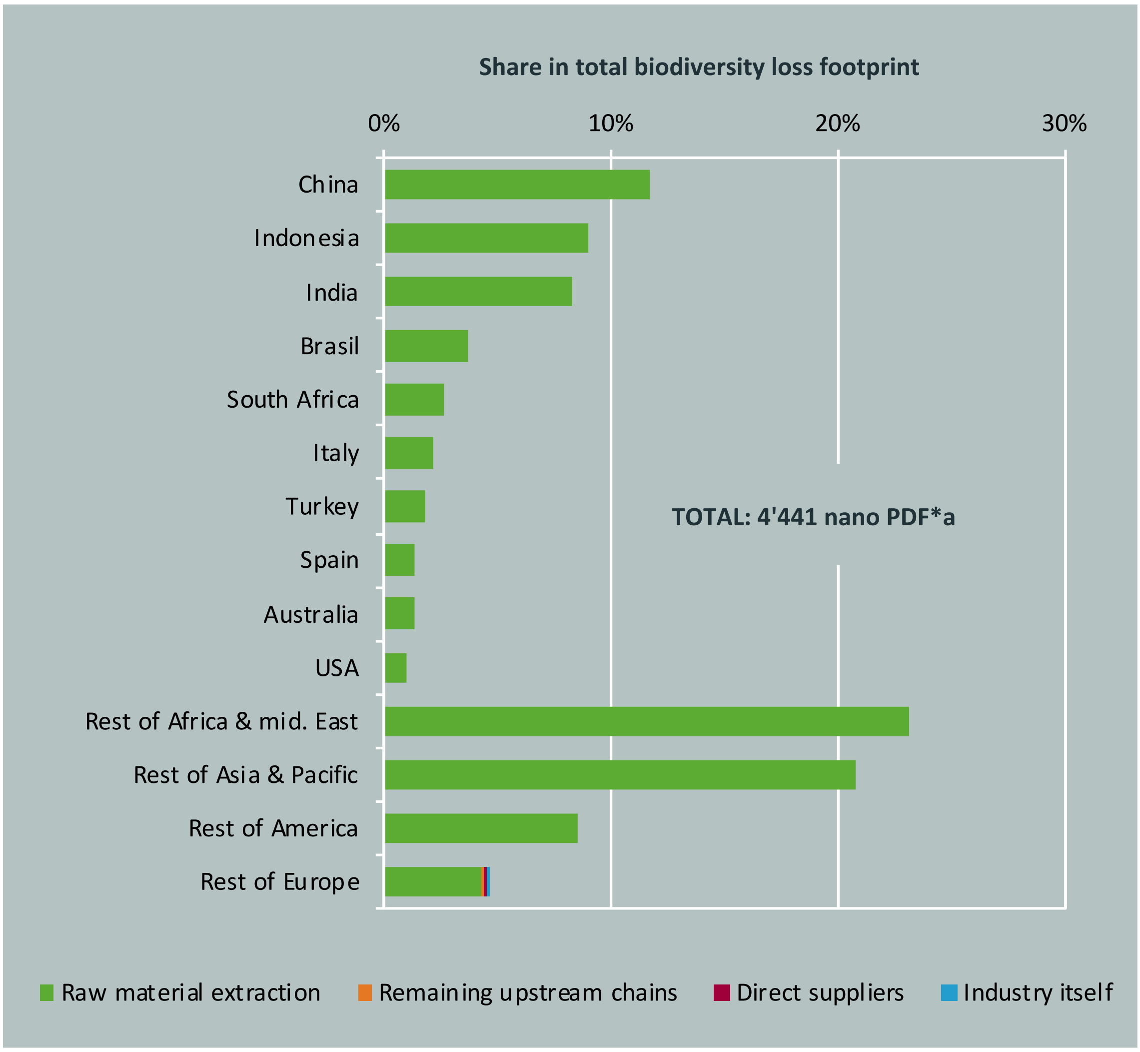

Fig. A.7.2.1: Biodiversity loss footprint caused by the Swiss industry 'textile trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

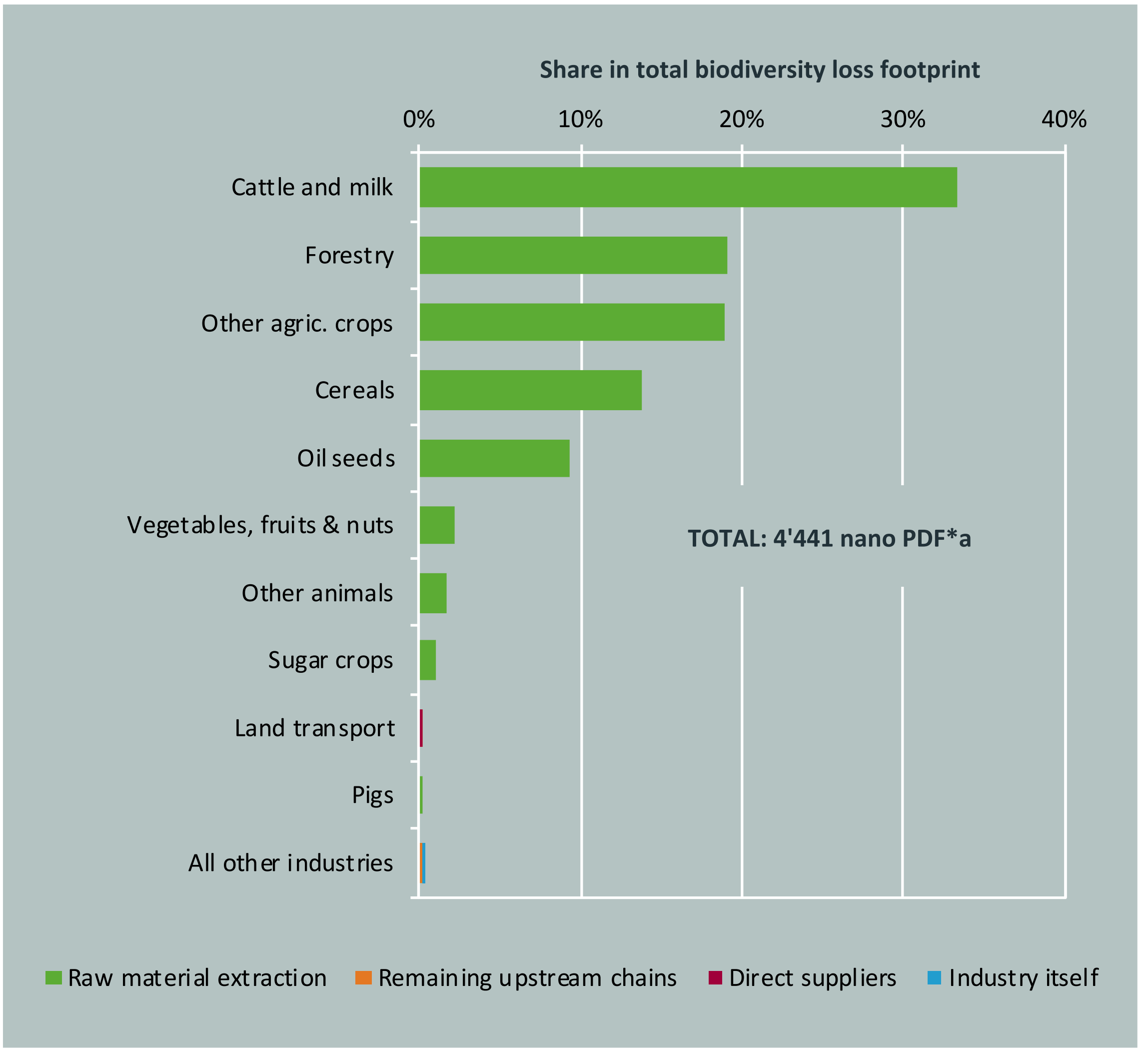

Fig. A.7.2.2: Biodiversity loss footprint caused by the industry 'textile trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

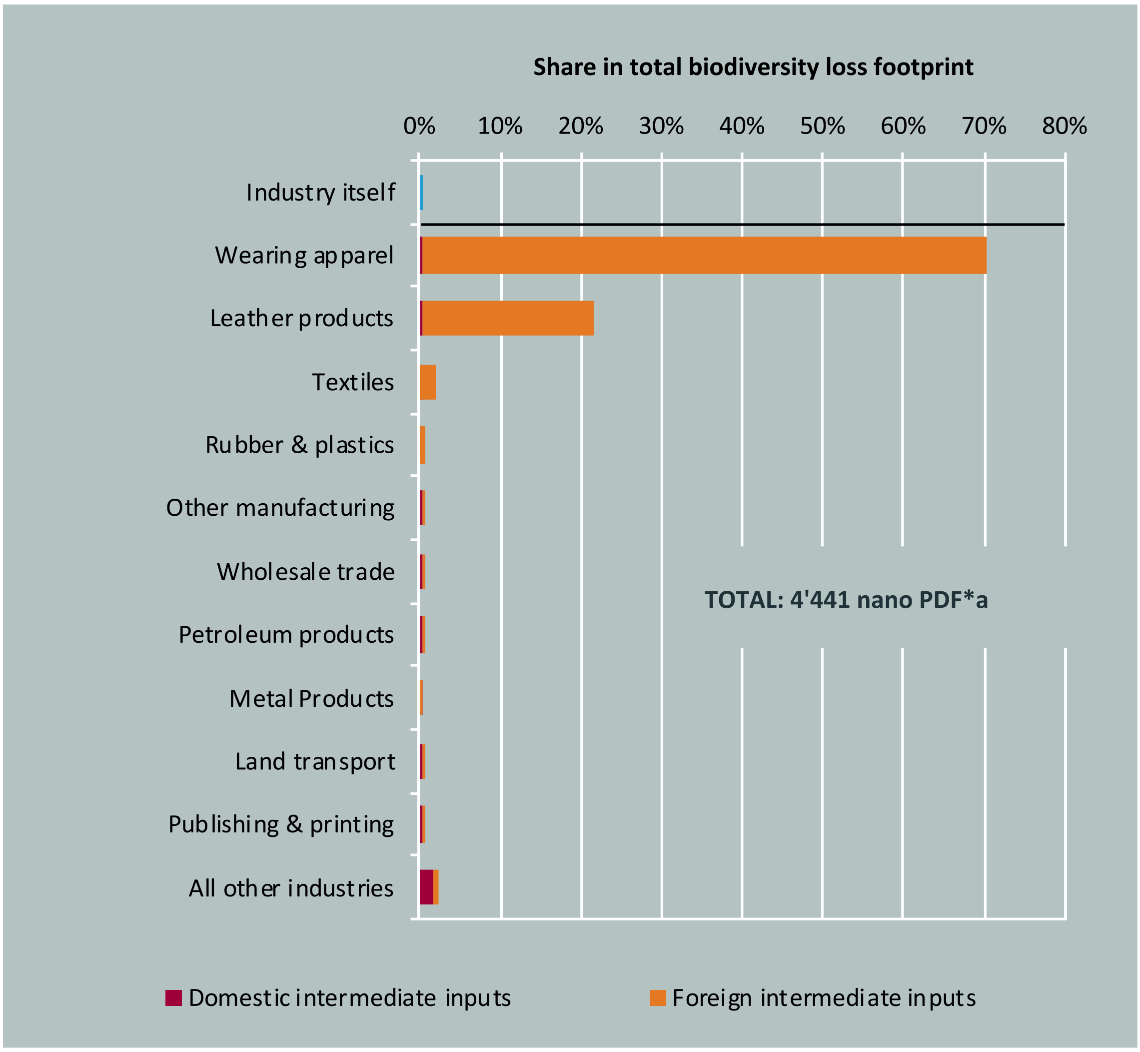

Fig. A.7.2.3: Biodiversity loss footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'textile trade' (Source: Calculations Rütter Soceco)

A.7.3 Air pollution footprint

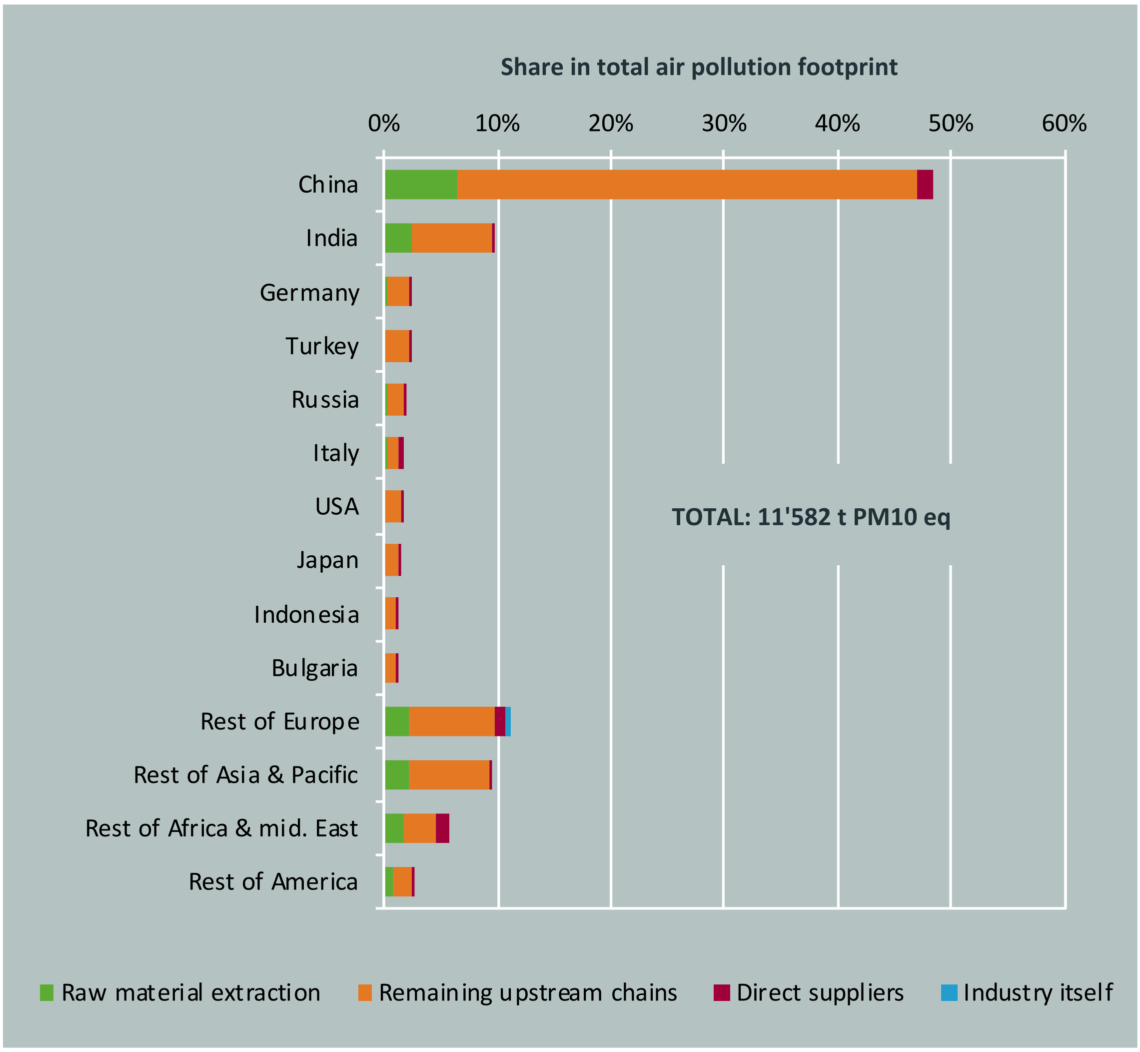

Fig. A.7.3.1: Air pollution footprint caused by the Swiss industry 'textile trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

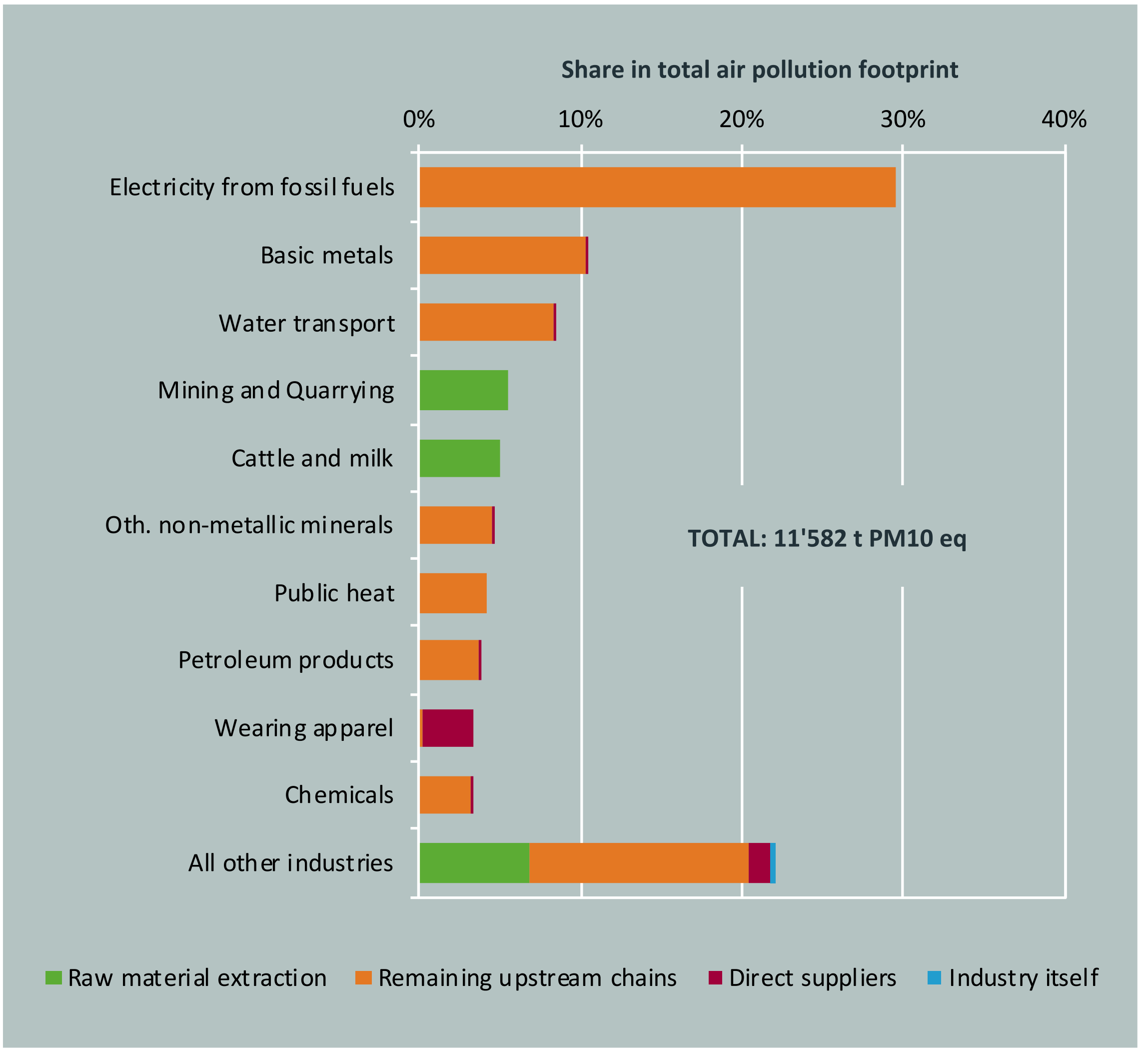

Fig. A.7.3.2: Air pollution footprint caused by the industry 'textile trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

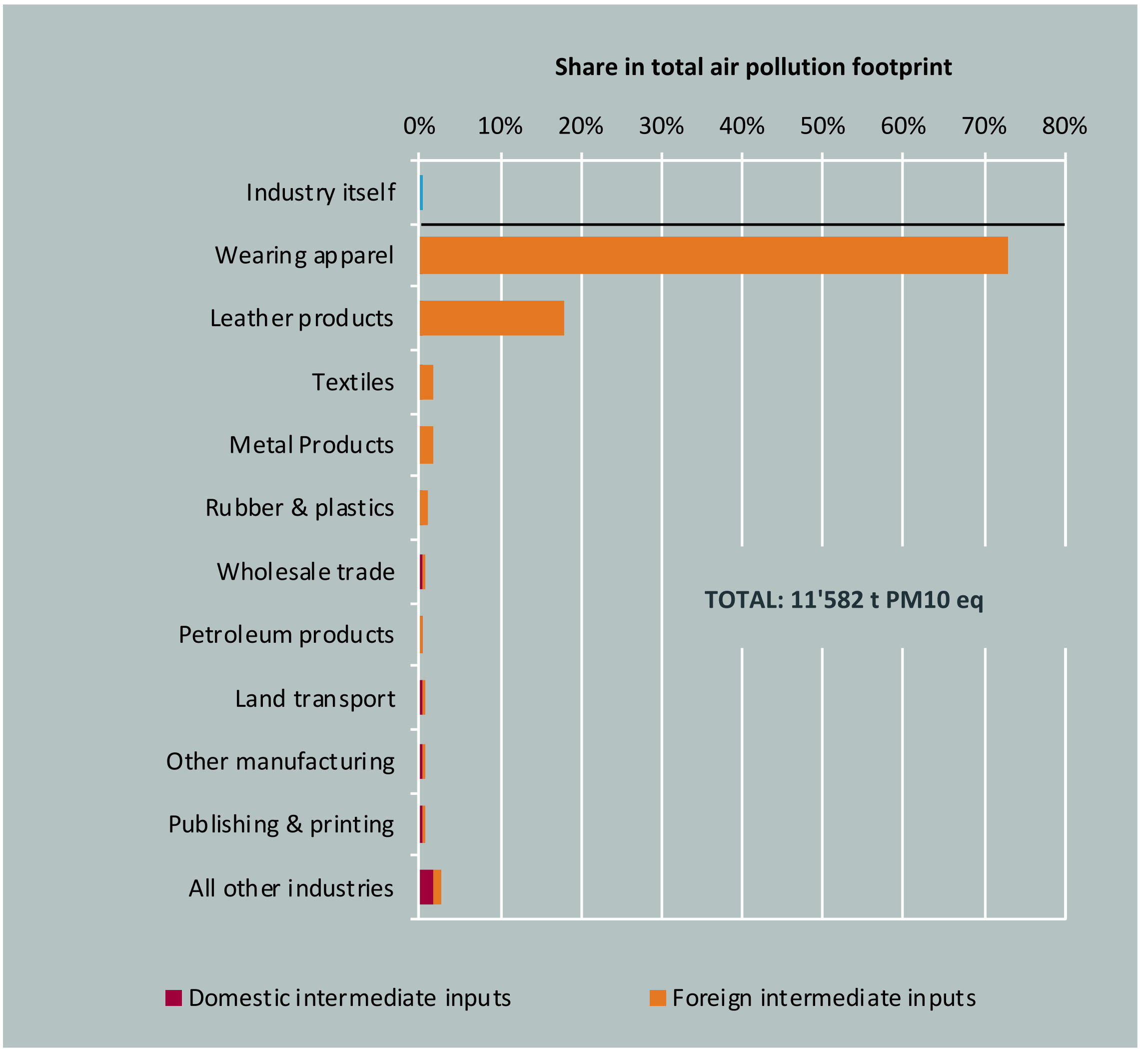

Fig. A.7.3.3: Air pollution footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'textile trade' (Source: Calculations Rütter Soceco)

A.7.4 Eutrophication footprint

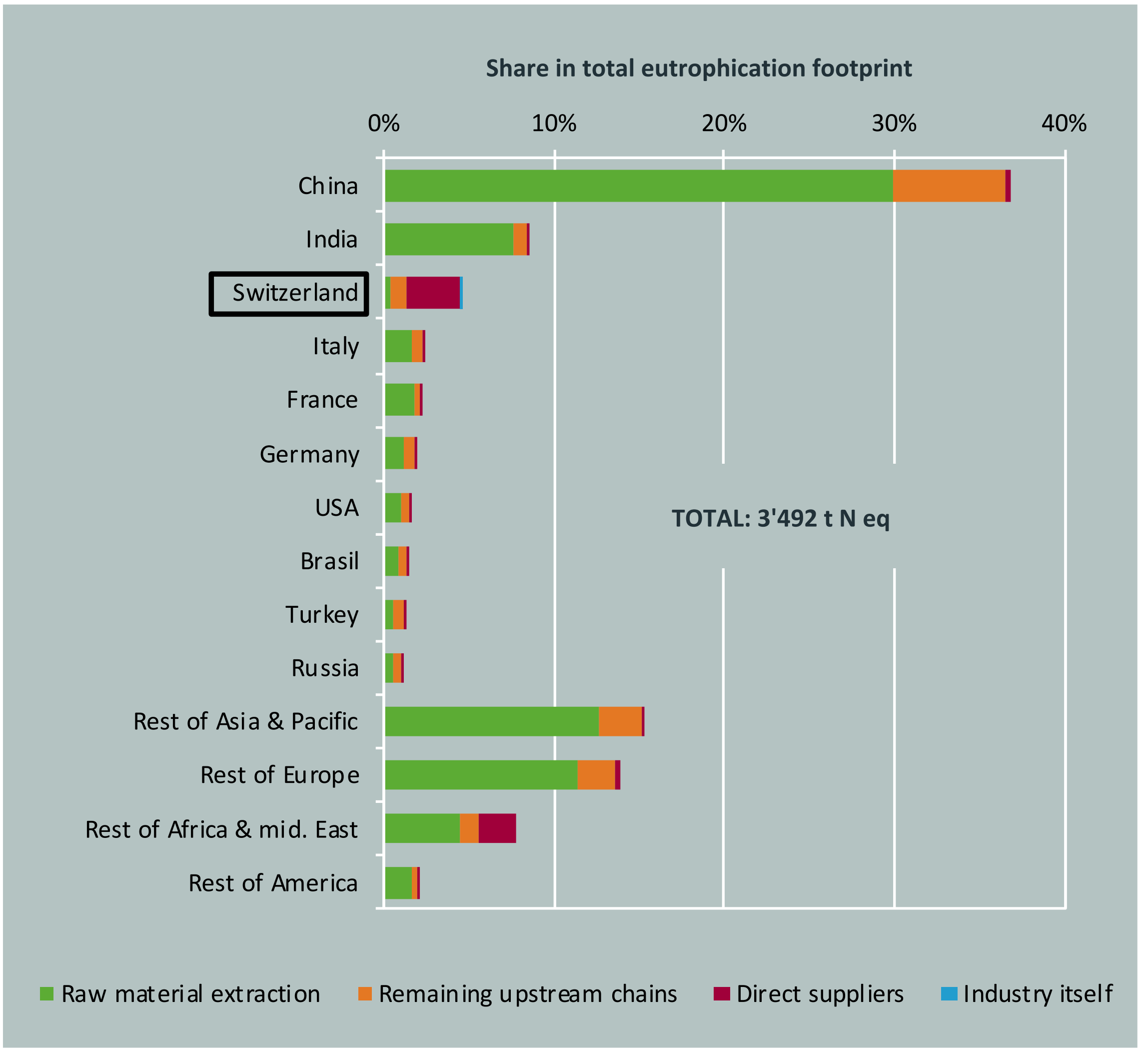

Fig. A.7.4.1: Eutrophication footprint caused by the Swiss industry 'textile trade', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

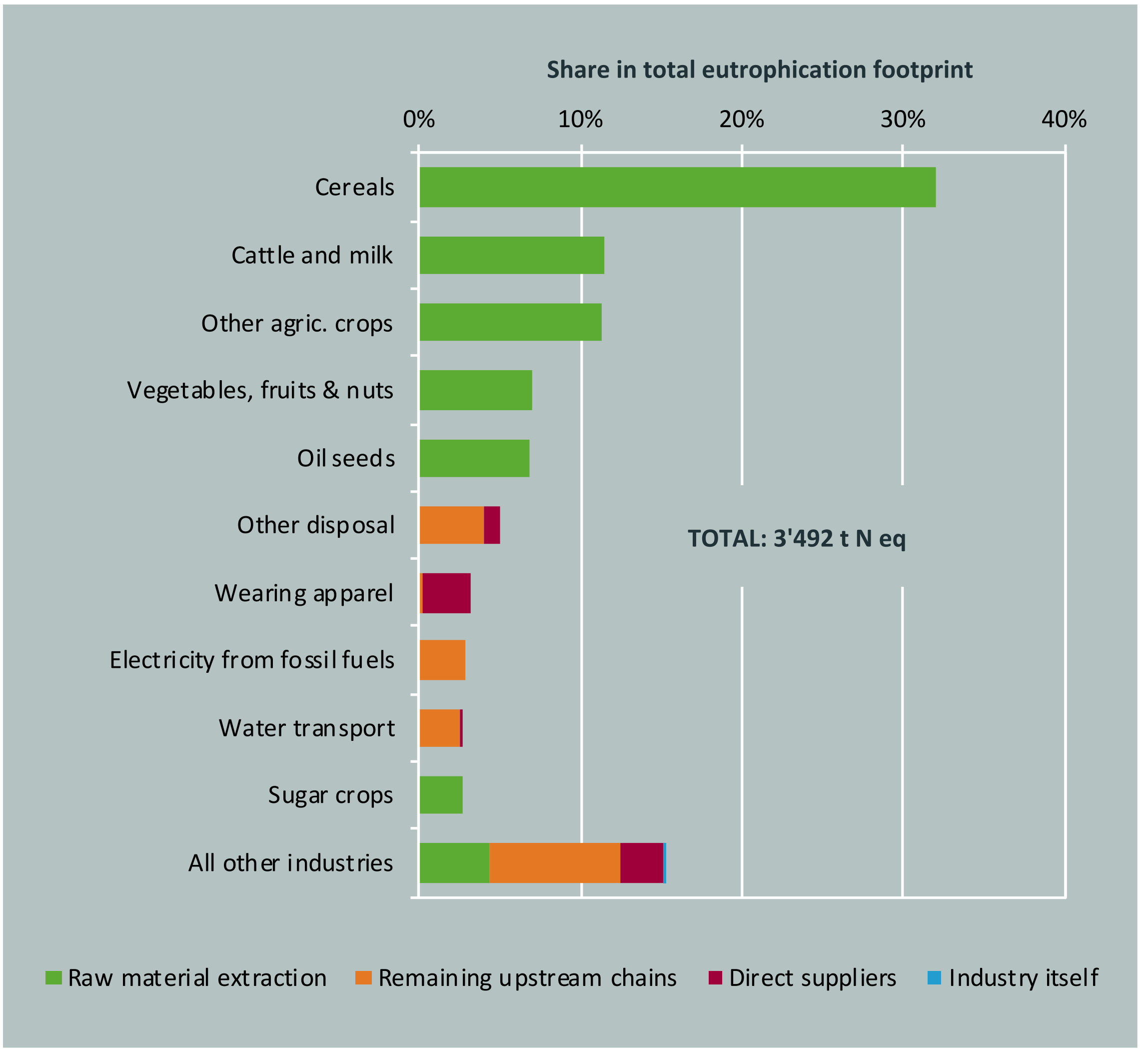

Fig. A.7.4.2: Eutrophication footprint caused by the industry 'textile trade' by supply chain stage and industry (Source: Calculations Rütter Soceco)

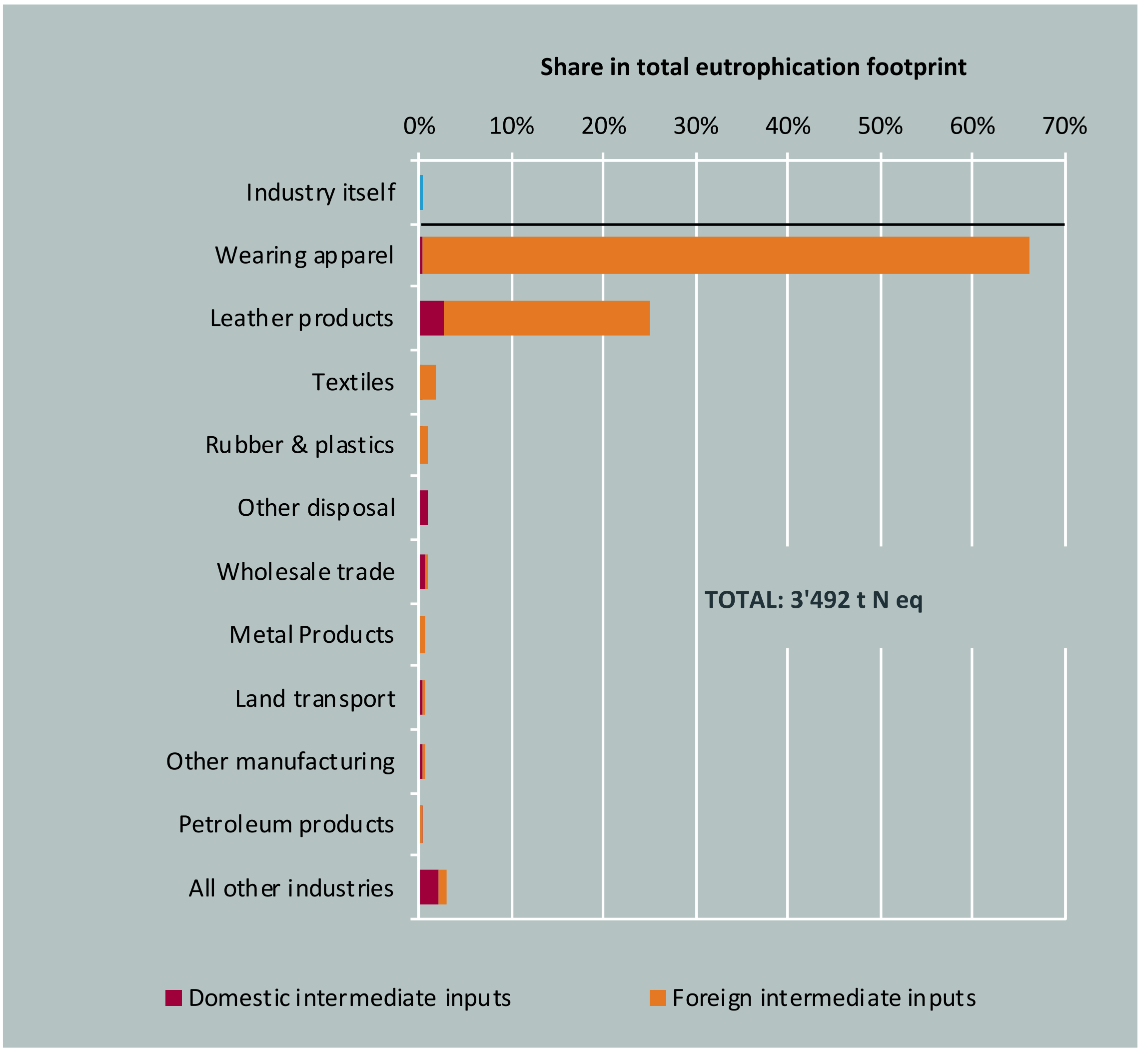

Fig. A.7.4.3: Eutrophication footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'textile trade' (Source: Calculations Rütter Soceco)

A.8 Trade with household devices

A.8.1 Greenhouse gas footprint

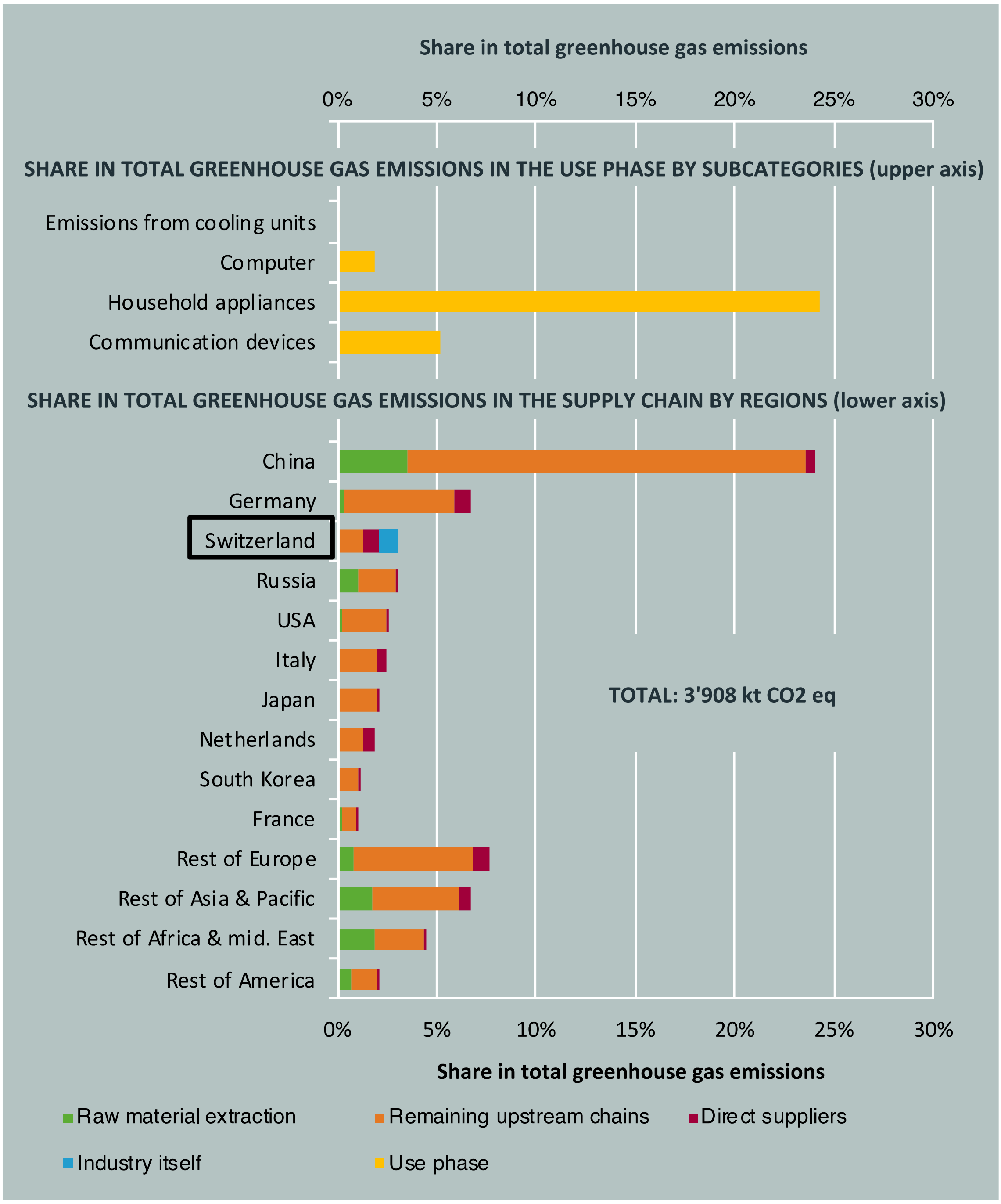

Fig. A.8.1.1: Greenhouse gas footprint caused by the Swiss industry ‘Trade with household devices’, differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

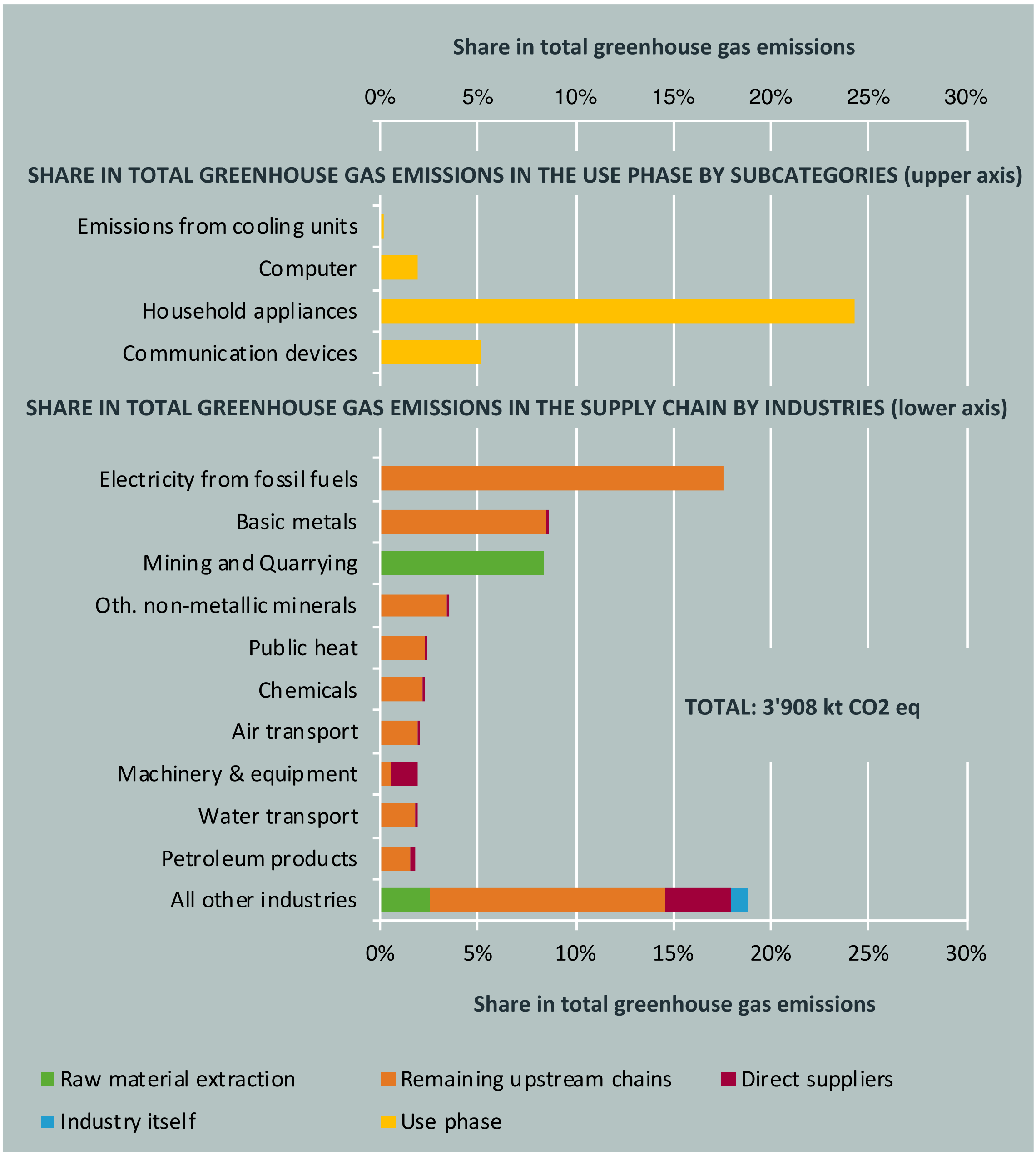

Fig. A.8.1.2: Greenhouse gas footprint caused by the industry ‘Trade with household devices’ by supply chain stage and industry resp. the use phase (Source: Calculations Rütter Soceco)

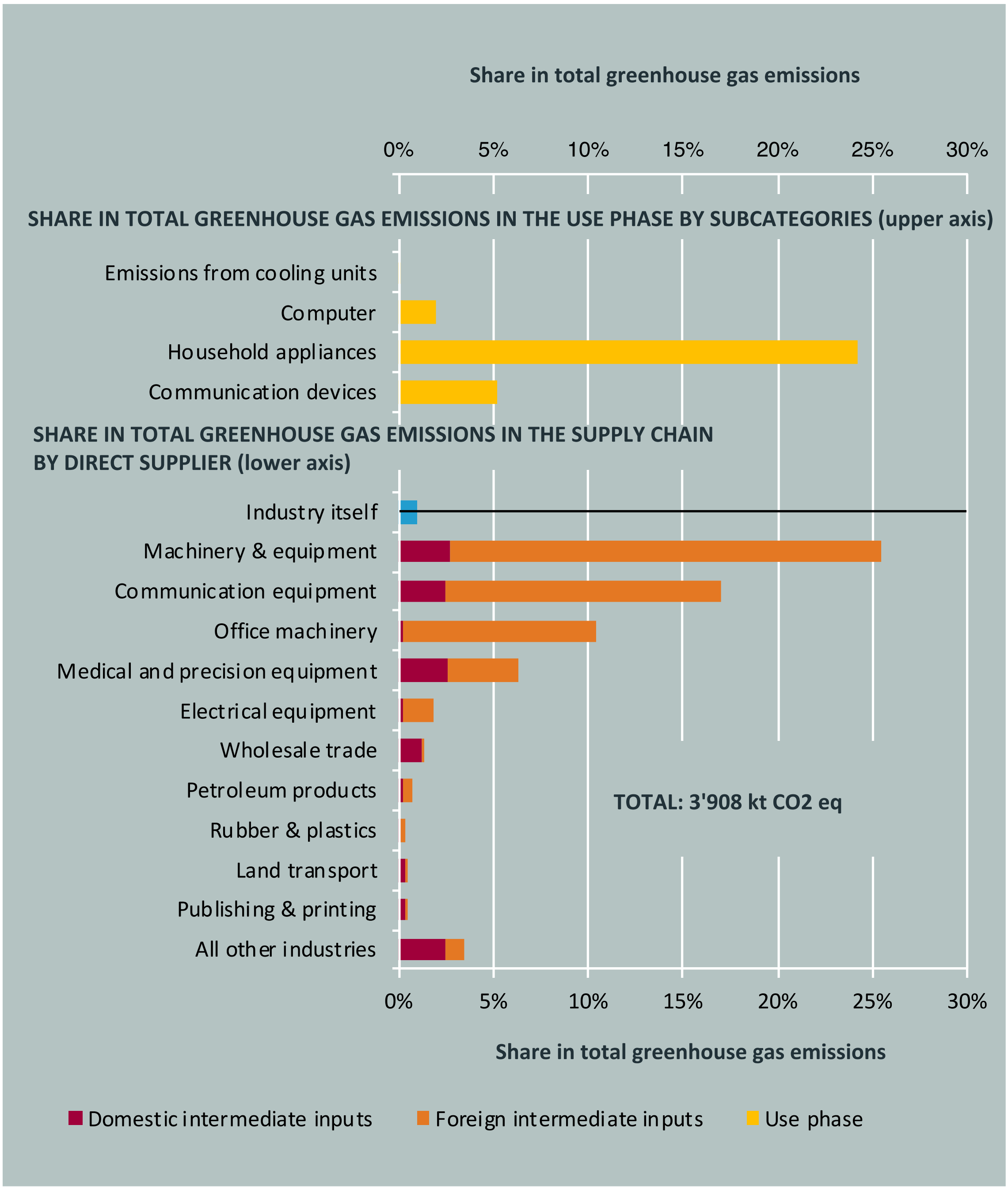

Fig. A.8.1.3: Greenhouse gas footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Trade with household devices’, the industry itself and the use phase (Source: Calculations Rütter Soceco)

A.8.2 Biodiversity loss footprint

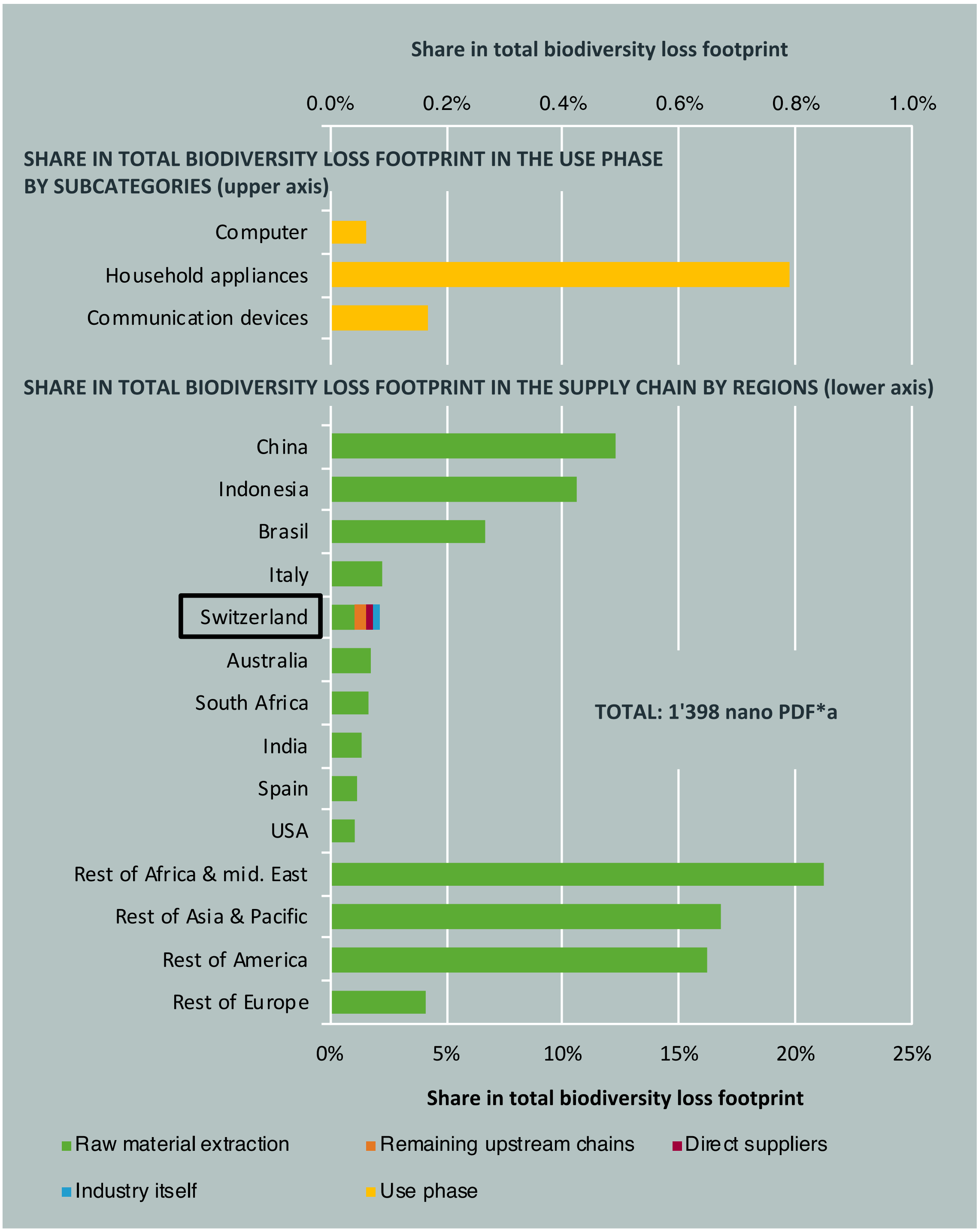

Fig. A.8.2.1: Biodiversity loss footprint caused by the Swiss industry 'Trade with household devices', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

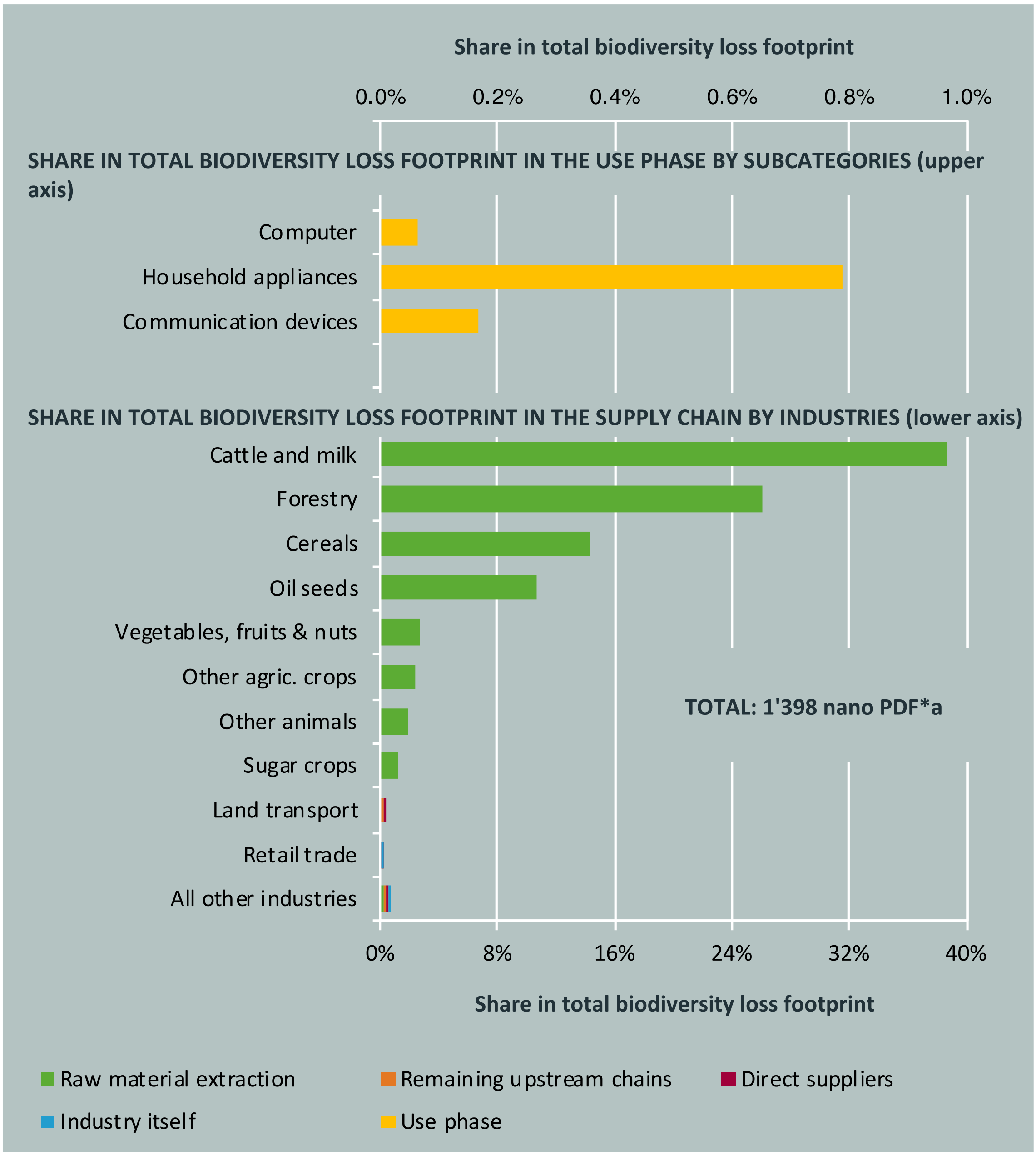

Fig. A.8.2.2: Biodiversity loss footprint caused by the industry ‘Trade with household devices’ by supply chain stage and industry resp. the use phase (Source: Calculations Rütter Soceco)

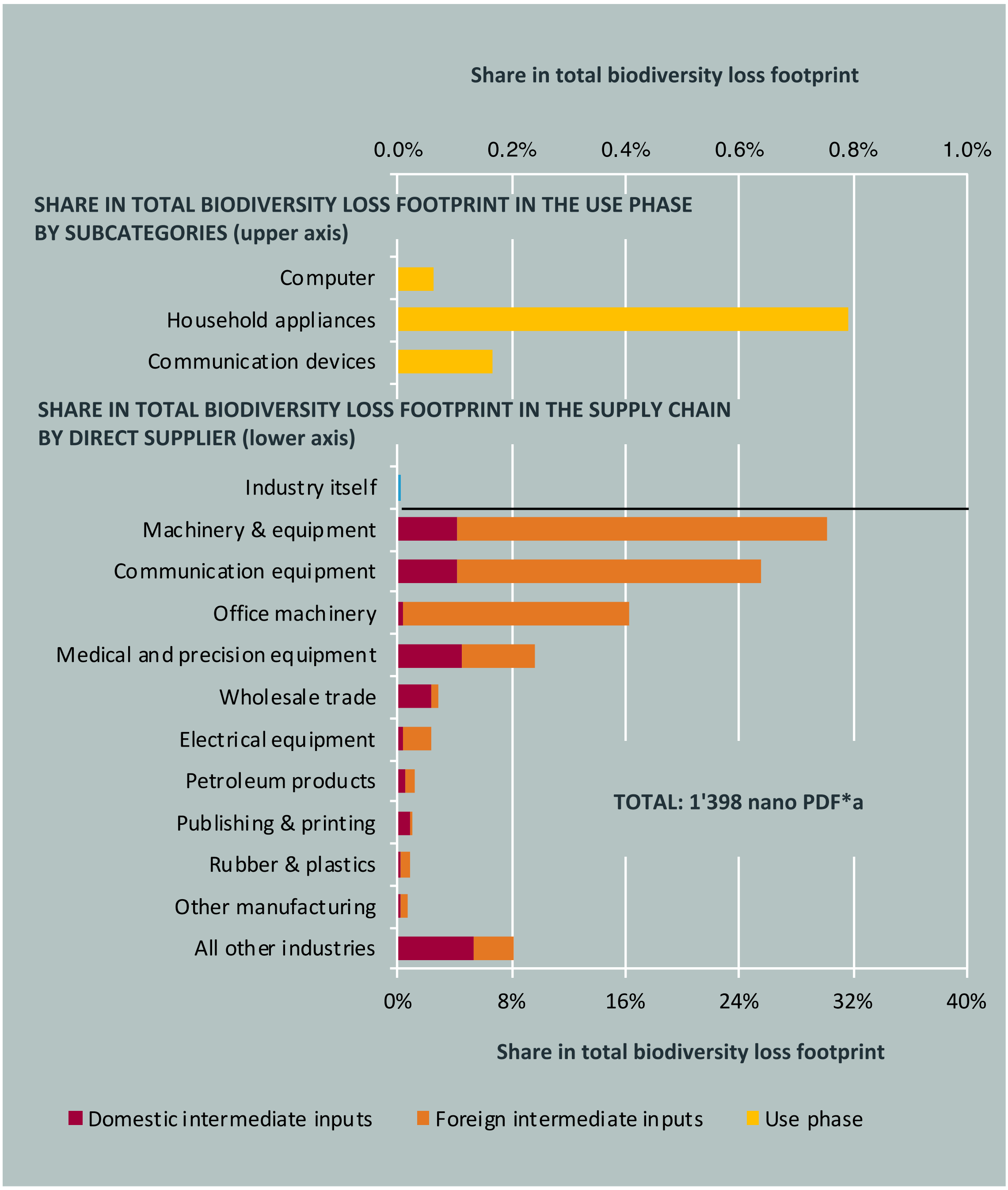

Fig. A.8.2.3: Biodiversity loss footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Trade with household devices', the industry itself and the use phase (Source: Calculations Rütter Soceco)

A.8.3 Water footprint

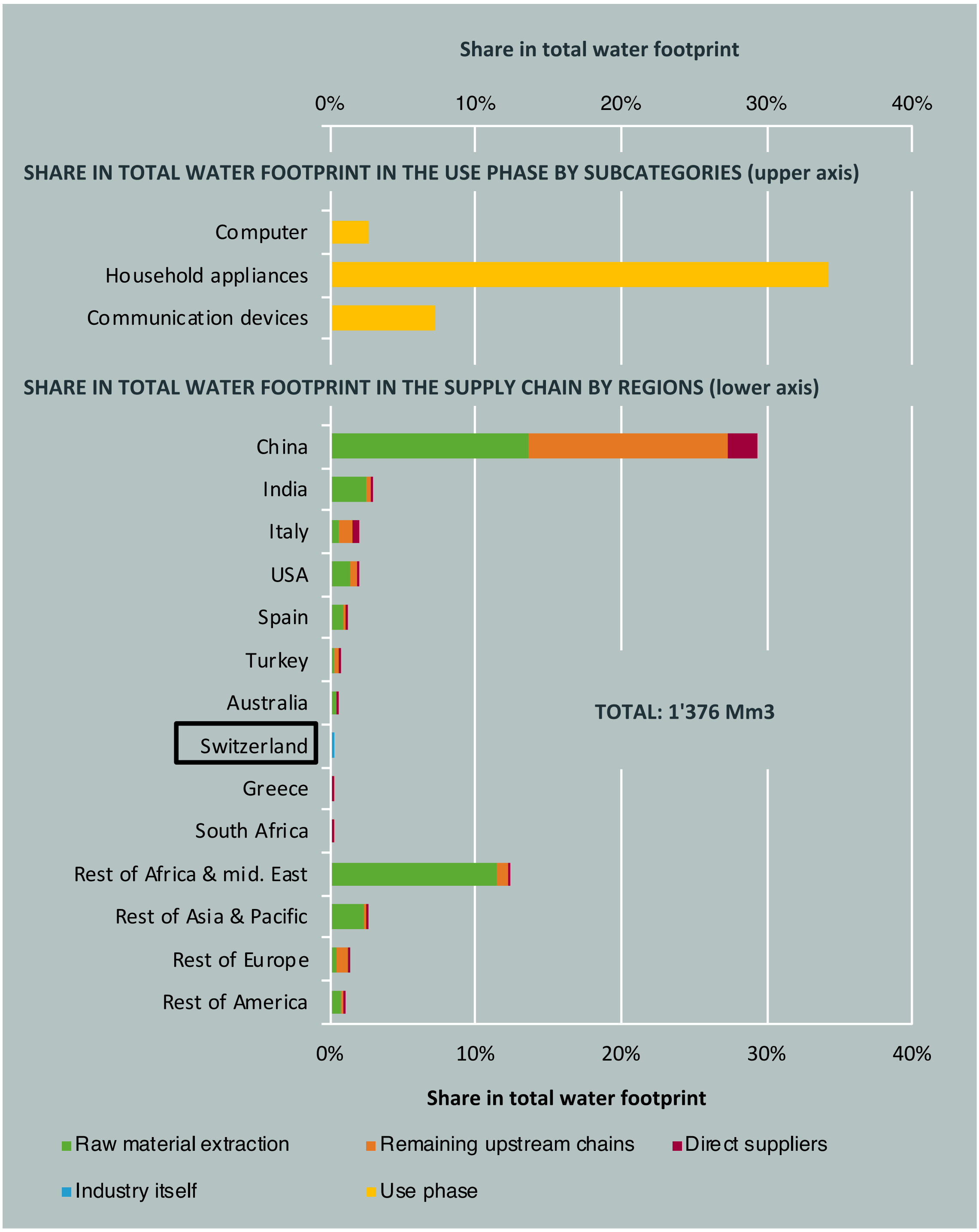

Fig. A.8.3.1: Water footprint caused by the Swiss industry 'Trade with household devices', differentiated by supply chain stage and source countries (Source: Calculations Rütter Soceco)

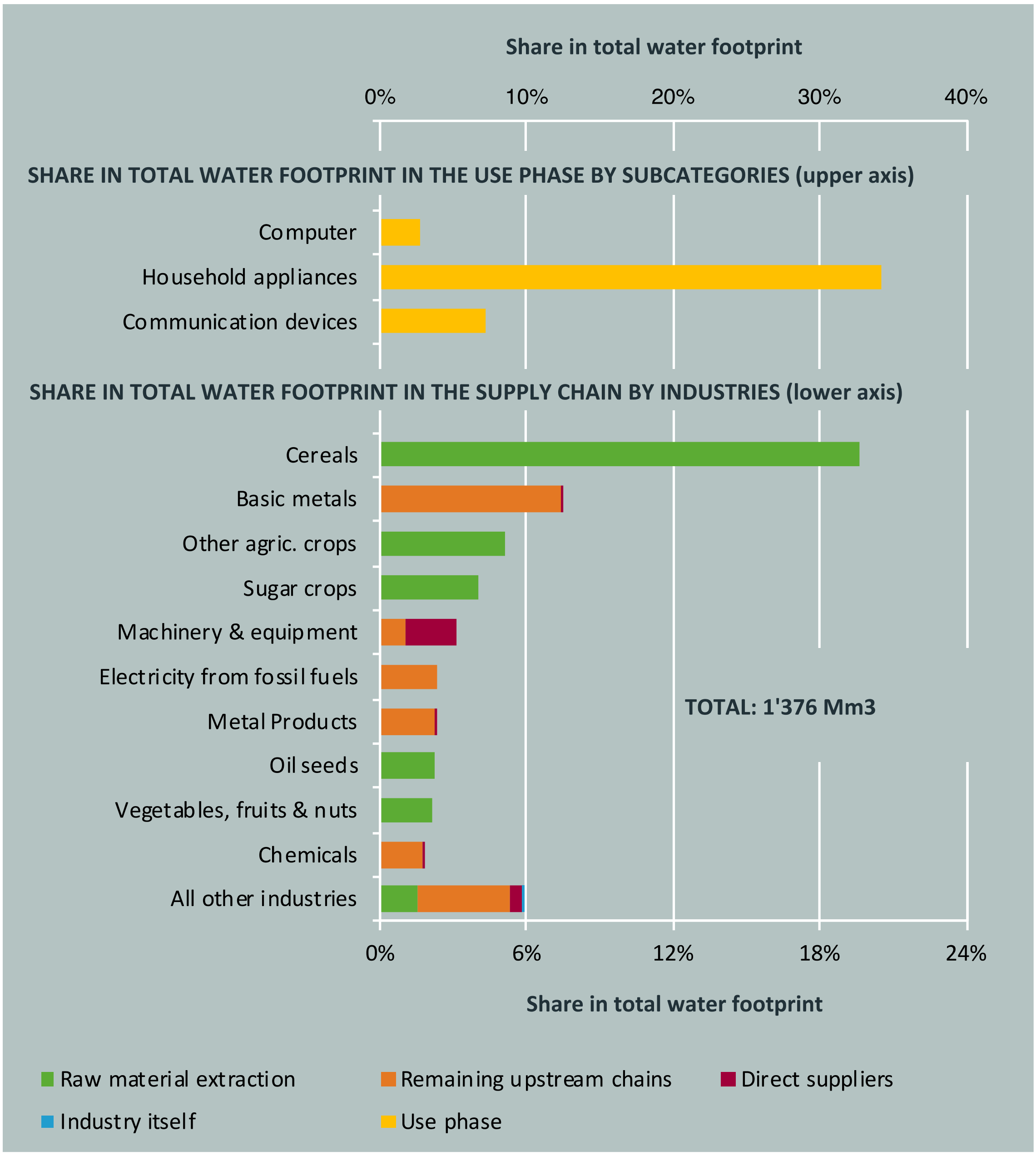

Fig. A.8.3.2: Water footprint caused by the industry 'Trade with household devices' by supply chain stage and industry resp. the use phase (Source: Calculations Rütter Soceco)

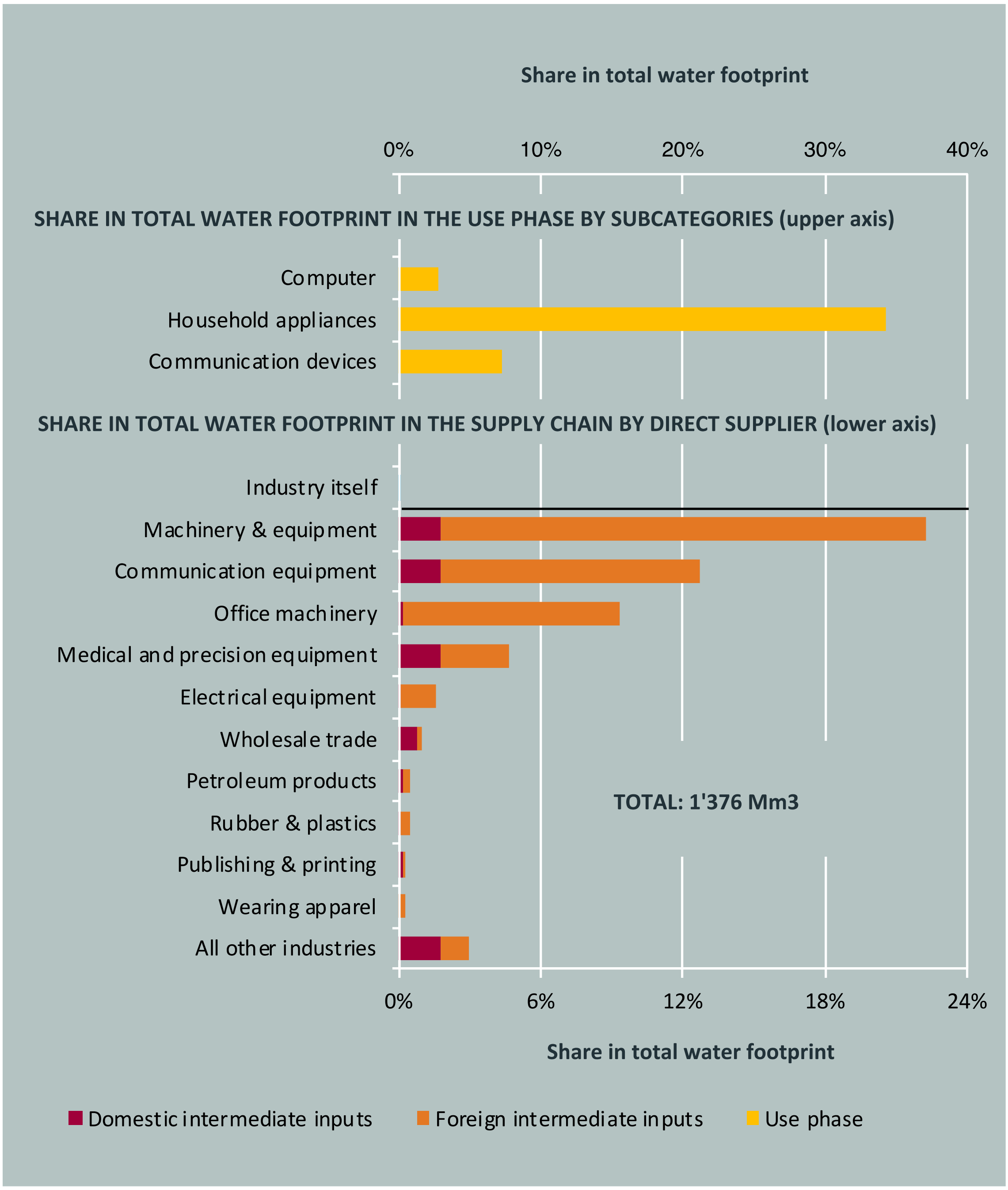

Fig. A.8.3.3: Water footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry ‘Trade with household devices’, the industry itself and the use phase (Source: Calculations Rütter Soceco)

A.8.4 Eutrophication footprint

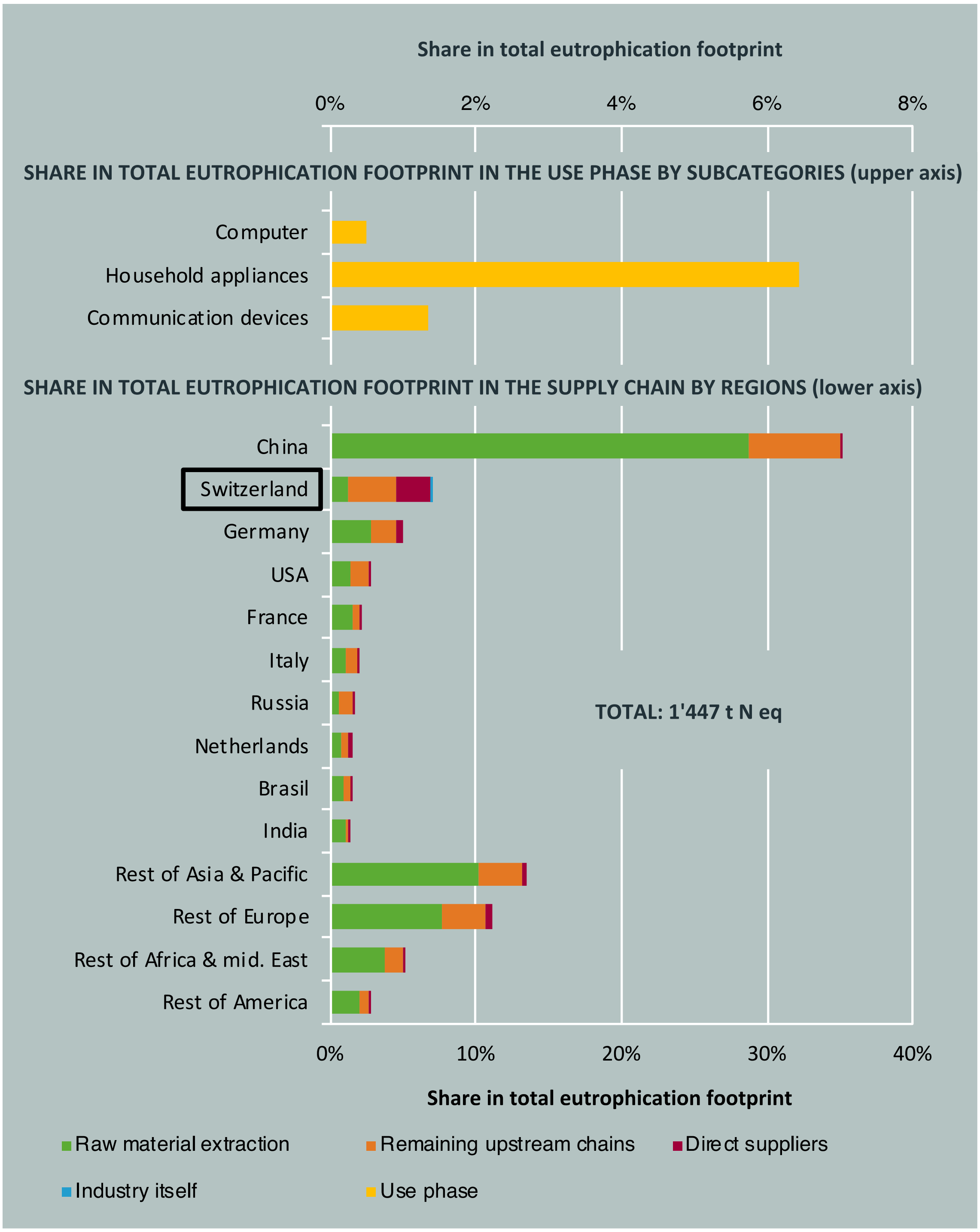

Fig. A.8.4.1: Eutrophication footprint caused by the Swiss industry 'Trade with household devices', differentiated by supply chain stage and source countries, resp. the use phase (Source: Calculations Rütter Soceco)

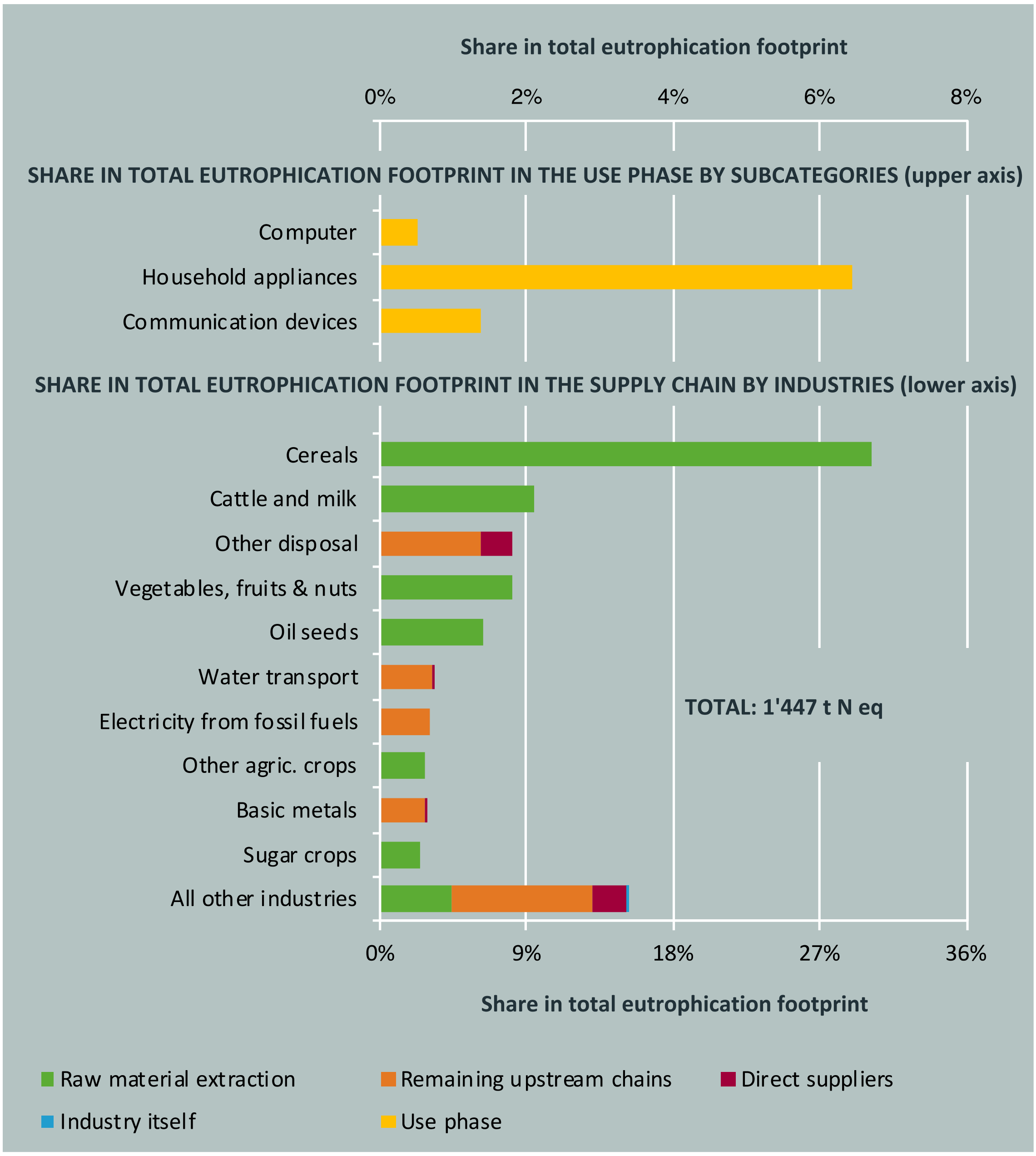

Fig. A.8.4.2: Eutrophication footprint caused by the industry 'Trade with household devices' by supply chain stage and industry resp. the use phase (Source: Calculations Rütter Soceco)

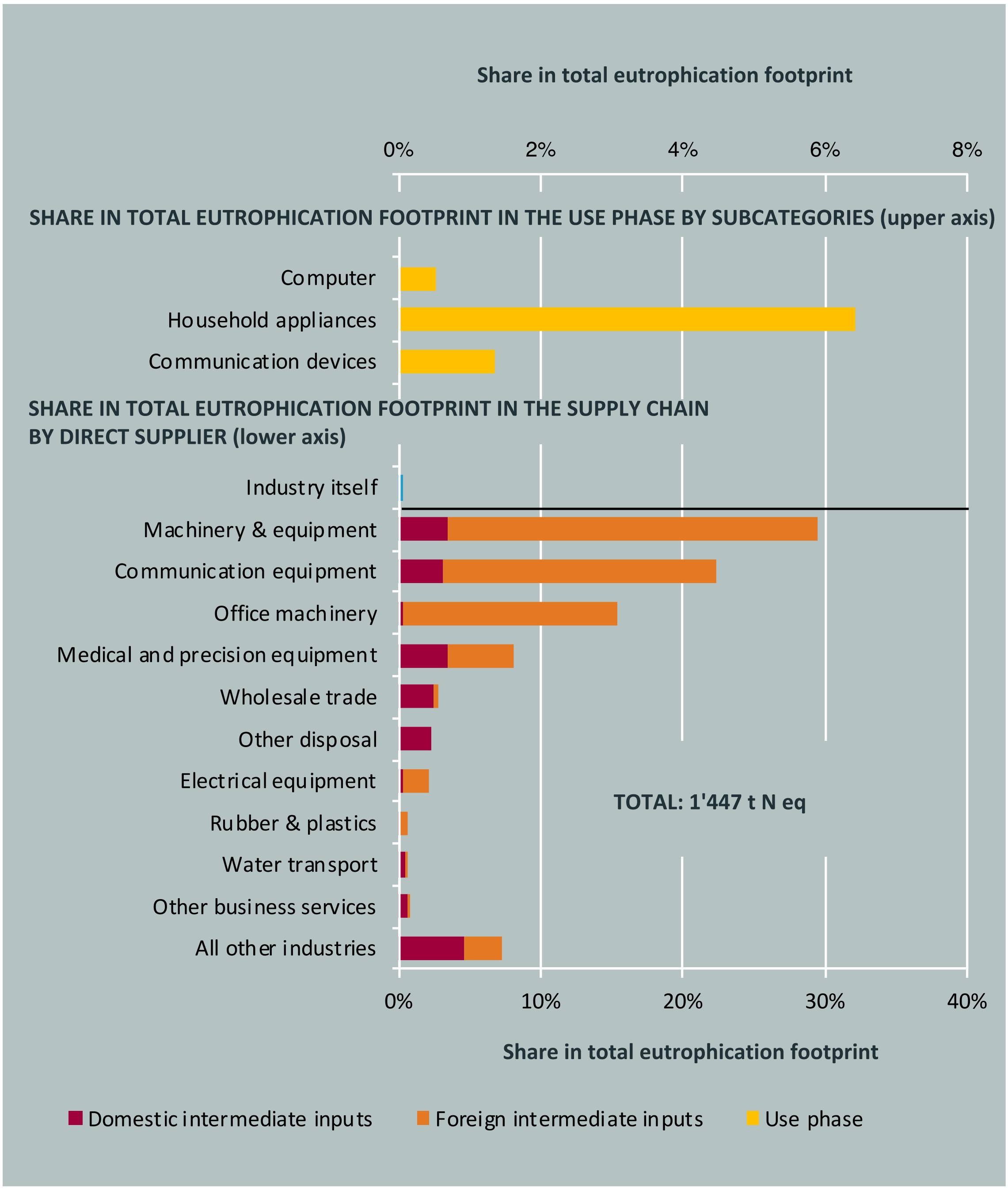

Fig. A.8.4.3: Eutrophication footprint allocated to the direct suppliers of intermediate goods and services for the Swiss industry 'Trade with household devices', the industry itself and the use phase (Source: Calculations Rütter Soceco)