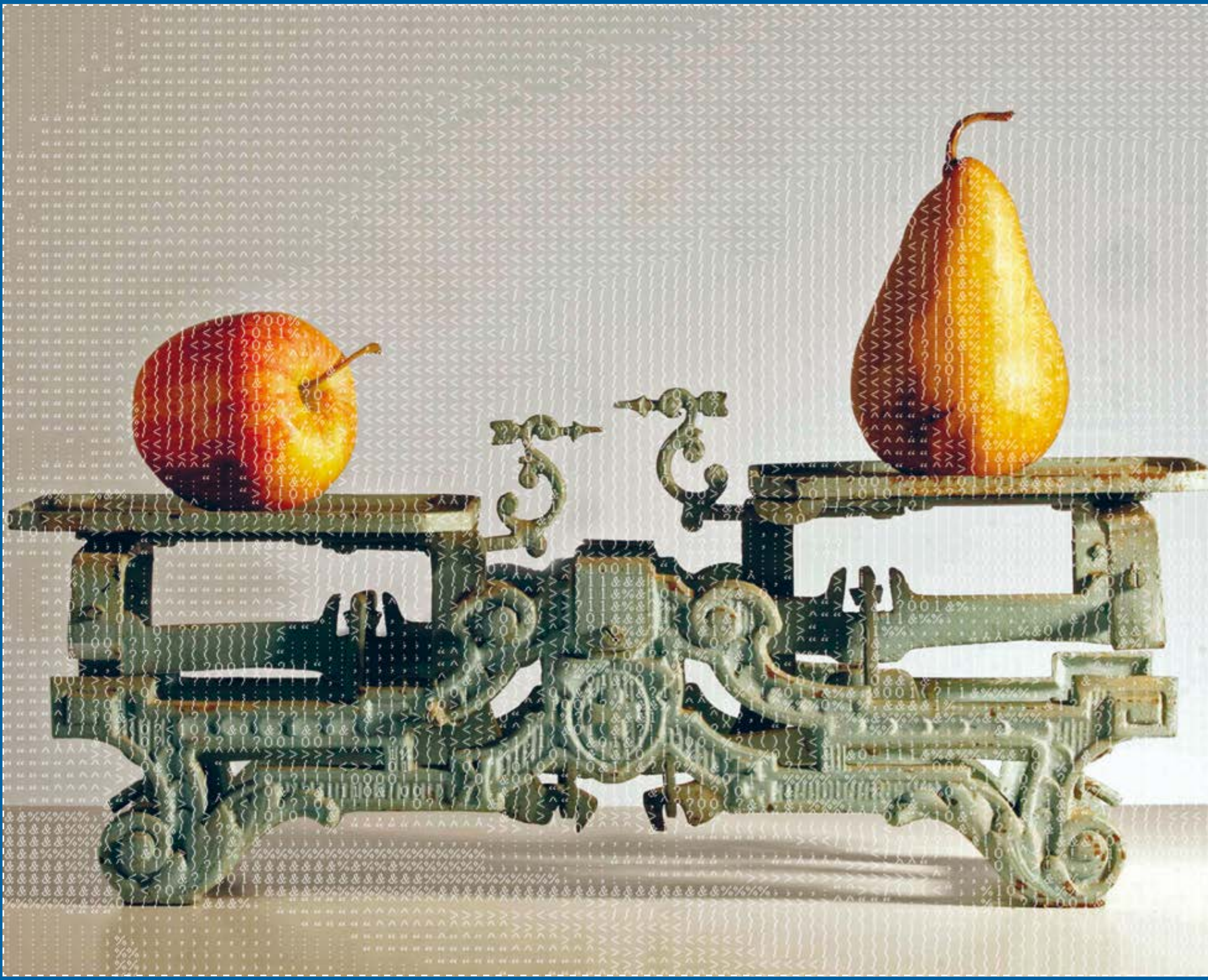
2013 | > Environmental studies | > Life Cycle Assessments

> Swiss Eco-Factors 2013 according to the Ecological Scarcity Method

Methodological fundamentals and their application in Switzerland



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Authors
Rolf Frischknecht, Sybille Büsser Knöpfel, treeze Ltd.

With the collaboration of (2010 – October 2012)
Karin Flury, ESU-services GmbH
Matthias Stucki, ZHAW Wädenswil

Author of Part 1: Life cycle assessments in short
Markus Ahmadi, ideja – Agentur für Kommunikation

Steering Commitee
Peter Gerber, BAFU (Chair)
Arthur Braunschweig, E2 Management Consulting AG
Norbert Egli, BAFU
Gabi Hildesheimer, Öbu

FOEN consultants
Christian Brütsch, Repower AG
Patrik Burri, Credit Suisse
Roland Högger, Geberit International AG
Elisabeth Huber, Geberit International AG (until December 2012)
Martin Kilga, Sinum AG
Peter Müller, Knecht & Müller AG
Paul Schnabl, Swiss Post (until November 2012)
Jörg Schwille, Ernst Schweizer AG, Metallbau
Marcel Sutter, BKW Energy AG
Patrik Walser, Federation of Migros Cooperatives
Anne Wolf, Swiss Post

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Garrett Montgomery, Montreal

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> Table of contents

> Abstracts

The ecological scarcity method makes it possible to assess the impact of pollutant emissions and resource extraction activities on the environment (impact assessment) as part of a life cycle assessment. The key metrics of this method are eco-factors, which measure the environmental impact of pollutant emissions or resource extraction activities in eco-points (EP=UBP) per unit of quantity. The main body of this publication describes how Swiss eco-factors are derived to reflect both the actual emission situation and the national or international emissions targets pursued by Switzerland. Accordingly, eco-factors can be used to assess the consumption and emissions data (eco-inventory) of processes and organisations. Eco-factors must be updated periodically to keep in step with the continuously evolving emission situation, new statutory and political requirements, the latest findings and advances in practical experience. This edition features updated data for the existing eco-factors and introduces new eco-factors for traffic noise, persistent organic pollutants and metal and mineral resources. It also provides eco-factors for land use and radioactive waste that were derived based on new scientific knowledge and further develops the method of disclosing theme-based interim results. Finally, it clarifies the characteristics of the UBP method that can be applied in other countries and regions and answers frequently asked questions about the general use of life cycle assessments and specific assessment methods.

Keywords:
LCA
eco-factors
assessment of impacts
ecological scarcity
eco-points

Die Methode der ökologischen Knappheit ermöglicht im Rahmen einer Ökobilanzierung die Bewertung der Wirkung von Schadstoffemissionen und der Entnahme von Ressourcen auf die Umwelt (Wirkungsabschätzung). Zentrale Grösse der Methode sind die Ökofaktoren, welche die Umweltbelastung einer Schadstoffemission respektive Ressourcenentnahme in der Einheit Umweltbelastungspunkte (UBP) pro Mengeneinheit angeben. Die Publikation beschreibt im Hauptteil die Herleitung der Schweizer Ökofaktoren, die einerseits die aktuelle Emissionssituation und anderseits die schweizerischen oder von der Schweiz mitgetragenen internationalen Emissionsziele widerspiegeln. Diese Ökofaktoren erlauben somit die Beurteilung von Verbrauchs- und Emissionsdaten (Ökoinventaren) von Prozessen wie auch Organisationen. Die Aktualisierung der Ökofaktoren ist aufgrund der sich laufend ändernden Emissionssituation, neuer gesetzlicher und politischer Rahmenbedingungen sowie neuer Erkenntnisse und zunehmender Praxiserfahrungen periodisch erforderlich. Mit der vorliegenden Ausgabe wurden die Datengrundlagen der bestehenden Ökofaktoren aktualisiert, neue Ökofaktoren für Verkehrslärm, für persistente organische Schadstoffe und für metallische und mineralische Ressourcen eingeführt, die Herleitung der Ökofaktoren für Landnutzung und radioaktive Abfälle an neue wissenschaftliche Erkenntnisse angepasst sowie die Methode entsprechend der Ausweisung von themenorientierten Zwischenergebnissen weiterentwickelt. Darüber hinaus werden die Eigenschaften der auch in anderen Ländern und Regionen anwendbaren UBP-Methode erläutert und häufig gestellte Fragen zur Anwendung der Ökobilanz im Allgemeinen und der Bewertungsmethode im Speziellen beantwortet.

Stichwörter:
Ökobilanzierung
Ökofaktoren
Wirkungsabschätzung
Ökologische Knappheit
Umweltbelastungspunkte

La méthode de la saturation écologique permet, dans le cadre d'un écobilan, d'évaluer l'impact sur l'environnement des émissions polluantes et de l'extraction de ressources. Les écofacteurs sont les variables centrales de cette méthode; ils représentent la charge environnementale due à l'émission d'un polluant ou à la consommation d'une ressource, exprimée en unités de charge écologique (ou écopoints; UCE=UBP) par quantité de matière. La partie principale de cette publication décrit comment les écofacteurs ont été obtenus, reflétant à la fois le niveau des émissions actuelles et les objectifs de la Suisse, qu'ils soient nationaux ou qu'ils découlent d'accords internationaux auxquels notre pays a adhéré. Ces écofacteurs permettent d'évaluer les données relatives à la consommation et aux émissions (écoinventaires) de processus et d'organisations. Vu l'évolution constante des émissions, les nouvelles conditions législatives et politiques ainsi que l'avancée des connaissances et l'expérience acquise dans le domaine, une actualisation régulière des écofacteurs est nécessaire. Aussi cette publication présente-t-elle une mise à jour des données des écofacteurs existants ainsi que de nouveaux écofacteurs pour le bruit du trafic, les polluants organiques persistants et les ressources métalliques et minérales. En outre, elle adapte les écofacteurs pour l'utilisation des sols et les déchets radioactifs aux dernières découvertes scientifiques et poursuit le développement de la méthode sur la base de résultats intermédiaires spécifiques. Enfin, elle explique les propriétés de la méthode relative aux impacts en unités de charge (UBP) applicable dans d'autres régions et pays, et répond aux questions fréquentes liées à l'utilisation des écobilans en général et à la méthode d'évaluation en particulier.

Mots-clés:
écobilan
écofacteurs
saturation écologique
écopoints

Nel quadro di un ecobilancio, il metodo della scarsità ecologica consente di valutare l'impatto delle emissioni di inquinanti e del prelievo di risorse naturali sull'ambiente (valutazione dell'impatto). Gli ecofattori costituiscono gli elementi centrali di detto metodo: indicano il carico inquinante dovuto all'emissione di inquinanti o al prelievo di risorse naturali, che viene espresso in punti di impatto ambientale (PIA=UBP) per unità quantitativa. Nella parte principale della pubblicazione viene descritta la modalità di determinazione degli ecofattori per la Svizzera. Questi ultimi rispecchiano sia lo stato attuale delle emissioni che gli obiettivi di emissione della Svizzera, siano essi nazionali o sostenuti dal nostro Paese nell'ambito di accordi internazionali. Gli ecofattori consentono quindi di valutare i dati relativi al consumo e alle emissioni (inventari ecologici) di processi e di organizzazioni. La continua evoluzione delle emissioni, le nuove condizioni quadro legali e politiche nonché le nuove conoscenze e l'esperienza pratica acquisite impongono un aggiornamento periodico degli ecofattori. Nella presente edizione sono stati aggiornati i dati di base degli ecofattori esistenti e ne sono stati introdotti di nuovi per l'inquinamento fonico provocato dal traffico, gli inquinanti organici persistenti e le risorse metallifere e minerarie. Inoltre, la modalità di determinazione degli ecofattori relativi all'utilizzo del suolo e alle scorie radioattive è stata adeguata alle nuove conoscenze scientifiche ed è stato sviluppato ulteriormente il metodo sulla base di risultati intermedi specifici. Infine, la pubblicazione illustra le caratteristiche del metodo UBP, applicabile anche in altri Paesi e regioni, e fornisce risposte alle domande frequenti sull'impiego dell'ecobilancio in generale e, nello specifico, sul metodo di valutazione.

Parole chiave:
ecobilancio
ecofattori
saturazione ecologica
ecopunti

> Foreword

Life cycle assessments make it possible to systematically evaluate environmental impacts. Companies around the world have incorporated this tool in their internal decision-making process in an effort to make their products or operations more environmentally friendly. They often use it for their external environmental reporting as well. All of these uses demonstrate the voluntary commitments made by companies to improve the environment and increase eco-efficiency. At the same time, consumer and environmental organisations can also use life cycle assessments to evaluate the extent to which products and services are environmentally friendly. In all of these cases, the life cycle assessment is a valuable, often irreplaceable tool.

Due to its use as a guide for decision-making, the life cycle assessment has also gained acceptance in recent years as a resource for political processes and issues. For instance, the proof required by the Biofuels Life Cycle Assessment Ordinance (TrÖbiV) to demonstrate the positive aggregate environmental impact of fuels from renewable feedstocks is based on the life cycle assessment calculations of the ecological scarcity method. Likewise, the green economy action plan adopted by the Swiss Federal Council in early March 2013 to improve information about the environmental pollution caused by products, particularly in the areas of consumption and production, is based on life cycle assessments. Reliable results from analyses are a condition for political acceptance.

Two requirements must be met to ensure that the results of life cycle assessment calculations are credible in all of these situations: First, the process data used to perform the calculations must be of high quality. This is achieved if the data is effectively collected according to transparent, consistent rules and documented in a way that is traceable for third parties. For that purpose, special data bases have binding data collection requirements to make sure that the available data is periodically updated and existing gaps are closed. Examples include Switzerland’s ecoinvent data base and the KBOB list of life cycle assessment data in the field of construction, which is based on the ecoinvent data base.

Furthermore, an appropriate assessment method must be applied in order to answer the questions being asked. An appropriate method provides the most realistic representation possible of the environmental pressures caused by a given product by taking into account the emissions generated and the resources consumed in its production, use and disposal throughout its entire life cycle. Therefore, assessment methods must be periodically updated so they can achieve this over the long term.

The ecological scarcity method (eco-points method) is specifically suited to representing Swiss conditions. It measures the current environmental situation based on politically determined environmental targets and makes it possible to assess relevant environmental pressures on the widest possible basis. This is why the FOEN has supported the continuous development of this method for over 25 years. The eco-factors based on this method were most recently updated for Switzerland in 2006. However, the situation in various areas has changed considerably since then. Legislators have given more attention to issues such as rising environmental pollution as a result of the increasing consumption of raw materials and the more complicated extraction methods caused by increasingly scarcer resources. On a methodological note, noise pollution from traffic was recently modelled and converted into eco-factors. In addition, the representation of biodiversity loss brought on by various types of land uses has been improved. As for the environment, the pollution situation has improved in several areas. The gap is widening between the current emission levels of greenhouse gases and the statutory target, which has become stricter over time. However, the situation of ozone depleting substances and "classic" airborne pollutants has eased. These changes are taken into account when updates are made.

Under the direction of the FOEN, the latest update of the eco-points method began in October 2010. Once again, many individuals contributed their knowledge to this project. The authors' in-depth methodological and technical knowledge of life cycle assessments was decisive in the acceptance of new eco-factors and the further development of existing ones. The expertise of the steering committee and its extensive experience in applying the eco-points method also contributed to this achievement. Furthermore, the firms of the Swiss Network for Sustainable Business (Öbu) that were consulted as part of this project made an invaluable contribution thanks to the practical knowledge they have gained from using the method in companies. Finally, specialists from various divisions of the FOEN provided their sectorial, environmental and political expertise. I would like to sincerely thank all of the above at this time.

For the first time ever, the report was divided into three parts. As in earlier versions, this report includes a chapter on the methodological fundamentals of the universally applicable ecological scarcity method and a chapter on the derivation of eco-factors for the Swiss context. A new feature of this report is a chapter that provides general answers to frequently asked questions about life cycle assessments and specific answers to questions about the eco-points method. This chapter should make it easier for non-specialists, such as life cycle assessment clients working for authorities or companies, as well as politicians and media professionals, to better understand its content. I would also like to sincerely thank the authors who wrote this important part.

Christine Hofmann
Deputy Director
Federal Office for the Environment (FOEN)

> Summary

According to ISO Standard 14040, life cycle assessments (LCA) of products, processes, companies or entire national economies comprise four phases:

> goal and scope definition,
> inventory analysis,
> impact assessment, and
> interpretation.

In the ecological scarcity method, an impact assessment of life cycle inventories is performed according to the “distance to target” principle. Eco-factors, expressed as eco-points (EP = UBP) per unit of pollutant emission or resource extraction, are the key parameter used by the method. With this method, eco-factors are determined based on the current emissions situation and the political targets set by Switzerland or by inter-national policy and supported by Switzerland. The method was first published in 1990.

New eco-factors were developed for various environmental impacts in the last update of the method (Frischknecht et al. 2008) and have been used widely since then. The update presented here became necessary to reflect new scientific findings, new statutory and political targets, new international agreements, developments in international standarization and experience gathered in practice. As part of this update, the set of substances assessed has been further expanded. The data and information on which the existing eco-factors were based was checked and updated. The key changes made since the last update in 2008 are as follows:

> The **eco-factor formula** that was slightly adjusted during the last update is still valid and was therefore retained.
> A reduction target of 80% has been set for CO_2 and other greenhouse gases. This falls in the upper range of the Swiss reduction target and within the range of the reduction required to achieve the 2°C target.
> To assess **energy**, the federal government's long-term target (2,000 W per capita) is interpolated to the usual time frame set out in the legislation, which is 2035.
> With regard to air pollutants, additional eco-factors are provided for **PAHs and radioactive isotopes**.
> In this version, **PAHs, dioxins and furans**, and **benzene** are all assessed for their carcinogenic potential.
> With regard to **heavy metal emissions** (both to air and to soil), the long-term maintenance of soil fertility is used once again as the goal.
> As for water pollutants, additional eco-factors for **oil emissions to the sea** are provided based on an international agreement to protect the North Sea. Furthermore, eco-factors for the emissions of **radioactive isotopes and persistent organic pollutants in watercourses** are included for the first time.
> In some parts of the world, **freshwater** is a scarce resource. The regionalized eco-factors introduced in the last update are now indicated for all countries and as

average values for continents. The eco-factor for water of unknown origin is now determined on the basis of scarcity in OECD and BRIC countries (Brazil, Russia, India and China). In addition, water scarcity can be individually determined using Google Earth^{TM} Layers for each water catchment area.

- It is now recommended that the eco-factor for **freshwater** be applied to consumptive water use (and not water extraction).
- In Switzerland, resource efficiency has become a relevant area of environmental policy. For that reason, a new eco-factor for **mineral primary resources (minerals and metals)** was introduced. The ratio of annual production to available reserves is used as the basis for the characterization.
- New eco-factors were introduced for **land use** in various biomes. Characterization is based on the impacts of land uses upon plant and animal biodiversity.
- New eco-factors are provided for **noise pollution** caused by road, rail and air traffic.

Overview of eco-factors for 2013

The following table lists the eco-factors according to the Swiss situation. Annexes A2 to A8 present the factors for other substances determined by characterization. The **“current flow”** column states today’s emission situation. The **“normalization flow”** column presents the reference quantity, which in most cases is identical to the current flow. The **“critical flow”** column represents the **political target.** If the critical flow is larger than the current flow, then today’s situation is in accordance with the target.

Tab. A > Overview of eco-factors for 2013

	Normalization flow		Current flow	Critical flow		Ecofactor 2013	UBP per
Emissions to air							
CO_2	53 040 000	t CO_2-eq	53 040 000	10 766 000	t CO_2-eq	0.46	g CO_2-eq
Ozone-depleting substances	191	t R11-eq.	191	150	t R11-eq.	8 500	g R11-eq
NMVOC	89 025	t	89 025	81 000	t	14	g
NO_x	78 704	t	78 704	45 000	t	39	g
NH_3 (as N)	51 463	t	51 463	25 000	t	82	g NH_3-N
SO_2	12 861	t $SO_{2\text{-eq}}$	12 861	25 000	t	21	g $SO_{2\text{-eq}}$
PM10	20 470	t	20 470	12 000	t	140	g
PM2.5–10	20 470	t	9 741	5 710 [1]	t	140	g
PM2.5	20 470	t	10 729	6 290	t	140	g
Diesel soot	1 661	t	1 661	208	t	38 000	g
Carcinogenic substances (Benzene, Dioxins and Furans, PAHs)	0.9	CTUh	0.9	0.576	CTUh	2.7 * 10^{12}	CTUh
Benzene	-		-	-		810	g
Dioxins and Furans	-		-	-		7.9 * 10^{10}	g
PAHs	-		-	-		1 400 [2]	g BAP-eq
Lead	23	t	23	32 [3]	t	22 000	g
Cadmium	1.26	t	1.26	1.65 [3]	t	460 000	g
Mercury	1.05	t	1.05	2.22	t	210 000	g
Zinc	378	t	378	260 [3]	t	5 600	g
Radioactive emissions	1.08	TBq C-14-eq	1.08	1 164	TBq C-14-eq	0.0008	kBq C-14-eq
Emissions to surface waters							
Nitrogen (as N)	36 197	t	28 656	19 875	t	57	g N
Phosphorus (as P)	1 854	t	-	-		890	g P
COD	37 002	t	37 002	73 527	t	6.8	g
Arsenic	10.7	t	13.2	40	mg/kg	10 000	g
Lead	27.4	t	33.8	100	mg/kg	4 200	g
Cadmium	0.66	t	0.41	1	mg/kg	250 000	g
Chromium	22.6	t	53.1	100	mg/kg	12 000	g
Copper	81.1	t	51.2	50	mg/kg	13 000	g
Nickel	62.4	t	42.3	50	mg/kg	11 000	g
Mercury	0.20	t	0.21	0.5	mg/kg	860 000	g
Zinc	123	t	176	200	mg/kg	6 200	g
Radioactive emissions to domestic waters	0.289	TBq U-235-eq	0.289	36.14	TBq U-235-eq	0.22	kBq U-235-eq
Radioactive emissions to seas	3.85	TBq C14-eq	26	46.6	TBq C14-eq	81	kBq C14-eq
Oil emissions to the sea	6 210	t	9 596	7 403	t	270	g
AOX (as Cl^-)	249.6	t	249.6	1 200	t	170	g Cl
Chloroform	2.9	t	0.06	0.6	µg/m³	3 400	g
PAHs	0.328	t	0.0068	0.1	µg/m³	14 000	g
Benzo(a)pyrene	15.7	kg	0.00033	0.01	µg/m³	1 900 000	g
Endocrine disruptors	2.9	kg E2-eq	2.9	19.2	kg E2-eq	7 800 000	g E2-eq
Persistent organic pollutants	290	t 2,4,6-T-eq	290	72	t 2,4,6-T-eq	17	g 2,4,6-T-eq

	Normalization flow		Current flow	Critical flow		Ecofactor 2013	UBP per
Emissions to groundwater							
Nitrogen (as N)	34 000	t	34 000	17 000	t	120	g NO_3-N
Emissions to soil							
Lead	29.4	t	13.9	19.4	g/ha.a	17 000	g
Cadmium	2.2	t	0.99	1.3	g/ha.a	270 000	g
Copper	118	t	73.4	58	g/ha.a	14 000	g
Zinc	763	t	442	303	g/ha.a	2 800	g
Plant protection products	8 241	t Glyphosat-eq	2 208	1 995	t	150	g Glyphosat-eq
Resources							
Primary energy carriers	1 428	PJ-eq	1 538	693	PJ	3.4	MJ Öl-eq
Land use, settlement area	2 437	km^2.a SF-eq	3 027	3 535	km^2.a	300	m^2.a SF-eq
Primary mineral resources	904	t Sb-eq	904	904	t Sb-eq	1 100	g Sb-eq
Gravel	33 460	1000 t	33 460	33 460	1000 t	0.03	g
Freshwater Switzerland	2.61	km^3	2.61	10.7	km^3	23	m^3
Freshwater OECD	2.61	km^3	2467	1 955	km^3	609	m^3
Wastes							
C to landfill	183 222	t	183 222	183 222	t	5.5	g C
Hazardous wastes to underground disposal sites	37 223	t	37 223	37 223	t	27	g
High-level radioactive wastes	146.6	m^3 HAA-eq	135 700 000	52 220 000	Mio. RTI	46 000	cm^3 HAA-eq
Noise							
Noise road	803 882	HAP	715 754	436 058	HAP	3 400 000	HAP
• Passenger transportation						21	vkm
• Transportation of goods						210	vkm
Noise train	803 882	HAP	60 934	32 754	HAP	4 300 000	HAP
• Passenger transportation						5.2	pkm
• Transportation of goods						15	tkm
Noise aircraft	803 882	HAP	27 194	15 042	HAP	4 100 000	HAP
• Passenger transportation						1.4	pkm
• Transportation of goods						14	tkm

[1] Value derived from PM10 critical flow and PM2.5 proportion

[2] Ecofactor for PAH, world average

[3] Value calculated from ratio of current to critical flow of emissions to soil

Temporal reference: The figures are based on the data available in 2011 and 2012.

On data accuracy: The flows are not rounded, thus allowing for optimal traceability in source texts. Scarcity and weighting factors are rounded to two digits

> User information

This publication, entitled "Swiss Eco-Factors 2013 according to the Ecological Scarcity Method", has three main parts:

- > **Part 1** describes the characteristics of life cycle assessments as a method of determining the environmental impact of products (goods and services), processes and companies, and more specifically the characteristics of the ecological scarcity method, also known as the eco-points method, in its Swiss version. It is intended for interested individuals, particularly clients of life cycle assessments at companies and in the administration, policy-makers and media. The section entitled "Basic Information for decision-makers" briefly describes the focus of a life cycle assessment, its quality criteria and the strengths of the eco-points method.
  The detailed, thematically-structured catalogue of the "Frequently Asked Questions" (FAQ) section makes it possible to gain more in-depth knowledge of specific items. Attention is given to both basic information and key aspects.
- > **Part 2** presents the ecological scarcity method in detail. The explanations are intended for clients, specialised users and research and applied scientists. The content is focused on the principles behind the method and the formulas used to derive the eco-factors.
- > **Part 3** explains how the method is applied to the conditions in Switzerland. It provides a detailed description of how the eco-factors are derived. This is where specialists will find the parameters derived from science and environmental policy for the assessed emissions and resources.

Part 1

> Life cycle assessments in short

Part 1 describes the characteristics of life cycle assessments as a method of determining the environmental impact of products (goods and services), processes and companies, and more specifically the characteristics of the ecological scarcity method, also known as the eco-points method, in its Swiss version.

1 > Basic information for decision-makers

Target audience: interested individuals, particularly clients of life cycle assessments in companies and administrations, policy-makers and media.

What is a life cycle assessment

A life cycle assessment determines the environmental impact of products, processes, services, installations or entire economies. It is typically used to assess products over their entire life cycle, from extracting the raw materials, manufacturing and use of products to their disposal and entire transport. Life cycle assessments cover the consumption of energy and raw materials, the release of pollutants in the air, water and soil and noise levels from traffic within the determined scope of a study. The individual emissions and raw material extractions are assessed with regard to their environmental impact and aggregated to several different indicators or one single figure. Life cycle assessments are used to help decide between alternatives, optimise operations, raise awareness and demonstrate ecological services. For example, an authority can use a life cycle assessment to decide whether the separate collection of natural waste makes sense from an environmental perspective, while consumers can use it to learn more about the potential environmental benefits of seasonal, local tomatoes. Life cycle assessments (LCA) get their name from the fact that they consider a product's life cycle.

Reliable total picture

A life cycle assessment is carried out according to an international standard (International Organization for Standardization (ISO) 2006a) and has the following four phases: goal and scope definition, life cycle inventory, impact assessment and interpretation. The ISO standard also defines the quality requirements. Furthermore, in every case, critical review of the results is performed, for example, by a specialist not involved in the study. The FOEN also recommends that the impact should be assessed using more than one method in order to provide additional certainty about the direction of the statement. In addition, the underlying values of the study should be made transparent. The FOEN's criteria should ensure that the life cycle assessment complies with the principle of a true and fair view (Schwegler et al. 2011).

Necessary values

In the impact assessment phase, the data on emissions and resource consumption acquired in the life cycle inventory are assessed. Without this assessment, life cycle assessment data would not be meaningful. Here is an example: it is possible to come to a decision when you know that 2 grams more of pesticides are released into the environment with alternative A, while 50 grams more of CO_2 are caused by alternative B.

To be able to compare the various alternatives, an impact must be allocated to the individual emissions. These impacts are weighted according to two different approaches: damage modelling or distance to target. Damage modelling tries to use science to capture the risks to human health and ecosystems and the extraction of resources. The set of values expressed in the weighting are usually determined by a panel of experts.

In the distance to target approach, the metric is coupled with nationally or regionally-specific emissions and consumption targets. These approaches include, for example, EDIP (Hauschild et al. 1998) and ECER (Wang et. al. 2011) and the ecological scarcity method presented in this publication. The latter weights emissions and resource consumption using eco-factors. Eco-factors are calculated from the ratio of current emissions or consumption figures to tolerance values resulting from legislative or policy-based environmental quality targets. The eco-factor is expressed in eco-points (UBP) per unit of quantity. For each emission or resource concerned, the determined quantities are multiplied to produce an EP number, which is then added up to a total. This procedure is called aggregation. The ecological scarcity method is also known as the eco-points method due to the points that result from it.

Definite benefits

The eco-points method has many benefits:

> It conveys a total picture of the actual conditions. Because the eco-points method integrates a wide range of relevant environmental impacts, it fulfils the most important requirement of a true and fair view. Its fully aggregated approach considers more than just selected emissions and includes key factors. For example, a study of fuels from renewable raw materials would not be comprehensive and therefore not significant if only greenhouse gases were considered. To convey a reliable and comprehensible total picture, it is important to consider the other impacts of cultivating crops, such as the use of fertilizers, pesticides, soil, energy and water. Thanks to the fact that the result is presented as one single figure, it is comprehensible and useful to inexperienced practitioners.
> The eco-points method is explicitly based on legally-enshrined and democratically legitimised environmental quality targets. Therefore, this approach expresses clear, transparent and commonly supported values. This type of assessment offers value by providing users with reproducible, clear results.
> The eco-points method is widely supported and includes a review system. To prevent a random approach, it clearly divides up the tasks of the actors, similar to the principle of separation of powers. The sciences (physics, chemistry, biology, medicine) provide basic knowledge about the toxicity of substances, the greenhouse impact of emitted gases or the risk to health of noise. Lawmakers, followed by competent authorities, develop environmental targets from this knowledge and lay the foundations for the assessment criteria. The authors of life cycle assessments (industrial and consulting companies, research institutes) then adopt the assessment criteria without changing them.
> Since the method and the assessment criteria are separate, the eco-points approach can be used anywhere in the world. In addition to Switzerland, where the approach was first developed, countries such as Belgium, Sweden, Norway, the Netherlands, Jordan and Japan also use it. Environmental targets set out in the policy of the concerned country and knowledge of the current state of emissions are conditions for determining the adapted assessment criteria. Because it can be adapted to different countries, specific statements are possible. For example, particulate matter emissions in countries with an exceeded limit value are weighted higher than in countries where this is not the case.
> The Swiss version of the eco-points method is based on the environmental quality targets and limit values set out in Swiss legislation. In the FOEN's view, this makes it a reference standard for studies that concern Switzerland. The method makes it

possible for companies that are active in Switzerland to adequately determine their environmental impact.

- The eco-points method assesses a wide range of consumption and emissions. In the Swiss version, these include water resources, energy resources, primary mineral resources, land use, greenhouse gases, ozone-depleting substances, the most important air pollutants and particles, carcinogenic substances in the air and water, heavy metals in air, water and soil, water pollutants, plant protection products, radioactive emissions in air and water, radioactive and non-radioactive wastes and traffic noise.

2 > Questions and answers concerning life cycle assessments (FAQ)

Overview of the 35 questions, divided into 22 general questions about life cycle assessments and 13 specific questions about the ecological scarcity method.

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Keyword index

2.1 Life cycle assessments in general

2.1.1 What does a life cycle assessment calculate?

Calculation

The idea behind the life cycle assessment method is to show environmental impacts in numbers.

Scientists arrive at these figures in two steps: life cycle inventory and impact assessment. In the life cycle inventory, scientists measure the quantities of raw materials and energy required for each individual production process, as well as the emissions. Here is an example: a study is conducted on a product that causes 180 g of carbon dioxide (CO_2), 10 g of methane (CH_4) und 7 g of nitrogen (NO_X) emissions from the extraction of the raw materials and the production process to the product's use and disposal (see table below).

This type of life cycle inventory requires detailed environmental and product data, which can be found in life cycle assessment data bases for many standard processes, such as heating oil or cement production. *Ecoinvent*, one of the most comprehensive data bases in the world, is used by many Swiss research institutes. The exceptional transparency of its data sources is what particularly sets it apart.

In the next step, a life cycle inventory is used to determine the impacts on the environment and human health. Emissions and resources are also classified and characterized. Emissions are classified by allocating them to specific impact categories. For example, methane contributes to climate change, but not to over-fertilization. Next, the classified emissions are characterized according to their impact category, which means that they are converted into a standard metric based on scientific knowledge. For example, methane has an impact on climate change that is 25 times stronger than the impact of carbon dioxide. Therefore, one kilogram of methane causes the same impact caused by 25 kilograms of so-called CO_2 equivalents.

The weighting determines how severely the environmental impacts of one category are assessed compared to the impacts of other categories. There are several ways of doing this. Most methods fall into one of two basic categories: damage modelling or distance to target. For example, damage modelling uses models to calculate the number of years a human life is shortened or the number of plant species that disappear from a region when a specific pollutant contaminates the environment. The distance to target approach uses the environmental quality goals set out in legislation as its standard: the more the tolerated quantity of emissions or raw materials is exceeded, the stronger the impact is weighted.

The ecological scarcity method discussed in this publication follows the second approach. It totals all of the environmental impacts using the metric of eco-points (UBP). This is why it is also called the eco-points method. The quantities determined in the life cycle inventory are multiplied by their respective → eco-factor. For example: 0.46 UBP per gram of CO_2, 12 UBP per gram of CH_4, 39 UBP per gram of NO_X. The UBP quantities of all weighted emissions and uses are then added up to calculate the total number of points. In the above example, this would be 83 UBP + 120 UBP + 273 UBP = 476 UBP.

Tab. 1 > UBP calculation (example)

Emission	Impact category	Characterization	UBP per gram	Quantity	Total
Carbon dioxide (CO_2)	Greenhouse gases	1 CO_2-equivalent	0.46	180 g	83 UBP
Methane (CH_4)	Greenhouse gases	25 CO_2-equivalents	12 (= 0,46 * 25)	10 g	120 UBP
Nitrogen oxide (NO_X)	Nitrogen oxide	-	39	7 g	273 UBP
Total					**476 UBP**

2.1.2 How are life cycle assessments developed?

Development

A life cycle assessment has four phases.

Based on international standard (International Organization for Standardization (ISO) 2006a), a life cycle assessment has four phases:

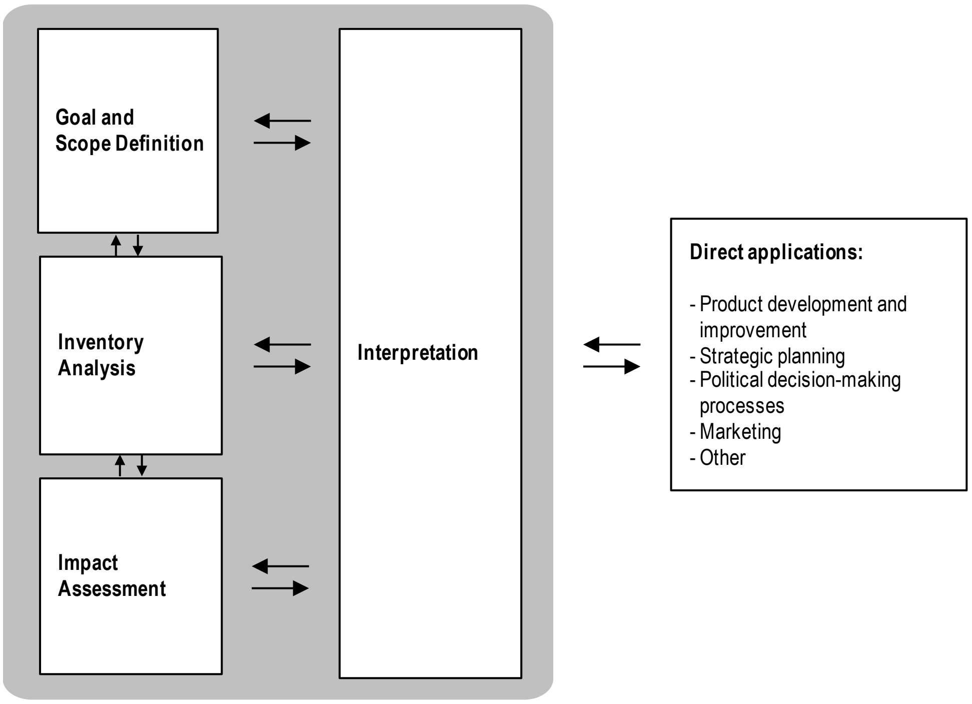
1. goal and scope definition,
2. life cycle inventory,
3. impact assessment and
4. interpretation.

In practice, these phases are often repeated several times in order to refine the results. New knowledge acquired since the last round is integrated in each new round.

The definition of the goal and scope in phase 1) particularly affects the results since the assumptions made, the constraints imposed and the boundary of the system studied (→ system boundaries) are revealed in this phase. When examining several alternatives, the results are compared on a standard basis. The standard of comparison is the → functional unit. For example, when comparing the environmental impact of passenger cars, the environmental impact per kilometre and transported person can be selected as the functional unit. If various alternatives to hand dryers are being compared, the functional unit could be called “1000 dried pairs of hands”.

Phases 2) and 3) are described above (→ calculation). In phase 4), the results are interpreted and the previous phases are subjectted to a critical review: is the study complete and consistent? An uncertainty analysis indicates the margin of uncertainty with regard to the results. The → sensitivity analysis shows how stable the results are, when individual parameters (e.g. the average speed of the passenger cars or the electricity mix of the hand dryers) are changed. Finally, a study identifies the key contributions to the entire environmental impact of a product (relevance analysis), evaluates alternative products or processes, where applicable, and recommends actions that should be taken.

Fig. 1 **> Life Cycle Assessment Framework**



2.1.3 What are the characteristics of a proper life cycle assessment?

Quality

Basically, a life cycle accessment should be comprehensive, transparent, traceable, fair and therefore reliable.

Assumptions and approaches must be disclosed and fit within the scope of the study. The ISO 14040 series of standards (International Organization for Standardization (ISO) 2006a) has a number of rules on this subject. The important points are that the → functional unit on which the study is based is objectively and convincingly defined, suitable data and assessment methods (→ assessment) are used, a (self-)critical review of the key assumptions is conducted, and the results do not have a greater influence over the interpretation than permitted by the data quality. Special attention must be given to these elements of life cycle assessments, as their results affect considerable financial interests. Therefore, it is important that the individuals who are entrusted to carry out the study have enough experience to be able to identify the relevant elements.

A key quality assurance tool is the → critical review described in this standard. There are three types of critical reviews:

> internal review by experts who are not involved in the study but work in the office entrusted to carry it out,
> external review by experts who are not associated with the office carrying out the study,
> panel review carried out by a group of at least three experts, which may include individuals from interested circles and life cycle assessment experts.

According to ISO 14040, the critical review report must be published together with the findings of the study. The type of critical review that should be used not only depends on the requirements of ISO standards 14040 and 14044, but also (in the event that ISO compliance can be dispensed with) on the scope and significance of the life cycle assessment study. In order to ensure objective results, it helps to ask the following question: “Would the same result have occurred if the study had been carried out for the client’s competitor?”

2.1.4 What does ISO 14040 mean?

ISO standards

ISO 14040 is the name of the international standard for life cycle assessments.

The life cycle assessment procedure with the abovementioned four phases (→ Development) is set out in an international standard. ISO 14040 (International Organization for Standardization (ISO) 2006a) describes the principles and general framework, while ISO 14044 (International Organization for Standardization (ISO) 2006b) defines the requirements and provides practical instructions on the steps in the process. The principles are particularly important to determining the extremely critical tasks, which are setting the → system boundaries, defining the → functional unit, carrying out the → allocations and assessing impacts.

One highly discussed item in the standard is that it actually permits the use of fully aggregated assessment methods in internal life cycle assessment studies and for operational purposes, but not in studies that compare products on the market. This implies that → fully aggregated assessment methods always result in a lack of transparency and have a peculiar consequence: if this provision of the standard was strictly observed, then decisions could be made based on fully aggregated methods, such as decisions of some importance about exempting fuels made from renewable raw materials from the mineral oil tax. However, the points generated by the eco-points method that are used to justify the decision may not be published, even though they are suitable for publication because they are easy to understand.

In the opinion of various life cycle assessment experts, this provision of the standard does not give full consideration to the latest developments in assessment methods and does not comply with the principle of public access. The FOEN believes that the use of fully aggregated methods does not make it any easier to come to a decision. Yet, ISO standards 14040/44 have definitely contributed to the fact that life cycle assessments are carried out in systematic, reproducible processes.

2.1.5 What do life cycle assessments deliver?

Significance

Life cycle assessments provide bases for making environmentally-relevant decisions about alternatives.

Alternatives are compared and assessed on a uniform basis. Alternative products and processes, before and after situations in companies and entire economies can be studied. The ecological relevance of operational areas and the related improvement potential can be demonstrated.

Since they emerged in the mid-1980s, life cycle assessments have been able to refute many preconceptions. For instance, plastics used to have, and still do to some degree, a bad reputation because they are produced from petroleum. However, life cycle assessments succeeded in demonstrating that plastics can be more beneficial in suitably optimised packaging than competing renewable materials such as paper and paperboard, which seem more environmentally-friendly at first glance, and even glass. This is due to their lighter weight and the fact that fossil energy sources are also required to produce alternative materials. When fuels made from renewable raw materials arrived, life cycle assessments managed to prove yet again that "natural" does not automatically mean environmentally-friendly. In this case, energy-intensive production processes and environmentally harmful intense cultivation of agricultural raw materials are not beneficial.

2.1.6 What don't life cycle assessments of products and companies deliver?

Boundaries

Economic, social and legal aspects, as well as risks, are not covered by life cycle assessments.

More specifically, life cycle assessments do not give consideration to whether construction projects comply with environmental leglisation; these issues are assessed as part of environmental impact assessments. Environmental risks are also not studied (→ Risk). Furthermore, it should be noted that life cycle assessments answer only the questions raised in the goal definition phase and are not meant to be interpreted beyond that scope (→ Questions).

The scope of the study can be somewhat limited by the availability of data on processes and semi-finished goods. Even though life cycle assessment data bases are continuously updated, there are not enough good publically accessible data in all fields, such as in the rapidly evolving field of electronics.

A life cycle assessment is not "true" or "false". Rather, it is as good as the assumptions made in it and the data and methods used for the questions and subject of the study. The required decisions, limitations and assessments are always based on selected values. And every assessment method has blind spots. Therefore, every life cycle assessment essentially merits discussion. Some of the methods used to avoid flawed interpretations, random results and manipulation include transparency, standard quality requirements (→ true and fair view) and competent, experienced study authors.

2.1.7 Do life cycle assessments also assess risks?

Risk

No, life cycle assessments are not risk analyses.

When examining processes, life cycle assessments consider the normal course of operations. They take into account regularly occurring events, but generally not unusual events with low probability and major effects (e.g. accidents) for methodological reasons. For example, it is normal for some methane to be leaked in the normal course of gas pipeline operations. Life cycle assessments consider the impact of these emissions on the climate. However, they do not consider the related risk of explosion since these types of accidents fortunately occur only very rarely. A comprehensive assessment of the risks can be performed in a separate risk analysis.

2.1.8 When can I trust a life cycle assessment?

Reliability

When it is comprehensive, transparent and reproducible.

A reliable life cycle assessment meets a full range of quality criteria (→ Quality). The → ISO standard requirements are useful guides. The independence and experience of the entrusted life cycle assessment experts are also decisive factors. In order to keep their good reputation, they must maintain their position in all circumstances and even despite the interests of their → clients. This also applies to the → critical review: the more independent and experienced the experts involved are, the more reliable the study is.

In principle, a serious study is reproducible and transparent. In order to comply with a → true and fair view, the assessment of the subject of study must be comprehensive. The impact assessment should clearly reveal the full range of environmental impacts that can be expected.

2.1.9 How can different environmental pressures be compared?

Basis of comparison

Comparisons are made on the basis of scientific knowledge and require a measure of value.

Reducing different environmental pressures such as air pollution and water consumption to their common denominator is one of the main methodological challenges of life cycle assessments. This is achieved in two steps. The first step, which is known as characterization, concerns the relative environmental pressure within a specific group of substances. In the endocrine disruptor category, for example, the extent of the potential influence of hormones in specific substances is determined according to scientific knowledge. In this case, the common denominator is known as “oestrogen potential”. Similar comparative assessments exist for greenhouse gases, energy resources, plant protection products, acidifying substances, radioactive emissions, etc. (→ Calculation).

In the second step, the various substance categories are weighted in relation to each other, such as how the oestrogen potential is generally weighted in relation to the greenhouse gas potential. Damage-oriented approaches such as ReCiPe 2008 or Eco-indicator 99 develop damage categories (known as natural capital), particularly human health, ecosystem quality and resource consumption. To build a model of their influence on human health, the impacts of emissions such as radiation or air pollution are converted into a shorter life expectancy. Ecosystem quality is measured by the potential decline in species diversity triggered by acidification or plant protection products. Resource consumption can be measured in megajoules in terms of the additional energy used for the future extraction of low concentrations of ore. When weighting damage categories in relation to each other, damages to natural capital and their potential reversibility, for example, are taken into account. Some methods (ReCiPe, Eco-indicator) determine this weighting through surveys, but a few standard weighting sets are available. In this way, practitioners can directly integrate their values and thus influence the assessment.

The eco-points method is based on the distance to target approach and weights the environmental impacts of pollutant emissions and resource extractions through so-called → eco-factors. The eco-factor of a substance is derived from environmental legislation or corresponding policy goals and current pressure situations. The more current emissions or resource consumption exceed the set target, the greater the eco-factor, expressed in eco-points (EP), will be. Users of this method have no influence over the weighting factors (→ Strengths).

2.1.10 Are there good and bad questions for life cycle assessments?

A clearly defined question is a requirement for each significant life cycle assessment.

Questions

Precise questions are the only way to ensure that the subject of study is aligned with its goal and that the right data are processed. Ordinary questions must be clearly defined so that their answers make sense. To achieve this, the intention behind the questions must be retained.

These challenges can be perfectly illustrated in an example. A study should answer the following ordinary questions: should I heat with oil, gas or wood? The author of the study must determine where the heating is to be done (Switzerland, Scandinavia or Australia) and whether this is an advance or regular replacement investment. If this is an advance replacement investment, the existing heating system will be compared to other heating systems in order to determine the best time to replace it. However, when it is an advance replacement investment, only new heating systems are compared to each other.

In the life cycle assessment, the author of the study also has to consider the source of the raw materials (wood from the local or a distant region), the dryness of the wood and the efficiency of the heating systems.

In conclusion, general questions are not usually suitable for life cycle studies when they are supposed to be applied to a specific situation, and vice versa.

2.1.11 What is a functional unit?

It is the basis of comparison of a life cycle assessment.

Functional unit

The functional unit is the key parameter used by a life cycle study. It is the quantified use of the studied products or processes and serves as an essential basis of comparison. The functional unit has a considerable influence on the result of the study since all resulting analyses are based on it (see example at → System boundaries). Examples of functional units are: “transport of 1 t of goods over 1 km”, “1 kg of baked beans on the table,” “1000 litres of mineral water poured into bottles at a regional beverage facility” or “1 m² of vaccuumed carpet”.

2.1.12 What kind of influence do system boundaries have?

The selection of system boundaries has decisive influence on the results of a life cycle assessment.

System boundaries

A 100% comprehensive life cycle assessment does not exist: processes are excluded in every study. Otherwise, the analysis would have no boundaries. The goal is to identify and include the relevant aspects. The ISO standard suggests that if an input accounts for less than an amount of the total mass, the total energy demand or the total environmental impact to be determined, this input can be excluded (i.e. cut-off criterion).

System boundaries must also be temporally set. Emissions from landfills may appear only after a longer period of time. In such an example, it must be decided how such long-term impacts can be taken into account. Most of the time, there is no right or wrong decision. The boundaries of the analysis must correspond to the questions raised and the available budget.

Setting the system boundaries also determines the processes related to the subject of study that will be included in it. This can have a decisive influence on the result. In general, the boundaries should be reproducible and not exclude any essential factors. To that end, ISO standard 14044 (International Organization for Standardization (ISO) 2006b) notes that the exclusion of life cycle stages or unit processes and inputs and outputs is only allowed when this does not essentially change the general conclusions of the study. The criteria that are used to justify the exclusion must be transparent.

Greenhouse gases from renewable raw materials are a good example of just how influential the selected system boundaries can be. If the study is assessing the production of one litre of fuel from production to its sale at the pump, then this life cycle assessment study is called a cradle to gate LCA. When these system boundaries are selected, preference is given to fossil fuels because their CO_2 emissions appear only after they are used. However, the environmental costs of biofuels are primarily incurred by the agricultural production of basic products. Further distortions occur when considerations such as the fact that it is usually possible to drive farther on one litre of diesel than on one litre of petrol are not taken into account.

Life cycle assessment studies must be as comprehensive as possible in order to reduce such distortions. A suitable definition of the → functional unit is just as important. In the aforementioned example, consideration should be given to one kilometre of distance travelled by car, not one litre of fuel. If the use of the product, which in this case means its use in a motor vehicle, is included in the assessment, then the study covers its life cycle from cradle to grave.

2.1.13 Is an explicit assessment method required in a life cycle assessment?

Yes, because an assessment cannot be avoided, whether intentionally or unintentionally.

Assessment

If the purpose of a life cycle assessment is to show the specific type and scope of environmental impacts caused by a product or process, then an assessment is not required. The result merely specifies the environmental impacts, such as the greenhouse gas potential, acidification potential or land use of the studied products.

But if the goal is to find out whether one product generally causes more or less pressure on the environment than another, the various environmental impacts need to be assessed. Otherwise, the answer merely provides information such as rapeseed-based diesel, or some other fuel, requires more land and emits more nitrate in groundwater, while oil and diesel, for example, cause more CO_2 emissions and pollution in the oceans because they are transported by ship. These statements are not actually meant to help make a decision. An assessment is only necessary when you simply want to know how much the individual environmental impacts contribute to the overall environmental impact.

When the data of a life cycle inventory are assessed, the various environmental impacts are compared to each other according to specific criteria and totalled based on this measured variable. The result expresses the environmental pressure in one single figure. This makes it very easy to decide which alternative puts less pressure on the environment and how significant the differences are. It also reveals the areas under particularly high pressure in relation to statutory environmental targets (→ Strengths).

If a life cycle assessment is used to make decisions without a pre-defined assessment method, the results are still indirectly assessed. There are basically three ways of doing this. Often, only one environmental impact is considered: mostly greenhouse gas emissions. In this type of process, all other impacts are considered equal to zero and therefore excluded. Other cases are evaluated on the basis of the method used within the particular study. When this is done, it is often difficult to determine the information and interests involved in the assessment and the extent of their involvement. Otherwise, the assessment is performed without a methodological framework within the study and mainly takes the form of a text. In such a case, third parties generally have a hard time understanding the basis on which the statements are made.

Regardless of the selected approach, each application-oriented interpretation of results is based on a value judgement. Given the necessity of assessments, the FOEN recommends that comprehensive and explicit assessment methods should be given priority. Current approaches may not be perfect, but they are discussed in scientific circles, user-friendly and generally transparent (→ Weaknesses).

2.1.14 Why should different assessment methods be used?

Assessment methods

Because no method can fully and consistently cover all ecological aspects.

When several assessment methods are used, the direction of the results can be checked for consistency. If the results are inconsistent, the differences must be discussed and the various points of view justified in the interpretation.

Contradictory trends in the results of different assessment methods reveal blind spots and provide experts with additional information they can use to interpret the results. For example, the Eco-indicator 99 method and its more advanced version ReCiPe 2008 weight climate change (greenhouse gas potential) heavily, but they do not take radioactive waste and water consumption into account in the general assessment. Therefore, a comparison of electricity from different power plants using atomic, fossil and renewable sources would not comply with with the → true and fair view principle if it only used Eco-indicator 99 or ReCiPe 2008 for the assessment.

2.1.15 What does allocation mean?

Allocation

Allocation defines, for example, the portion of the environmental impacts of grain cultivation that can be attributed to the product of wheat or straw.

The processes studied in life cycle assessments, and in some circumstances products and processes that fall outside the boundaries of the study, may have multiple uses. Allocation refers to the assignment of expenditures and emissions to the individual uses of a process. Cattle breeding, for example, may be used to produce milk and meat. If the environmental pressure caused by cheese is being studied, the allocation procedure must be performed to determine the portion of the environmental pressure caused by cattle breeding for milk and for meat production. The allocation procedure is performed differently depending on the breeding system, i.e. pure meat breeds or dairy cattle breeds, and the production goals (more meat or more milk).

Allocation is also necessary when it comes to recycling resources, such as in the production of paper from waste paper. The expenditures and emissions of initial production (production of paper from fresh pulp) and the expenditures and emissions of recycling (collection and cleansing of waste paper and production of recycled paper) must be divided up between new paper and recycled paper. The author of the study can use the allocation procedure to determine the portion of the expenditures and emissions that belong to the new materials and the portion that belong to the recycled materials.

The selected allocation factors often have a great deal of influence over the results of life cycle assessments. In fact, ISO standard 14044 makes recommendations on how to conduct allocation procedures (International Organization for Standardization (ISO) 2006b). Most of the time, there is no “right” or “wrong” when performing allocation procedures. Specific values often need to be set to ensure that allocation procedures are performed consistently. The most important thing is for the allocation procedures to be appropriate to the questions justifying the life cycle assessment and sensibly selected. An important issue is whether the allocation carried out is neutral or not for all studied alternatives. This is why a key step in the → critical review is to make sure that good quality allocation procedures have been performed.

2.1.16 What does fully aggregated mean?

Fully aggregated approach

Various partial statements are reduced to their common denominator so that they can be fully and meaningfully aggregated.

The term “fully aggregated” refers to the result of the impact assessment (→ Calculation). If various environmental impacts such as the greenhouse effect, acidification or hormonal impacts are separately accounted for in this phase, then the result is still not fully aggregated. These are called midpoints. Provided the trends of all results point in the same direction, it is easy to determine the alternatives that are less harmful to the environment. However, when there are contradictory trends among the various alternatives, the question must be asked how the individual impacts should be weighted in relation to each other: is a certain contribution to climate change or acidification now worse for the environment?

In this situation, the benefits of a fully aggregated approach become clear. A quantity of points is generated for each considered effect on the environment and then added up to a total. The result is a single, fully aggregated number that expresses the overall pressure on the environment. Fully aggregated methods of impact assessment are easier to understand for less experienced users. Furthermore, this approach excludes a random assessment by the authors of the study, clients and observers. The FOEN disagrees with the common criticism that fully aggregated results are not transparent. The opposite is in fact true: aggregated results can be easily retraced. Eco-indicator 99, ReCiPe 2008 and the eco-points method are conventional fully aggregated assessment methods (→ Strengths).

2.1.17 What is a sensitivity analysis?

Sensitivity analysis

It shows how heavily various assumptions or uncertainties affect the results of a life cycle assessment.

Sensitivity analyses are carried out as part of a sensitivity test in the interpretation phase. Sensitivity analyses examine how changes in the principles and framework affect the results. Furthermore, the study results are compared with results that have been achieved using modified assumptions, methods or data. Sensitivity can be indicated as the percentage of change or absolute deviation from the original results.

A sensitivity analysis should show how heavily results and conclusions of life cycle studies are influenced by uncertainties and assumptions. A sensitivity analysis can result in certain factors or processes being excluded from the study if they prove to be insignificant to the study result. Conversely, it may reveal that additional factors need to be considered. Sensitivity analyses are especially important in situations of uncertain data, heavily varying data or extremely different modelling approaches. This is the case, for example, when the technological development of the subject of study or the production process is still in flux, a wide range of assumptions seem plausible (e.g. concerning the service life of a device) or recycling can be modelled in different ways (→ Allocation).

2.1.18 Why is a critical review of the results necessary?

Critical review

The critical review ensures that the assumptions made and the questions raised during the study are appropriate.

In every life cycle assessment, assumptions are made and parameters are set based on values. For example, the definition of the → functional unit, the → allocations and the selection of the assessment methods are all part of this process. Basically, transparency and comprehensibility are essential. The critical review affords some quality assurance because the experts who perform it are otherwise not involved in the study. In practice, just knowing that an external critical review is imminent often causes those involved in the life cycle assessment to produce more thorough and qualitatively better work since no one wants to risk receiving a poor assessment from their fellow colleagues. The comprehensive and transparent publication of all models, assumptions and calculations has a similar effect on quality.

The critical review should ensure that a study assumptions and settings were not intentionally or unintentionally influenced by its authors or clients in an objective, unpersuasive manner. Furthermore, the review checks whether the study's conclusions are consistent with its assumptions and boundaries. These are the decisive steps for the → quality and objectivity of the study.

2.1.19 What kind of influence does the client have over the result?

Client

The client can greatly influence the result of the study, especially since it defines the goal of the study.

The client sets the goal of the life cycle assessment, and the life cycle assessment expert works with the client to define the scope of the study. Together, they select the → functional unit, the → system boundaries and the → assessment methods. By participating in the definition of these factors, the client has considerable influence over the results. This means that clients need to be aware of their accountability. It also means that individuals not involved in the study should question the potential interests of the clients when considering life cycle assessments.

The funding made available for life cycle assessment studies also has some influence over their quality. The scope of the study, the level of detail in the data collected, the type of → critical review and the type and number of assessment methods used in the study are directly affected.

2.1.20 What does a true and fair view mean?

True and fair view

This phrase means that the presentation of the results should be comprehensive and relevant to decision-making.

The concept of a true and fair view comes from financial reporting and refers to a faithful representation of the actual situation based on a true and fair analysis. Based on this formula, the FOEN has defined quality criteria for environmental information (Schwegler et al. 2011). Eight quality requirements should be used as guidelines by clients and practitioners of life cycle assessments. The authors of these quality requirements view the first two requirements discussed below as the key requirements. They view the other requirements as conditions for the first two.

1. Relevance for decisions. Reporting should provide all of the information that is relevant for the decisions to be influenced. Misleading, unreliable and incomplete information is generally excluded (Schwegler et al. 2011, p. 42).
2. Focus on the overall picture. All relevant environmental impacts along the whole life cycle should be considered, and if possible, at the place they occurred. The total picture carries more weight than compliance with specific rules or procedural requirements (Schwegler et al. 2011).
3. Reliability
4. Transparency
5. Comprehensibility
6. Coherence and comparability
7. Accessibility of information
8. Up-to-date information

2.1.21 In which areas are life cycle assessments becoming increasingly important?

Areas of focus

Life cycle assessments are being used in more and more spheres of life and decision-making processes.

The Swiss public generally pays a great deal of attention to environmental issues. The requests for information received by the FOEN, environmental and consumer organisations reflect consumer interest in more detailed product information, especially as concerns food at the moment. The ecological comparisons made by life cycle assessments play an important informative role and are held in high esteem.

Life cycle assessments are used by companies and administrations because environmental aspects are considered highly relevant in many decisions. Examples of typical questions that administrations have answered using life cycle assessments studies include: is collecting organic and regular waste separately better for the environment? What is the most environmentally-friendly type of tableware for large events? What type of paper is the least harmful to the environment? Companies use life cycle assessments to answer the following questions: which production site could reduce its environmental impacts the most with a specific amount of money? Which product characteristics should be developed to definitively improve its environmental impact? Would using plastic products made from renewable raw materials instead of fossil-based raw materials be better for the environment? Which supplier offers the most environmentally-friendly alternative of a product?

The life cycle assessment has become so established as a tool that it is also used for standards and requirements. Building labels such as Minergie-Eco require product declarations based on life cycle assessments. And since 2008, life cycle assessments have been used in the decision-making process for Swiss tax legislation: fuels made from renewable raw materials enjoy certain tax exemptions, but only if they provide evidence of their “positive aggregate environmental impact” (MinöStV 2008).

Efforts are even being made abroad to use life cycle assessments more extensively. In the United States, the Sustainability Consortium is developing a data base for retailers. Its goal is to develop an assessment system that is easy to understand for consumers and informs them about the sustainability of products. France’s environmental law (Loi Grenelle 2) primarily requires environmental labels for buildings. This decision was based on life cycle assessments that took the entire life cycle of buildings into account.

In Europe and around the world, environmental product declarations (EDP) are gaining ground, especially in the construction sector. Europe’s standards committee, CEN 350, is working on a group of standards to govern the quantification of the economic, social and environmental impacts of construction. When it comes to life cycle assessments of building products, standard SN EN 15804 is of particular interest (European Committee for Standardization (CEN) 2012).

2.1.22 What is eco-efficiency?

Attention: eco-efficiency is a term that refers to various concepts.

Eco-efficiency

There are different approaches to eco-efficiency: ecological and economical efficiency, on the one hand, and eco-efficiency based on the use of a good, on the other. One example of rising eco-efficiency in the second case is when a better device with the same output is used, such as an LED lamp instead of a light bulb.

Ecological economic efficiency compares the economic costs and benefits of an optional course of action in relation to its impact on the environment. This type of assessment rounds out the purely environmental perspective of the life cycle assessment by adding an economic perspective in the interpretation phase (→ Development) in an effort to demonstrate the best options from both an economic and an ecological perspective.

Different approaches and methods of presentation are selected based on the subject of study and the questions it raises. The portfolio matrix is often used. In this matrix, the costs of the studied alternatives are plotted downward from left to right along the x axis. The environmental impacts are plotted downward along the Y axis. The field is divided into four sections. The lower left hand section shows the worst alternative. The upper right hand section is where the most eco-efficient, or optimal, alternative is located. In this case, maximum eco-efficiency means the lowest possible environmental impacts that can be achieved at the lowest possible cost.

Fig. 2 > Portfolio matrix of ecological and economical efficiency

Costs

Environmental impacts		high	low
	low		Optimal (good eco-efficiency)
	high	Poor eco-efficiency	

Another widespread practice is to express eco-efficiency as a quotient of a product's environmental impacts divided by its economic value. In this case, the goal is to reduce the quotient by either decreasing the pressure on the environment or increasing the value of the product. The calculation can be performed inversely (with the reciprocal value) in order to increase the quotient. It is important to make sure that the quotient also changes if the pressure on the environment remains constant, but the value of the product increases. For example, a flight from Zurich to Brussels that costs CHF 800 has a better quotient than if the same flight cost only CHF 50. However, the pressure on the environment caused by the flight is no different, provided it has the same capacity utilisation.

The definition of product value and environmental pressure is a decisive factor in the concept of eco-efficiency. An index must be selected as a measure of the environmental pressure (→ Fully aggregated approach, → Assessment). An appropriate economic quantity must be selected as a measure of the value of the product, which can be its selling or purchase price, life cycle costs, profit margin, value chain or something similar.

2.2 The ecological scarcity method (eco-points method)

2.2.1 Eco-points: a random or scientific method?

Eco-points method

This assessment method is widely supported, legitimised by legal bases and not very susceptible to being influenced by interested parties due to its system of controls.

The eco-points method has two support structures for the environmental impact assessment. The first is scientific data. Data are consulted in order to determine the current quantities of emissions and extracted resources. The modes of action and relative environmental impact of substances in the same category (→ Eco-factor) are also evaluated based on scientific methods and/or assessments of specialised bodies. For example, the climate impact of gases is assessed on the basis of the Intergovernmental Panel on Climate Change (IPCC).

In addition, national or international regulations and limit values are used to define the tolerance quantities. These can include intergovernmental agreements or targets set by national political bodies. In the example of climate gases, the Kyoto Protocol, the CO_2 Act and the "Sustainable Development Strategy" of the Swiss Federal Council are used to derive the Swiss eco-factors.

The quality of the eco-points method is ensured by a system that is similar to the principle of separation of powers. To avoid a random approach, the tasks are divided up between different actors:

- The sciences (physics, chemistry, biology, medicine) provide fundamental knowledge, such as on the toxicity of substances, the greenhouse effect of emitted gases or the risk to health caused by noise.
- Lawmakers, followed by the competent (environmental) offices, develop environmental quality targets from this knowledge and lay the foundations for the assessment criteria.
- The authors of life cycle analyses (industrial and commercial companies, research institutes) then adopt the assessment criteria usually without changing them.

The eco-points method is set apart from other fully aggregated assessment methods by its widespread support and legally legitimised statements. The eco-points method is used in life cycle assessments intended for the public because it is not very susceptible to the influence of interested parties.

2.2.2 Does the eco-points method use scientific or political weighting?

Science

The eco-points method is supported by both scientific and legal evaluations in its assessment of environmental impacts.

The eco-points method assesses the emissions or uses of relevant substances on the basis of statutory requirements. The maximum sustainable emission or resource extraction is determined by specialists in the particular region based on scientific knowledge of environmental impacts, set out by parliament in laws or specified by the government in the form of environmental targets. The scientific aspect of the eco-points method is questioned because its assessment is subject to political decisions.

This criticism cannot be dismissed. However, the following should be taken into consideration:

- In essence, assessing environmental pressure is not a strictly scientific proposition. For example, it is possible to make the scientific claim that phosphate causes algae to grow, oxygen to become scarcer and fish to die. But over thousands of years, this process would create new mires. The fact that this is an unwanted process is not the result of a scientific, but rather an (environmental) policy evaluation. All assessments of the varying environmental impacts have an evaluative component. The eco-points method selects a reference framework for this: national targets set out in environmental legislation.

- In democratically governed countries, environmental targets are a result of the opinion forming process, in which all relevant actors can participate. For that reason, the targets enjoy broad legitimacy.
- The development of the scientific basis is widely supported since there are experts at work in every specialised division of authoritative bodies who are familiar with the entire scientific discussion.
- A conclusive → assessment cannot be avoided in a life cycle assessment since conflicts over the targets are mostly to be expected when life cycle assessments are compared. This begs the question of what would be the alternative to assessments based on legislation. In damage-oriented approaches such as Eco-indicator 99 or ReCiPe 2008, a panel of experts discusses the relative significance of the harm to human health, the quality of ecosystems and resources. Compared to a specialised body, the way the eco-points method applies the weighting basis is more representative. Furthermore, it is much more relevant: the national guidelines are decisive for companies, which is why they try to base their decisions on the national environmental legislation (legal compliance).

2.2.3 The eco-points method is useful in Switzerland. Why?

Switzerland

Because it is based on the state of the environment in Switzerland and measured according to democratically-legitimised environmental goals.

In studies that concern Switzerland, an assessment should be carried out using the eco-points method. The most important reason for this is that the Swiss version of the eco-points method is based on the environmental quality targets and limit values enshrined in Swiss legislation. In the FOEN's view, this makes it a reference method for studies that concern Switzerland. However, the method has also been adapted for several other countries (→ International).

The Swiss design reflects Switzerland's environmental goals and assesses the following wide range of emissions and resource extractions:

- water resources (freshwater, according to regional scarcity)
- energy resources (renewable and non-renewable)
- primary mineral resources (extraction of metal ores, gravel, gypsum etc.)
- land use (loss of biodiversity, differentiated by biomes)
- greenhouse gases (e.g. CO_2, methane, N_2O, SF_6)
- ozone-depleting substances (e.g. CFC, halons)
- the most important air pollutants and particles
- carcinogenic substances in the air and water
- heavy metals in the air, water and soil
- water pollutants (including endocrine disruptors)
- plant protection products
- radioactive emissions to the air and water
- radioactive and non-radioactive waste
- noise (traffic noise)

2.2.4 Can the eco-points method be applied in other countries?

Yes, this method is universal, even though the assessment criteria must be adapted.

International

The eco-points method is based on a basic principle and assessment criteria. While the basic principle of the ecological scarcity method is universal, the assessment criteria are based on the nationally binding goals of environmental policy. For that reason, the eco-points method can be applied around the world. The requirements are the environmental targets set out in the legislation of the concerned country or region and knowledge of the actual state of emissions and resource consumption. Accordingly, eco-factors can be derived for each country, just like the eco-factors used for Switzerland that are described in this publication. Countries such as Belgium, Sweden, Norway, the Netherlands, Jordan and Japan have their own version of the eco-points method, which was developed based on their specific national environmental legislation.

Because it can be adapted for different countries and regions, specific statements are possible. For example, particulate matter emissions in countries with an exceeded limit value are weighted higher than in countries where this is not the case. However, it should be noted that the eco-factors of different regions cannot be directly offset against each other, but rather converted for direct comparisons like “eco-currencies”.

2.2.5 Are domestic conditions a reasonable gauge of environmental pollution abroad?

Basically, yes, if environmental dumping is to be avoided.

Abroad

In principle, the eco-points method assesses the pressures on the environment abroad as if they were caused domestically. This results in a somewhat stricter weighting than when regionally or nationally-adapted metrics are used. However, this also prevents the environmental pressures that occur abroad due to domestic demand from being downplayed and the export of pollution from being rewarded as a result. The values of the eco-points method are based on the following principle: “Do unto others as you would have others do unto you”.

However, there are cases in which ecosystems abroad are more greatly affected by the extraction of resources or emissions than by the same activity carried out domestically. Examples are water consumption in arid regions or intensive agricultural use of soil in areas that were once very rich in biodiviersity. For this reason, weighting should ideally be regionalised in cases where local ecological scarcity is greater abroad than domestically. Differentiated → eco-factors already exist for the given examples. In this way, products and processes can be assessed with a regional weighting (current regional quantities and regional tolerance quantities) and normalization based on domestic conditions. For example, given the scarcity of water in Morocco, the current eco-factor weights one litre of water used in Morocco to grow tomatoes exported to Switzerland as if more than 1000 litres of water were used in Switzerland. Accordingly, it is possible to weight the regional resource or emission scarcity situation so that it can be compared to the weighting of the same resource or emission based on Switzerland’s scarcity situation. In the example of Moroccan tomatoes, this approach can be used to add up the eco-points of agricultural production in North Africa and food production in Switzerland.

2.2.6 What are the strengths of the eco-points method?

Strengths

The eco-points method is comprehensive, transparent, easy to understand and user-friendly.

The strengths of the eco-points method can be summarised as follows:

> It is comprehensive in its coverage of environmental impacts. Because the eco-points method integrates a wide range of relevant environmental pressures, it conveys a total picture that closely reflects the actual conditions. Despite its broad approach, it provides a clear result when it is applied. This definitely offers added value (→ True and fair view).
> It makes clear statements. The results are easy to understand and interpret (→ Fully aggregated approach) for both inexperienced practitioners and the general public.
> It offers a transparent assessment. The eco-points method is a reproducible metric. The derivations can be checked and all documentation is accessible to the public (see this publicaion). Thus, manipulating the results is virtually impossible.
> It is useful in decision-making. When the assessment results are developed on the basis of the targets set out in environmental legislation as they are in the eco-points method, it is easier to include environmental arguments in the decisions of companies, authorities and individuals. Decision-makers can be certain that they comply with the relevant national environmental legislation when they use the eco-points method (legal compliance).
> It is completely legitimised. The eco-points method is explicitly based on environmental quality targets that are set out in legislation and thus generally democratically supported. Ecological sustainability is evaluated by authorised experts and not by the actors involved. As a result, the assessment is independent of the individual interests of method developers or practitioners (separation of powers). The legislative targets not only take into account the protection of the environment and human health, but also technical and financial feasibility and social acceptance. The data and models used enjoy widespread scientific support (→ Eco-points method).
> It provides specific information. The eco-points method can achieve results that are specific to the environmental situation in the concerned country (→ Switzerland, → International).
> It is practical in application. This is especially the case when life cycle assessment software and life cycle inventories that link emissions with eco-factors are used. The method is very easy for practitioners and thus cost-effective as well.
> It is easy to update. The principles behind the eco-points method are independent from the assessment criteria and generally remain constant. Current emissions and consumption quantities, as well as any adaptations in the characterization process, can simply be inserted in the eco-factor formula (→ Eco-factor). Emissions can easily be inserted into the existing system when they are being reassessed (→ Adaptation).

2.2.7 What are the weaknesses of the eco-points method?

Weaknesses

The eco-points method must be adapted to the specifics of countries, and based on their differentiated legal requirements.

One of the problems of the eco-points method is dealing with environmental pressures abroad. In cases where emissions and resource extractions are not always similarly relevant from region to region (such as freshwater consumption, land use or SO_2 emissions), they cannot always be effectively represented. One solution is regionalised weighting, which is applied in the current version for freshwater consumption and biodiversity loss. Other eco-factors are still not sufficiently regionalised, such as acidifying emissions outside Switzerland (→ Abroad).

While the eco-points method can essentially be used anywhere in the world, the assessment criteria must be adapted to the environmental targets set out in the legislation of a country or a larger region. In addition, the legal requirements must be differentiated. If the requirements have gaps, this can lead to an incomplete set of national eco-factors (→ International).

Because the eco-points method is based on limit values, it does not directly illustrate the damage potential, in contrast to other methods. Indeed, scientifically established harmfulness plays a role in setting limit values, but so do political factors. Because legal requirements are necessary, they can in some circumstances delay the assessment of new or increasingly occuring substances, as is currently the case of the wideranging effects of nanoparticles. This delay is accepted in favour of widely supported legitimacy. Emissions and resource extractions that are not subject to targets set out in legislation are therefore not generally taken into account. The political system is – like the sciences and all other social systems – imperfect, and the environmental targets stated by the political system can be influenced by different interests and even contradictory in both democracies and dictatorships.

2.2.8 What is an eco-factor?

Eco-factor

An eco-factor measures the pressure on the environment based on the difference between the current situation and the targets set out in legislation.

The eco-points method uses eco-factors to weight environmental impacts – emissions of pollutants and noise as well as resource extractions – and expresses them in eco-points (UBP). Examples: the emission of one kilogram of CO_2 produces 460 UBP, while the emission of one kilogram of phosphate in water produces 890 000 UBP. Each emission and consumption quantity determined in the life cycle inventory is multiplied by its eco-factor and the resulting points are totalled (→ Calculation).

An eco-factor is essentially derived from three elements: characterization, normalization and weighting.

Characterization quantifies the relative harmfulness of an emission or resource extraction vis-à-vis a similar substance. This occurs within a specific pollutant category, such as greenhouse gases, plant protection products, primary energy consumption or radioactive isotopes. The numbers used in relation to the conditions are based on scientific knowledge. According to information from the IPCC, the radiative forcing of methane (CH_4), for example, is 25 times higher than that of carbon dioxide (CO_2), while sulphur hexa fluoride (SF_6) is up to 22 800 times higher. It is common practice to express the characterized quantity in equivalents of the reference substance. In the case of greenhouse gases, these are CO_2 equivalents (CO_2 eq.). One kilogram of methane has the same effect as 25 kilograms of CO_2, which is why its eco-factor is 25 times greater.

Normalization measures the contribution of the unit of quantity to the total current pressure in a region per year. If 100 000 tonnes of a substance are released every year, then the contribution of 10 grams is small, whereas if a total of only 70 grams are released every year in Switzerland, then the same contribution of 10 grams is very large.

Weighting expresses the relationship between the current emissions or resource consumption quantities and the tolerance quantities set out in environmental legislation. The weighting factor is squared in order to strengthen the effect. As a result, it is very noticeable when tolerance quantities are greatly exceeded or the opposite.

The eco-factor formula is:

$$Eco-factor = \underbrace{K}_{\substack{Characterization\\(optional)}} \cdot \underbrace{\frac{1\cdot UBP}{F_n}}_{Normalization} \cdot \underbrace{\left(\frac{F}{F_k}\right)^2}_{Weighting} \cdot \underbrace{c}_{constant}$$

K = *Characterization factor of an emission or resource*
F_n = *Normalization quantity (technical term: normalization flow): current annual quantity (emission or consumption), with Switzerland as the system boundary*
F = *Current quantity (technical term: current flow): current annual quantity (emission or consumption) in the reference area*
F_k = *Tolerance level (technical term: critical flow): statutory limit value in the reference region*
c = *Constant (10^{12}/a): serves to obtain readily representable numerical quantities*
UBP = *Eco-point: the unit of environmental impact assessed*

Example: eco-factor for diesel soot

The tolerance level for diesel soot is derived from the Swiss Federal Ordinance on Air Pollution Control (Luftreinhalteverordnung). Following the precautionary principle, because diesel soot is a carcinogenic emission, all technologically and operationally feasible measures must be taken to reduce it to economically sustainable levels. Based on this requirement, a tolerance quantity of 208 tonnes per year was calculated. Since current emissions levels equal almost seven times this amount (1700 tonnes) and the weighting is squared, the result is a higher eco-factor of 38 000 EP per gram of diesel soot.

$$Eco-factor = \underbrace{1}_{\substack{Characteri-\\zation\\(optional)}} \cdot \underbrace{\frac{1 \cdot UBP}{1\,660\,000\,000\,g}}_{Normalization} \cdot \underbrace{\left(\frac{1\,660\,000\,000\,g}{208\,000\,000\,g}\right)^2}_{Weighting} \cdot \underbrace{10^{12}}_{constant} = 38\,000\,\frac{UBP}{g}$$

2.2.9 Is continuously adjusting the assessment criteria allowed?

Adjustment

This is not allowed within the same life cycle assessment comparison. Yet, each method must absolutely be updated over the years.

The eco-points method is subject to a thorough review every few years. Emission and consumption quantities, as well as tolerance quantities are subject to change when the targets set out in legislation change. New scientific knowledge is integrated in the assessment, approaches are refined (e.g. the → eco-factor for land use in this edition) or a new eco-factor is calculated for emissions and resources (e.g. traffic noise in this edition).

These adjustments are necessary and provide the eco-points method with an advantage: based on the → true and fair view principle, a statement is only meaningful if it is up to date. The disadvantage of updates is that they seem to limit comparability over the years and create uncertainty for planning. While time series provide information about long-term changes, earlier life cycle inventory data must be recalculated using the current assessment method. Essentially, the results of different studies can only be compared if they were developed with the eco-points method of the same year (e.g. UBP 2013). For longer-term planning, such as for a product with a long service life or a large infrastructure, it may make more sense to subject the eco-factors to a → sensitivity analysis so that potential future developments can be assessed. But this occurs only in specific cases.

2.2.10 How are substances assessed that are subject to several different targets set out in legislation?

Multiple impact assessments

Emissions and consumptions must be covered as comprehensively as possible, while avoiding double counting.

The same pollutant can cause different environmental impacts. For example, when fossil fuels are burned, nitrogen oxide (NO_x) is released. These pollutants promote the formation of ground-level ozone, contribute to over-fertilization and acidification of soil, harm plants and can cause lung diseases. Damage-oriented assessment methods add up the various impacts. The eco-points method, however, takes into account only the very strictest target set out in legislation when calculating an → eco-factor. Multiple impacts are generally factored in the process of determining environmental targets. For this reason, multiple counting, and the resulting above-proportional weighting of substances that have multiple effects, is avoided. The strictest requirements in the example of nitrogen oxide are the limit values for ground-level ozone and acidification. If these limit values are respected, then the limit values for over-fertilization are respected as well.

When carrying out a life cycle inventory, an emission is only counted once, particularly the first time a man-made substance enters the natural environment (and the opposite for resources). Substance flows within nature, even from man-made substances, are not taken into account in the life cycle inventory since they would otherwise be counted twice. The eco-points method counts this type of substance only once in the weighting – as illustrated above based on the impact that produces the highest eco-factor.

When a pollutant is listed twice among the eco-factors, this is the result of varying limit values and emission situations depending on the environmental compartment (air, water, soil). Depending on whether an emission is first released in the water, air or soil, different eco-factors are generated for different statutory emissions targets. This is especially the case of heavy metals, which, for instance, have an eco-factor for "lead in the air" and one for "lead in the ground". But double counting is also avoided in this case too.

2.2.11 Is the eco-points method transparent?

Yes. It also allows a transparent presentation of the results.

Transparency

As far as transparency is concerned, it is important to distinguish between the method itself and the presentation of results. The eco-points method is very transparent: the principles are disclosed, the methodology published and more detailed documents on many evaluated environmental topics can be viewed.

Transparency can take different forms when presenting the results. If there is only one figure for the result (e.g. one trip by car causes 200 UBP per person-kilometre), then the UBP figures of other modes of transport can easily be compared. If the environmental impacts that determine the result and the proportion of the specific processes involved are also differentiated in the presentation of the result, then the eco-points method has a high degree of transparency and comprehensibility.

2.2.12 Why isn't the eco-points method merely geared toward the harmfulness of substances?

Because the complex transformation processes and change impacts in nature make it so that not every emission directly causes damage.

Harmfulness

The eco-points method indirectly assesses the harmfulness of an emission by evaluating the extent to which national and international environmental targets are achieved. In this way, the method is supported in every evaluated area of the environment based on the the expertise of specialists who are involved in the development of the environmental requirements. This process makes it possible to consider a wide range of scientific views.

Environmental requirements generally define the harmfulness of emissions in three ways. If a substance can be attributed to damage potential through direct cause and effect relationships, then the environmental requirements are based on them. For instance, this is the case of sulphur dioxide (SO_2). Conversely, if a substance is involved in complex reaction chains, the requirements are based to the greatest extent possible on a model of this response pattern and its distribution over time. This is what occurs, for example, with nitrogen oxides (NO_x) and climate gases. Their reaction to other components of air depends on the temperature and solar radiation, among other things.

Furthermore, there are cases where a substance cannot be attributed to any direct damage potential. In this case, the precautionary principle is applied. For example, carbon can cause unpredictable destructive reactions in stored wastes, without being directly harmful itself. Therefore, carbon levels in stored wastes are limited in Switzerland. Consequently, the eco-factor for stored wastes is based on this limitation in the eco-points method.

2.2.13 Is it possible to measure impacts on biodiversity?

Biodiversity

Yes, but the process of measuring them is definitely very complicated.

When humans change the way that an area of land is used, this often triggers changes in biodiversity. For example, a total picture of the environmental impact of soy from Brazil takes into account the clearing of primary rain forest for agricultural use. In addition to CO_2 emissions from the soil and the cleared trees, the loss of biodiversity is also covered. The latter can be determined by the way the land is used. The current assessment criteria of the eco-points method integrate a scientific classification of the world that has fourteen different biodiversity zones (biomes) and a scientific classification of types of land use. Accordingly, an → eco-factor is calculated for each type of land use in each biome. This results in the fact that the agricultural use of tropical land per unit of area causes environmental pressure that is two and a half times greater than that caused by the same type of use in Switzerland.

Part 2

> Methodological fundamentals

Part 2 presents the ecological scarcity method in detail. The explanations are intended for clients, specialised users and research and applied scientists. The content is focused on the principles behind the method and the formulas used to derive the eco-factors.

3 > The ecological scarcity method

3.1 The basic principle

The ecological scarcity method is the “distance-to-target” method as defined by SETAC (Udo de Haes 1996). The method offers standardized, generic weights.

distance-to-target

Weighting is based on primarily national, but also some international environmental protection targets. These targets are

- ideally adopted in legally binding form or at least defined as targets by competent authorities,
- formulated by a democratically elected or legitimated body,
- and oriented to sustainability as much as possible.

Weighting is conducted on the basis of goals set by Swiss environmental policy. In specific cases, global, international or regional goals are used and converted to the Swiss level. The method can also be applied to other countries and regions independently of its implementation in Switzerland. To do so, information about the current environmental situation and the official environmental targets of the country concerned is required. The method described here has been used to develop eco-factors for Holland, Norway, Sweden (Nordic Council of Ministers 1995, Tab. A22/A23), Belgium (SGP 1994) and Japan (Büsser et al. 2012; Miyazaki et al. 2004).

The ecological scarcity is suitable for evaluating the environmental pressures caused by products (goods and services) and specific processes, as provided by life cycle inventory databases such as ecoinvent and others. The method is also suitable for evaluating the environmental performance of an organisation within the context of environmental management, such as for evaluating environmental aspects and their developments, in accordance with ISO 14001.

Through the manner in which the eco-factor is calculated, the ecological scarcity method permits **optimization within the framework set by environmental policy targets.**

The method converts the various environmental pressures into points so that the values can be added and compared. Thus, the eco-factors have the formal nature of a utility value analysis, whereby they can be determined from the current environmental situation (current flow), the target situation aimed at by the environmental policy (critical flow) and the calculation algorithm (see Part 2, Section 3.3).

3.2 Original formula and derivation of the applied formula representation

The ecological scarcity method was introduced by Müller-Wenk (1978) and refined for the first time by Braunschweig (1982). It was then further developed a second time in the context of the interpretation of the life cycle assessments for packaging materials published by the BUWAL, the precursor agency from which the FOEN emerged, in 1984 (Ahbe et al. 1990).

Ahbe et al. (1990) discussed various formulae that can be used to calculate eco-factors and introduced the following function, in which the eco-factor (as a percentage of the critical flow) is proportionate to the ratio of the current to the critical flow. From this, the authors derived the following formula:

$$Eco-factor = \frac{1 \cdot UBP}{F_k} \cdot \frac{F}{F_k} \cdot c \qquad (1)$$

F = *Current flow: current annual pollutant load or resource extraction with Switzerland as the system boundary*
F_k = *Critical flow: critical annual pollutant load or resource extraction with Switzerland as the system boundary*
c = $10^{12}/a$
UBP = *Eco-point (the unit of the assessed result)*

In the update performed by Brand et al. (1998), the formula was retained unchanged. The following reasons prompted the mathematical reformulation and careful modernization of this formula:

- International life cycle assessment standard ISO 14044 prescribes the basic structure of an impact assessment. As set out in Section 3.3, the aim is to largely comply with its prescriptions.
- Environmental problems can vary greatly in time and place. This is the case for freshwater, for example, a resource that is very scarce in some regions in the world, but available in surplus in others. As there is no water scarcity in Switzerland, there was no eco-factor for freshwater as a resource in the first two versions of the assessment method. As a result, these aspects, which may be of environmental relevance, could not yet be taken into account in life cycle assessment studies of foods and resources from arid regions (e.g. tomatoes from southern Spain, or cotton from China). The recently updated formula permits both regional and temporal differentiation.

As the new representation is based on a mathematical reformulation, a high degree of continuity is ensured, whereby

- if the critical and current flows of a pollutant are unchanged, the same eco-factor results from the revised formula as it did with the original formula,
- the linear dependence of the eco-factor (as a percentage of the critical flow) upon the ratio of the current flow to the critical flow remains,

- the past characterization applied to pollutants that have the same type of impact (e.g. global warming potential of CO_2, methane and other greenhouse gases) remains, but it is at the same time facilitated through systematization,
- the eco-factors can be applied as they were in the past: a table listing the eco-factors is provided and used to weight the inventory analysis results.

The representation of the original equation (1) (Ahbe et al. 1990; Brand et al. 1998) was modified slightly. In mathematic terms, this changes nothing in the formula at first. The derivation from the original equation (1) of the new equation introduced with the update in 2006 for annual flows of an individual pollutant for all of Switzerland shown in (2) and (3) illustrates that the outcome of the two forms of representation is identical.

In the original formula (1), normalization was initially performed on the basis of the critical flow, while weighting was performed using the ratio of F to F_k. Equation (2) shows the form extended by the current flow F/F. Finally, the reconfiguration of the coefficients resulted in the equation (3), the starting point for the eco-factor formula (4) used since 2006, which is explained in the following section.

$$Eco-factor = \frac{1 \cdot UBP}{F_k} \cdot \frac{F}{F_k} \cdot c \qquad (1)$$

$$Eco-factor = \frac{1}{F_k} \cdot \frac{F}{F} \cdot \frac{F}{F_k} \cdot c \qquad (2)$$

$$Eco-factor = \frac{1}{F} \cdot \left(\frac{F}{F_k}\right)^2 \cdot c \qquad (3)$$

3.3 Ecological scarcity and eco-factor calculation

The formula

The ecological scarcity method weights environmental pressures, i.e. pollutant emissions and resource extractions, with “eco-factors”. The eco-factor is derived from environmental legislation or corresponding political targets. In its basic form, it can be composed of the following 3 elements in accordance with ISO Standard 14044

- characterisation,
- normalization and
- weighting

(International Organization for Standardization (ISO) 2006b). The starting point for the revised eco-factor formula is equation (3) as set out above.

For every environmental pressure, the eco-factor is defined as follows:

$$Eco-factor = \underbrace{K}_{\substack{\text{Characterization}\\\text{(optional)}}} \cdot \underbrace{\frac{1\cdot \text{UBP}}{F_n}}_{\text{Normalization}} \cdot \underbrace{\left(\frac{F}{F_k}\right)^2}_{\text{Weighting}} \cdot \underbrace{c}_{\text{constant}} \qquad (4)$$

with:
K = *Characterization factor of a pollutant or a resource*
Flow = *Load of a pollutant, quantity of a resource consumed or level of a characterized environmental pressure*
F_n = *Normalization flow: Current annual flow with Switzerland as the system boundary*
F = *Current flow: Current annual flow in the reference area*
F_k = *Critical flow: Critical annual flow in the reference area*
c = *Constant* ($10^{12}/a$)
UBP = *Eco-point: the unit of the assessed result*

Characterization

Characterization factors are determined for pollutants and resources that can be allocated to a specific environmental impact (e.g. global warming potential). Here, the effect of a certain pollutant (e.g. the global warming potential of methane) is placed in relation to the impact of a reference substance (carbon dioxide in this case). Section 4.4 in Part 2 discusses the rules for applying the characterization. Characterization was already introduced in an earlier version of the ecological scarcity method (climate change, ozone depletion, acidification and primary energy).

Normalization

Normalization serves to adjust the scarcity situation (weighting) to the current emissions/resource extractions in a region. ISO 14044 and the relevant SETAC publications (e.g. Udo de Haes 1996) also propose conducting normalization on the basis of the current flows in a region.

Scarcity (weighting) is a dimensionless quantity determined exclusively by the ratio of current to critical flow, but not by the absolute values of these flows. Normalization adjusts (normalizes) the assessment to Swiss conditions. Therefore, **normalization is performed on the basis of the annual pollutant emissions** or resource extractions for all of Switzerland.

Weighting

The final weighting of pollutants, resources or characterized environmental impacts is performed on the basis of their “distance to target”, or “**ecological scarcity**”. For that purpose, the method usually uses the total present flows of an environmental pressure in Switzerland per year (current flows) and the maximum permissible flows of the same environmental pressure in Switzerland per year (critical flows) within the context of environmental policy goals. Depending on the way the specific environmental target or environmental legislation is formulated, either individual substances or (characterized) environmental impacts are considered.

The ratio of current to critical flow is squared. The effect of this is that a major exceedence of the target value (critical flow) is weighted over-proportionately, and if the current flow is substantially lower than the critical flow, it is weighted under-proportionately. This means that the higher the current pollution already is, the more strongly every additional emission is weighted.

Weighting is a dimensionless quantity determined exclusively by the **ratio of current to critical flow**. The absolute level of the flows has no influence whatsoever on the weighting. Thus, regardless of whether there is a current flow of 2000 t/a and a critical flow of 1000 t/a, or whether these flows are much lower at 6 and 3 kg/a respectively, an identical weighting factor will result. In both cases, the ratio of the flows is 2:1, and the weighting factor is 4.

The constant

Factor c is identical for all eco-factors and serves to make the factor easier to present; it delivers more practicable orders of magnitude and takes account of the temporal dimension that remains from the quantitative units.

The eco-factor

The unit in which the eco-factor is expressed is "eco-point (UBP) per unit of environmental pressure", e.g. "21 UBP per gram SO_2", or "eco-points (UBP) per unit of environmental pressure", e.g. "460 UBP per gram CO_2-equivalent".

The new representation of the formula makes it possible to determine temporally and spatially differentiated eco-factors and eco-factors for the sub-groups of specific pollutants. These eco-factors are all fully compatible with the basic scheme and the annual eco-factors for Switzerland and can be combined seamlessly. The following sections describe the differentiation options.

3.4 Regionalization of eco-factors

The breakdown of the eco-factor into characterization, normalization and weighting terms permits conversion from and to different regions. The weighting factor is calculated on the basis of the current and critical flows of a certain area. Normalization is calculated on the basis of the current flow of the region to which the eco-factor should apply, which is Switzerland in the case above (see equation (5)). Equation (5) corresponds to equation (1) if Region 1 is identical to Switzerland.

$$Eco-factor^{Region\ 1} = K \cdot \frac{1 \cdot UBP}{F_n^{CH}} \cdot \left(\frac{F^{Region\ 1}}{F_k^{Region\ 1}}\right)^2 \cdot c \qquad (5)$$

with:

K = *Characterization factor of a pollutant or a resource*

Flow = *Load of a pollutant, quantity of a resource consumed or level of a characterized environmental pressure*

F_n^{CH} = *Normalization flow: current annual flow with Switzerland as the system boundary*

$F^{Region\ 1}$ = *Current flow: current annual flow with Region 1 as the system boundary*

$F_k^{Region\ 1}$ = *Critical flow: critical annual flow with Region 1 as the system boundary*

c = *Constant* ($10^{12}/a$)

UBP = *Eco-point: the unit of the assessed result*

There are three ways in which this regionalized eco-factor calculation can be applied:

1. A weighting factor determined for a certain region can be normalized to Switzerland and thus integrated in the assessment. For example, a regional weighting factor can be calculated for freshwater consumption in Andalusia on the basis of the current and critical flows there, so that the much greater scarcity of freshwater in Andalusia compared to Switzerland can be taken into account. Normalization to the current Swiss flow results in an eco-factor that is compatible with Swiss eco-factors and represents the scarcity situation in Andalusia. Using this eco-factor, water consumption in Andalusia can now be assessed from a Swiss perspective.
2. Where environmental policy sets targets that vary greatly in terms of their spatial reference, eco-factors can be determined for smaller areas (e.g. regional or even site-specific factors) if substantially more critical situations arise that are not or insufficiently captured with an average factor for all of Switzerland. For instance, the state of Swiss lakes varies greatly. Lakes in the Central Plateau, such as the Lake of Greifensee or the Lake of Hallwil, have greater phosphorus pollution levels than, for instance, the Lake of Brienz or Lake Constance. Measures taken to reduce phosphorus loads in lakes with previously higher pollution levels lead to a greater reduction of environmental impacts.
3. In cases where Swiss environmental policy is bound legally to international objectives, weighting factors can be calculated for regions larger than Switzerland on the basis of these objectives. For example, European weighting factors are normalized to the Swiss situation. Thus, Switzerland has agreed with the North Sea states to cut nitrogen discharges to the North Sea by half (from their 1985 level).

If regionally specific eco-factors have been determined within Switzerland, then they should be used to calculate the average Swiss eco-factor. The weighted sum of the regional eco-factors is thus formed: Equation (6) shows an example with two regions:

$$Eco-factor^{CH} = Eco\text{-}factor^{Region\ 1} * r_1 + Eco - factor^{Region\ 2} * r_2 \qquad (6)$$

with:

r_1 = *Share of the current flow of Region 1 in the current flow of all of Switzerland*
r_2 = *Share of the current flow of Region 2 in the current flow of all of Switzerland*

Through the quadratic function of the weighting factor, spatial differentiation is not mathematically neutral, but gives greater weight to regions where environmental pressure is higher.

3.5 Temporal differentiation of eco-factors

In similar fashion, the new formula representation permits temporal differentiation of weighting and thus, the eco-factor. For instance, a distinction could be made for the current and critical flows of airborne pollutants in specific periods, such as the summer and winter halves of the year (cf. equation 7).

$$Eco-factor^{Period\ 1} = K \cdot \frac{1 \cdot UBP}{F_n^{Year}} \cdot \left(\frac{F^{Period\ 1}}{F_k^{Period\ 1}} \right)^2 \cdot c \qquad (7)$$

with:

K = *Characterization factor of a pollutant or a resource*

Flow = *Load of a pollutant, quantity of a resource consumed or level of a characterized environmental pressure*

F_n^{Year} = *Normalization flow: current annual flow with Switzerland as the system boundary*

$F^{Period\ 1}$ = *Current flow: current annual flow during Period 1 (e.g. in the daytime or in the summer half of the year) with Switzerland as the system boundary*

$F_k^{Period\ 1}$ = *Critical flow: critical annual flow during Period 1 (e.g. in the daytime or in the summer half of the year) with Switzerland as the system boundary*

c = *Constant* ($10^{12}/a$)

UBP = *Eco-point: the unit of the assessed result*

The resulting eco-factors can then in turn be weighted and aggregated to establish a daily or annual average. This is illustrated in an example with two periods:

$$Eco-factor^{Year} = Eco\text{-}factor^{Period\ 1} * p_1 + Eco-factor^{Period\ 2} * p_2 \qquad (8)$$

with:

p_1 = *Share of the current flow of Period 1 in the annual current flow*

p_2 = *Share of the current flow of Period 2 in the annual current flow*

The formula can be used for every kind of temporal differentiation; a breakdown into any number of periods is also conceivable, such as four periods in accordance with the four seasons of the year.

Here again, situations in which the current flow is substantially higher than the critical flow are weighted over-proportionately stronger due to the squared weighting factor. Therefore, an annual eco-factor calculated on the basis of temporally differentiated eco-factors is not the same as an eco-factor determined on the basis of annual loads.

3.6 Eco-factors for pollutant sub-groups

In certain cases, the legislators adopted an environmental target for a group of pollutants (such as PM10), but not for individual sub-groups that may be included in inventories or that users of the method may wish to examine separately for other reasons (such as PM2.5). In this situation, all sub-groups should receive the same eco-factor as the entire group since the applicable environmental law provides no grounds for differentiation.[1] However, the formation of pollutant sub-groups (PM2.5 and PM2.5–10) must not have any influence on the level of the eco-factor when the same environmental target applies to all sub-groups.

The original eco-factor formula did not permit free differentiation of pollutant groups, as every breakdown of substance flows led to appreciably higher eco-factors. The revised formula representation provides an elegant solution for such situations:

Eco-factors for parts of a pollutant group can be formed by using the flow of the entire pollutant group for normalization in the eco-factor formula; in our example, this would be the annual PM10 load for all of Switzerland.

As the PM2.5 and PM2.5–10 sub-groups are subject to the same relative reduction target, the weighting factor for PM10, PM2.5–10 and PM2.5 is identical. Therefore, the same eco-factors result for PM10, PM2.5 and PM2.5–10.

$$Eco-factor^{PM10} = K \cdot \frac{1 \cdot UBP}{F_n^{PM10}} \cdot \left(\frac{F^{PM10}}{F_k^{PM10}} \right)^2 \cdot c \qquad (9a)$$

$$Eco-factor^{PM2.5} = K \cdot \frac{1 \cdot UBP}{F_n^{PM10}} \cdot \left(\frac{F^{PM\,2.5}}{F_k^{PM\,2.5}} \right)^2 \cdot c \qquad (9b)$$

$$Eco-factor^{PM2.5\text{-}10} = K \cdot \frac{1 \cdot UBP}{F_n^{PM10}} \cdot \left(\frac{F^{PM\,2.5-10}}{F_k^{PM\,2.5-10}} \right)^2 \cdot c \qquad (9c)$$

In this way, inconsistent artefacts that previously arose when subdividing pollutant groups can now be prevented in a plausible manner.

A different procedure is applied if a different reduction target applies to individual substances within a pollutant group. These substances must be broken out of the group and analysed separately. This is the case for diesel soot emissions in the PM10 emissions group.

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[1] This applies despite the fact that PM2.5 tends to be more harmful than the entire PM10 group.

4 > Principles governing the derivation of eco-factors

4.1 Taking account of natural background levels

Anthropogenic flows

Wherever possible, only anthropogenic flows are considered for the calculation of eco-factors (e.g. nitrogen in bodies of water). Natural background pollution is outside of the system boundaries.

4.2 Aggregate parameters

Parameters that aggregate several substances (e.g. NMVOC, total nitrogen) are used if the environmental policy targets are only formulated for the aggregate parameter or if the environmental impact of the individual substances is similar. If an aggregate parameter is in widespread use in life cycle inventories, an eco-factor can be calculated for that parameter as a proxy.

Using aggregate parameters presents a risk of double counting if substances that are already contained in an aggregate parameter are also designated separately in life cycle inventory databases and are assessed twice as a result. For that reason, the assessment should be performed at the level of the individual active substances, wherever possible.

4.3 Precautionary principle

The precautionary principle is defined and handled in slightly different ways depending on the source, the country and the issue at hand. What is common to all definitions, however, is that the principle applies when there is not enough conclusive scientific evidence of cause-effect relationships, but there are indications that a threat to human or animal health or the environment is probable (BAG et al. 2003).

The article discussing the aim of the Swiss Environmental Protection Act (EPA) explicitly mentions the precautionary principle: “*Early preventive measures must be taken in order to limit pressures that* ***could*** *become harmful or a nuisance.*” The right or obligation to take precautionary action can be derived from the precautionary principle (BAG et al. 2003 p. 4f).

Even in cases where a threshold can be defined at which there is no harm, adverse effects continue to be possible for certain persons or environmental compartments. For example, individual sensitivity to exposure to ozone or other airborne pollutants varies widely. Nevertheless, pressures below the threshold of no harm or not subject to a defined threshold must be reduced only to the extent that is operationally (technically) feasible and economically viable. If the threshold of no harm is exceeded, this restriction does not apply and the mitigation action must be taken. Federal Swiss agencies other than the FOEN may use slightly different definitions (BAG et al. 2003, p. 8ff.). Their specifications, however, have little relevance to the derivation of eco-factors.

4.4 Using characterization factors

The fundamental condition determining the application of characterization factors is that the **characterization matches the legislators' intention**.

Two examples should make this clear. Volatile organic compounds (VOCs) contribute in varying degrees to creating ground level ozone. However, since legislators set the VOC levy per kg of VOC and not on the basis of ozone creation potential, no characterization is applied for VOCs.

The current CO_2 Act governs the emissions of all greenhouse gases. Consequently, characterization is appropriate for greenhouse gases.

In addition, the following applies:

a) The characterization factors used should be scientifically recognized.
b) The characterization factors can be derived from political targets.

4.5 Determination of normalization

The current flows on which the weighting is based are generally identical to the flows that are used for normalization. If, however, a characterization is performed or a regional or temporal differentiation is carried out, the current flow will differ from the normalization flow if the environmental target is not also formulated on the basis of the characterized emissions. The characterized flow comprises only those substance flows whose eco-factors are determined through the characterization. In accordance with the principle of the highest eco-factor (Part 2, Section 4.11), eco-factors must always be assessed in relation to the strictest target.

Certain rules must be observed when deriving the normalization flows:

- As a priority, the current annual loads in Switzerland should be used. This applies particularly and without exception to eco-factors that are differentiated within Switzerland (site-specific or cantonal eco-factors).
- If these are not known or if the environmental impact does not arise, European or global annual loads should be used and converted to "Swiss" loads through the ratio of the European/global population or area, or some other suitable metric, to that of Switzerland.
- If these are not known, the annual loads of a specific industrialized nation should be used and corrected by the population ratio or some other suitable metric.

In the case of pollutants and resources that are characterized, the characterized annual impacts must be used for normalization.

4.6 Determination of weighting

The representation of the formula results in an independent weighting term with a ratio of F to F_k squared. The quadratic weighting makes it possible for slight exceedences of the critical flow to receive a much smaller weighting than large exceedences: If, for instance, the current flow is 10% above the critical flow ($F = 1.1\ F_k$), this gives a weighting factor of 1.21. If the current flow is 40% above the critical flow ($F = 1.4\ F_k$), this gives a weighting factor around 2, and if the critical flow is exceeded by 100% ($F = 2\ F_k$), the weighting factor is 4.

National annual flows are generally used for weighting. Depending on the issue at hand, site-specific, cantonal, national, regional, continental or global, as well as seasonal or annual current and critical flows, can be used for certain environmental concerns. The flows are quantified either as individual substances or as environmental impacts in accordance with the environmental targets and in a suitable manner for the normalization.

The current and critical flows must therefore be expressed in the same unit. This is why the weighting term does not have any unit.

The weighting function is also quadratic when eco-factors are differentiated spatially and temporally. This differs from the proposal made by Dinkel et al. (2004), where the weighting factor is linear for regionalized eco-factors.

Current flow

Current flows should always be determined with regard to the reduction target. The system boundary used to determine the current and critical flows must be the same. In most cases, the current flow is identical to the normalization flow.

Critical flow

Critical flows are generally based on binding political targets (which in turn can be based on scientific findings). These are primarily protection targets established by law (annual loads, ambient limit values). Where no statutory provisions exist, critical flows are based on the most binding possible political statements of intent (e.g. the stated intent to limit settlement area needs per capita, which provides a basis for assessing land use).

4.7 Determination of the eco-factor

Through characterization, normalization and weighting, the eco-factors capture political and statutory evaluations of the ecological relevance of pollutants. For example, the emissions of various heavy metals to air, soil and water are assessed with specific eco-factors, which (ideally) are calculated from the specific current and critical flows. This normally leads to different eco-factors for the emission of one and the same pollutant to water, air or soil. These differences reflect the different statutory requirements and current pressures.

4.8 Temporal aspects of eco-factor determination

Stipulations enshrined in statutes, such as ambient limit values for airborne pollutants, generally do not set any explicit time horizon apart from transitional provisions. The provisions apply after they come into force. When political goals are set, in contrast, specific targets can be defined for certain points in time. As shown in its report on sustainable development in Switzerland (Schweizerischer Bundesrat 2012), the Swiss Federal Council seeks a long-term perspective, as already stipulated in the Federal Constitution (Art. 73). Moreover, the preamble to the Federal Constitution mentions the responsibility towards future generations.

In cases where there are several political targets with (very) different time horizons for the determination of an eco-factor, an appraisal of the current political situation should be used as the basis for either selecting one of the points in time or performing an interpolation to an intermediate point in time.

4.9 Time lag between current flows and future impacts

The ecological scarcity method proceeds from the present situation when determining eco-factors. But how should the pressures listed in inventories be handled if they already arose long ago or will only arise in the distant future?

Impacts listed in inventories that arose long ago can be taken into account or not, depending on the issue being analysed. In general, no special adjustment is necessary.

The situation is somewhat different for impacts triggered by current processes that will only arise in the very distant future. The long-term emissions of landfills (modelled in the ecoinvent data to 60 000 years in the future) generated by today’s wastes are such an example.

Such emissions in the distant future should not simply be assessed with an eco-factor of zero and thus neglected. However, these impacts may never arise: With sufficient engineering effort, landfills can be cleaned up at practically any time. For that reason, it is acceptable to either take only partial account of such emissions in the very distant future, or to determine a specific eco-factor for them. The ecological scarcity method is guided in principle by present political goals and the targets set out in environmental laws. A different assessment of long-term emissions is therefore conceivable in principle, as not only the goals and targets, but also the exposure situation at the point in time when the long-term emissions occur, can differ substantially from the present situation.

In any case, the way long-term emissions are handled in life cycle inventory data needs to be checked carefully. Depending on the method, a more differentiated analysis and assessment of long-term emissions may be required.

4.10 Spatial aspects

Political and statutory goals are sometimes spatially differentiated. For instance, this is the case for the limit values governing pollutants in surface waters and groundwater. In most cases, however, provisions apply uniformly across Switzerland. If a relevant distinction is made, this should be captured with corresponding eco-factors.

Differentiation is appropriate when there is a uniform limit value across Switzerland for pollutants but the pollution situation varies greatly from region to region. For airborne pollutants, the differences are usually too minute or cannot be quantified. For water pollutants, however, relevant and quantifiable differences in levels of pollution can arise (e.g. phosphorus in lakes, see Part 3, Section 10.3). In such cases, regionalized eco-factors should be applied in order to determine the eco-factor for all of Switzerland (see also Part 2, Section 3.4).

4.11 Eco-factor selection when several derivations are possible (highest eco-factor principle)

There are several ways to derive eco-factors for some pollutants. For example, specific ammonia emissions to air can be assessed on the basis of the political target for nitrogen, but also on the basis of their acidification potential. The principle governing the ecological scarcity method is that the **highest resulting eco-factor in each instance** is used. Weighting is then performed on the basis of the dominant assessable environmental impacts.

5 > Principles governing the application of eco-factors

5.1 Selection of substances

Ecological and political relevance

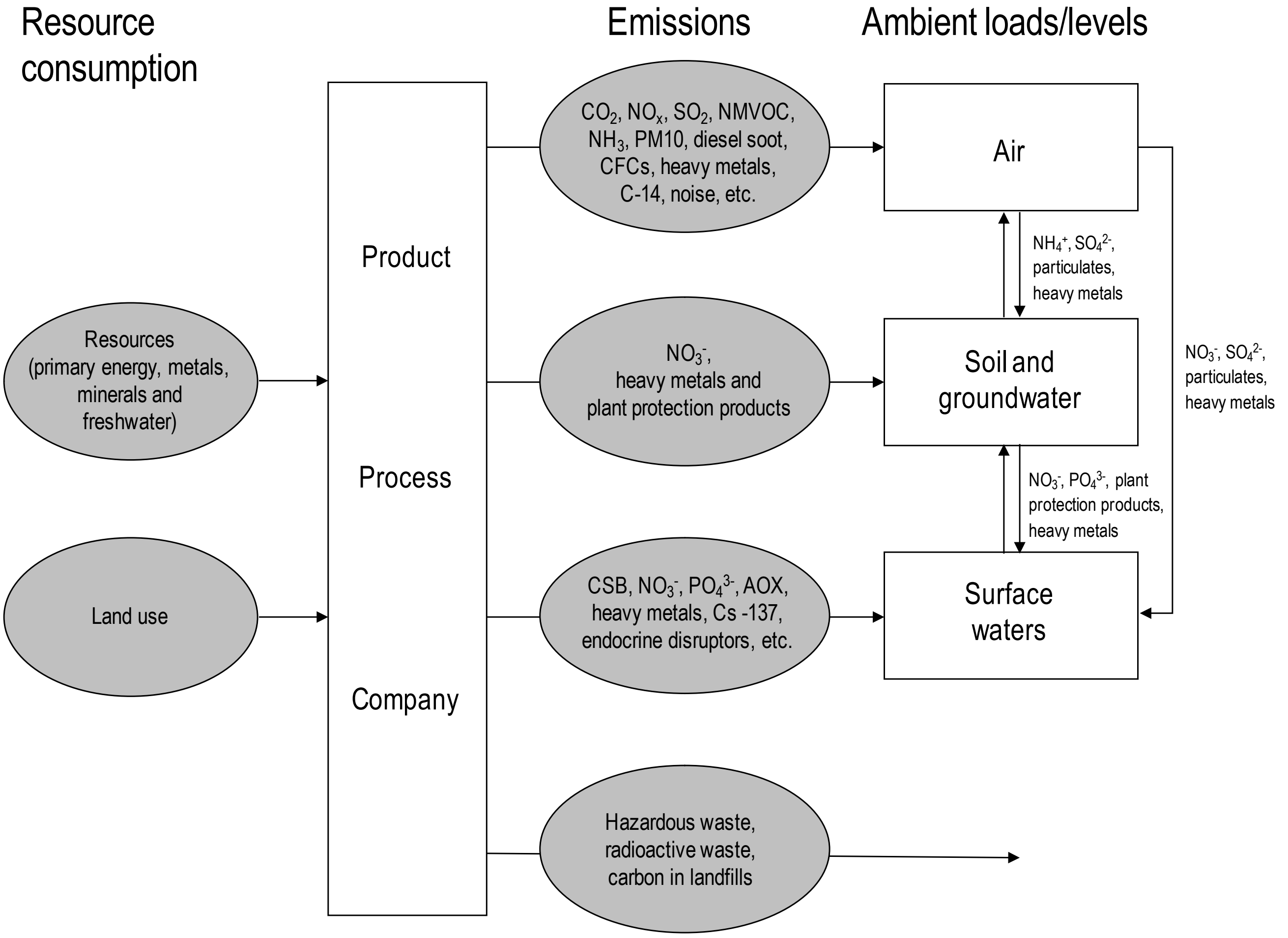
The ecological and political relevance of a substance is decisive in whether an eco-factor is determined for it. This limits the list of environmental pressures that can be weighted. After all, environmental policy by no means sets targets for all substances, especially not for those that have little environmental relevance in Switzerland and Europe (such as sulphate emissions to bodies of water) or for which knowledge is lacking (e.g. nanoparticles). The substance list has nevertheless been expanded each time it has been updated.

All of the eco-factors from the previous report (Frischknecht et al. 2008) continue to be determined. Almost all of the eco-factors are derived in the same way, but with updated values.

Substances are inventoried when they pass from the technosphere to the ecosphere. This boundary is not always clearly defined – especially between soil and groundwater. A more detailed discussion of this boundary is provided in the section on soil (Part 3, Sect. 12.1.2). fig. 3 provides a schematic overview of the points at which environmental pressures are assessed with eco-factors (fields shaded grey). Each emission should be assessed only once – when it first passes from the technosphere to the ecosphere. Other substance flows within the ecosphere, including those that are anthropogenic in origin, are not taken into account in order to prevent double counting.

Fig. 3 > Overview of system boundaries

The environmental pressures assessed by eco-factors are shaded grey.



5.2 Spatial and temporal validity of the eco-factors

Life cycle inventories of product systems generally comprise globally distributed emissions and resource consumption. Therefore, care must be taken when applying the eco-factors so that each emission is weighted as if it were taking place in Switzerland (except for freshwater, unless the life cycle inventory is differentiated accordingly, and radioactive emissions and oil emissions to the North Sea). Through this approach, even when a process is moved to another country, it does not affect the outcome of a life cycle analysis if the absolute emission level is the same. When environmental pressures have a globally uniform impact, such as greenhouse gas emissions, the eco-factors for all emissions are globally applicable. In other cases, the environmental impacts of a pollutant emission or resource extraction can differ from region to region (e.g. water pollutant emissions). The regionalization of eco-factors presented in the section above makes it possible to take account of such differences.

In practice, however, a great deal of effort is generally needed to take systematic account of specific regional circumstances for a product life cycle assessment, due to the lack of information on the specific environmental situation and the environmental policy goals that apply there. This would require an independent and systematic definition of eco-factors for that region. It is definitely conceivable for an eco-factor of particular relevance to a life cycle assessment to be adjusted to the specific regional scarcities in a manner similar to a sensitivity analysis (e.g. specific pollutant emissions to water in a region where pollution levels are very high or very low). However, such case-specific or scientifically based eco-factors must be interpreted with great caution.

This approach can also be taken when interpreting a site audit as part of the environmental management activities of a company, or when assessing the on-site pressures of a locally defined project (such as a major road or railway construction project).

As the eco-factors reflect present environmental targets, their informative value declines over time. However, a comparison of the 1990 eco-factors with those of 1997, 2006 and 2013 shows that the pollution situation, i.e. the current flows, and the political targets, i.e. the critical flows, have clearly changed to some extent.

It takes time for an environmental issue to be reflected in political targets. For that reason, target values rarely encapsulate the most recent scientific findings. In the same vein, the current flows are often based on an extrapolation of past values. This is why the eco-factors must continue to be updated in the future at regular intervals. Nevertheless, online updating, e.g. on the Internet, does not appear expedient, as a “daily quotation” of eco-factors would presumably engender more uncertainty than accuracy.

6 > Data quality

The stated data quality grades relate to the underlying data. For the current flows, they represent the accuracy of the available data. For the critical flows, the assignment of different quality grades reflects the binding nature of the underlying statutory provisions or political statements.

The quality or binding nature of the data is graded in the explanatory part of the report in accordance with the following table:

Tab. 2 > Indicators of the quality or binding nature of data

Quality indicator	Uncertainty with respect to the current flow
A	<20 %
B	20 to 40 %
C	>40 %

Indicator of the binding nature	Derivation of the critical flow
a	Calculation or derivation from statutory emission/ambient targets and/or from political statements of intent
b	Expert recommendation/expert estimate
c	Modelling assumption of advisory group

7 > Characterization

Characterization factors describe the relative environmental impact of substances compared to a reference substance. The characterized quantity is normally expressed in reference substance equivalents. In the case of greenhouse gases, carbon dioxide is the reference substance and kg CO_2-equivalent (kg CO_2-eq.) is the unit of the quantity characterized.

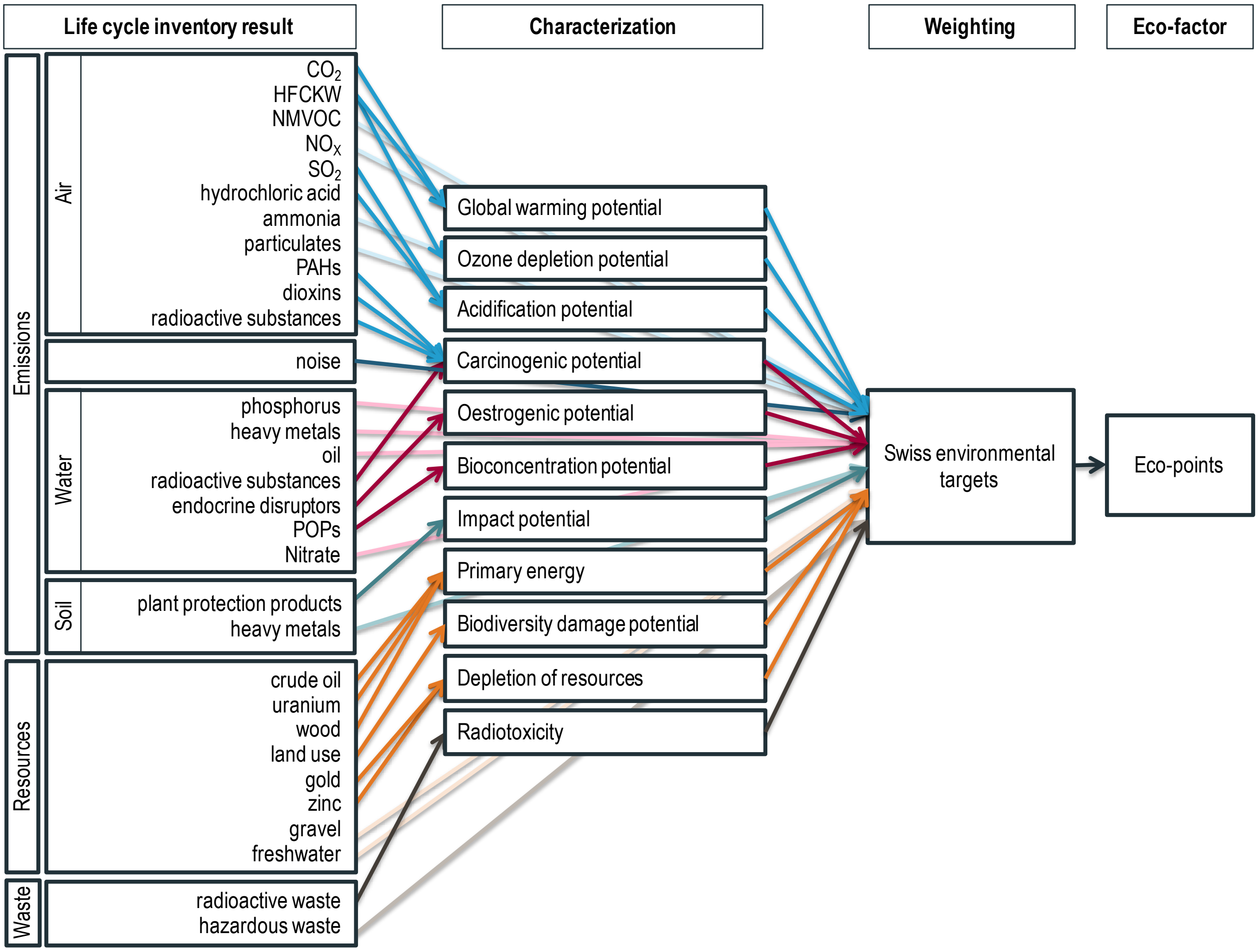
The characterization factors are based on scientific knowledge of the relative effectiveness of pollutants in terms of a specific environmental impact. In the case of greenhouse gases, for instance, the characterization value of 298 kg CO_2-eq./kg N_2O for nitrous oxide (N_2O) means that 1 kg of N_2O has the same global warming impact as 298 kg of CO_2.

In the ecological scarcity method, a characterization may be applied if the corresponding environmental impact played a key role when the target was set. Accordingly, the current CO_2 Act stipulates that all greenhouse gases must be taken into account. Therefore, it is both possible and appropriate to use global warming potential values.

Characterization is not, however, appropriate in every theoretically conceivable case. It should not be used in cases where the environmental impact of the characterization does not match the legislators' intention with regard to the way the reduction target (or the limit or target value) was set. For instance, the legislators adopted a uniform VOC levy. Characterizing individual NMVOCs according to their photochemical oxidation potential (PCOP) is therefore not appropriate.

The eco-factor formula includes an explicit characterization term (K). tab. 3 and fig. 4 list the characterizations used in this report and compare them to those of the report in 2006. Characterization of airborne carcinogenic pollutants, radioactive substances in air and surface waters, POP substances in surface waters, abiotic primary resources (minerals and metals) and radioactive wastes have all been added to this list. Dioxin, furan and benzene emissions to air have been newly characterized, along with polycyclic aromatic hydrocarbons, due to their carcinogenic potential. A new reference substance was selected for plant protection products in soil (glyphosate instead of the standard plant protection products used in Switzerland).

Fig. 4 > Basic diagram of the method including the life cycle inventory result, characterization and weighting steps



Tab. 3 > Characterization methods used in the 2013 and 2006 reports

	Abbr.	Reference unit	Implementation in the ecological scarcity method		
			2006	2013	Source 2013
Global warming potential	GWP	kg CO_2-eq.	Yes	Sect. 9.2	IPCC 2007
Ozone depletion potential	ODP	kg R11-eq.	Yes	Sect. 9.3	UNUBP 2000
Acidification potential	AP	kg SO_2-eq.	Partly	Sect. 9.7	Guinée et al. 2001b
Carcinogenic potential of PAH, dioxin, furan and benzene emissions to air	CTU	CTUh	No	Sect. 9.11	Henderson et al. 2011
Carcinogenic potential of radioactive emissions to air		kBq C-14-eq.	No	Sect. 9.16	Frischknecht et al. 2000
Carcinogenic potential of radioactive emissions to surface waters		kBq U-235-eq.	No	Sect. 10.6	Frischknecht et al. 2000
Carcinogenic potential of radioactive emissions to seas		kBq C-14-eq.	Yes	Sect. 10.7	Frischknecht et al. 2000
Oestrogenic potential of endocrine disruptors		kg E2-eq.	Yes	Sect. 10.13	Rutishauser et al. 2004
Bioconcentration factor of persistent organic pollutants	POP	2,4,6-tribromphenol-eq.	No	Sect. 10.14	Ruiz et al. 2012
Impact potential of plant protection products	PPP	kg glyphosate-eq.	Yes	Sect. 12.3	based on the Danish indicator in OECD 2001
2000-watt society primary energy resources		MJ oil-eq.	Yes	Sect. 13.2	Schweizerischer Bundesrat 2012
Biodiversity damage potential through land use	BDP	m^2 settlement area-eq.	Yes	Sect. 13.3	de Baan et al. 2012
Abiotic depletion potential	ADP	kg Sb-eq.	No	Sect. 13.4	Schweizerischer Bundesrat 2011a, updated based on Guinée et al. 2001b
Radiotoxicity of radioactive waste	RTI	cm^3 HAA-eq.	No	Sect. 14.4	NAGRA 2008

The sources cited relate to the 2013 report

8 > Eco-factors grouped by environmental issues

Eco-factors were previously grouped according to compartments (air, surface waters, groundwater, soil, energy resources, natural resources and wastes). In the interest of approximating the concept of midpoint indicators, eco-factors were largely regrouped according to environmental impacts and issues so that they could be used in life cycle assessment tools.

The environmental issues and classification of resources and pollutants are shown in tab. 4. For practical reasons, the list is a combination of impact-based groups (climate change, ozone layer depletion) and primarily theme-based groups (main air pollutants and particulate matter, heavy metals). Laws often govern individual pollutant emissions, but not their direct impact on the environment or humans. For instance, in the Swiss federal government's plan for clean air measures (Schweizerischer Bundesrat 2009), the clean air targets are described in the form of tolerable annual loads of the following airborne pollutants: NO_X, SO_2, NMVOCs, NH_3 and particulate matter.

A consistent and universally applied characterization is not used, primarily for technical reasons. The environmental policy targets refer to individual substances in most cases. However, they are often aimed at reducing all or several of the potentially negative environmental impacts of the individual substance concerned. Classification and characterization are therefore unnecessary. They would actually result in multiple assessments.

Tab. 4 > Classification of pollutants and resources by environmental impact and issue

English	German	Pollutants, resources
Water resources	Wasser-Ressourcen	Dissipative use of surface water, groundwater and aquifers
Energy resources	Energie-Ressourcen	*Non-renewable:* natural gas, crude oil, raw lignite, raw hard coal. Uranium *Renewable:* harvested quantities of wood, solar radiation, kinetic energy (wind energy) potential energy (water power), geothermal energy
Mineral primary resources	mineralische Primärressourcen (MIneralien und Metalle)	Dissipative use of aluminium (in bauxite), cadmium, chromium, iron ore, indium, copper, dolomite, lime, gravel, phosphorus, etc.
Land use	Landnutzung	Uses of various types of land
Climate change	Klimawandel	CO_2, CH_4, N_2O, FC, PFCs, SF_6, etc.
Ozone layer depletion	Ozonschichtabbau	CFCs, H-CFCs, halons, ether and ether compounds
Main pollutants and PM	Hauptschadstoffe und Partikel	SO_2, NO_X, NMVOCs, NH_3, PM10, PM2.5
Carcinogenic substances in air	Krebserregende Stoffe in Luft	Benzene, diesel soot, dioxins, PAHs
Heavy metals in air	Schwermetalle in Luft	Lead, cadmium, mercury, zinc
Water pollutants	Wasserschadstoffe	Nitrogen, nitrate, phosphorus, CODs, AOXs, chloroform, PAHs, endocrine disruptors
Heavy metals to water	Schwermetalle ins Wasser	Arsenic, lead, cadmium, chrome, copper, nickel, mercury, zinc
POPs in water	POP ins Wasser	Persisent organic pollutants
Pesticides in soil	Pestizide in den Boden	Plant protection products
Heavy metals in soil	Schwermetalle in den Boden	Lead, cadmium, copper, zinc
Radioactive substances in air	Radioaktive Substanzen in die Luft	Carbon-14, caesium 137, iodine-129, etc.
Radioactive substances in water	Radioaktive Substanzen ins Wasser	Carbon-14, caesium 137, iodine-129, etc.
Noise	Lärm	Noise emissions from trucks, cars, trains and airplanes
Non-radioactive waste in landfills	Nicht radioaktive Abfälle in Deponie	Hazardous wastes stored underground in landfills, landfills with wastes containing carbon
Radioactive waste in disposal sites	Radioaktive Abfälle in Endlager	Radioactive waste deposited in radioactive waste disposal sites

Part 3

> Derivation of eco-factors for Switzerland

Part 3 explains how the method is applied to the conditions in Switzerland. It provides a detailed description of how the eco-factors are derived. This is where specialists will find the parameters derived from science and environmental policy for the assessed emissions and resources.

9 > Emissions to air

9.1 Introduction

9.1.1 Selection of substances

The report on “Human-induced air pollutant emissions in Switzerland from 1900 to 2010” (BUWAL 1995) quantifies the emissions of 17 different pollutants and allocates them to four source groups: transport, industry and commerce, agriculture and forestry, and households. Air pollutants are selected on the basis of their ecological relevance for the entire country of Switzerland. In addition, eco-factors are calculated for greenhouse gases and ozone-depleting, acidifying, carcinogenic and radioactive substances by means of characterization.

A range of different measures has succeeded in reducing emissions to air in recent years, in some cases substantially. Some of the remaining emissions and their impacts in Switzerland are therefore of subordinate importance. However, the fact that eco-factors are applied not only to emissions from Swiss processes, but also to processes taking place abroad, must also be taken into account. An eco-factor is therefore retained for substances that may be unproblematic in Switzerland, but have the potential to continue to be environmentally relevant abroad.

tab. 5 lists the air pollutants assessed with an eco-factor. It also has broad categories that specify the impacts of pollutants and which impacts are significant in the determination of the eco-factor.

Tab. 5 > Impact mechanisms of the assessed air pollutants

	Environmental								Human						Notes
	Global warming potential(GWP)	Ozone depletion potential (POCP)	Ozone creation potential (POCP)	Eutrophication	Acidification	Damage to flora	Impairment of soil fertility	Damage to built structures	Respiratory diseases	Carcinogenicity	Mutagenesis	Embryonal damage	Other / further types of damage	Characterization	
CO_2 and other greenhouse gases	#	x	x											GWP	
Ozone-depleting substances	x	#	x											ODP	
NMVOCs			#			x			x	x		x	x	-	
Nitrogen oxides (NO_x)			*	*	*	x			x					-	Targets are designed to protect humans, animals and plants
Ammonia (NH_3)				*	*			x						-	Targets are designed to protect ecosystems. Alternative assessment via AP
SO_2 and other acidifying substances					#	x		x	x					AP	
Particulates (excluding diesel soot)									#	x			x	-	Derivation from the Swiss Air Pollution Control Ordinance
Diesel soot	x								x	#				-	Application of precautionary principle
Carcinogenic pollutants (benzene, PAHs, dioxins/furans)			x							#	(x)	x	x	CTUh	Application of precautionary principle
Lead (Pb)						x	#						x	-	Emissions to air are assessed using the weighting factor for soil, as the greatest scarcity prevails there
Cadmium (Cd)							#		x	x		(x)	x	-	ditto
Zinc (Zn)						x	#						x	-	ditto
Mercury (Hg)						x	x			#			x	-	
Radioactive isotopes										#	x			C14	

x = Impact or link proven; (x) = Impact or link presumed; # = Impact significant in determining the eco-factor; * = Several significant impacts

9.2 CO_2 and other greenhouse gases

9.2.1 Environmental impact

Human-induced amplification of the greenhouse effect has very likely contributed to the 0.6 to 0.9°C global warming in the last 100 years and the simultaneous rise in sea levels by 10 to 20 cm (IPCC 2007). Warming in Switzerland has been twice as high as the global mean and will continue to rise (Schweizerischer Bundesrat 2012). Modelling shows that the global mean temperature can be expected to rise by 1.1 to 6.4°C between 1990 and 2100, depending on the development of greenhouse gas emissions, and the sea level can be expected to rise by 18 to 59 cm. Furthermore, more precipitation and extreme events are expected, with regionally disparate patterns. There is sufficient documentation showing that the global temperature has never changed at a comparable rate in the past 10 000 years (IPCC 2007).

The Swiss Sustainable Development Strategy (Schweizerischer Bundesrat 2012) states the reduction of CO_2 emissions as a priority goal of environmental policy. Several measures are in place or in preparation (buildings programme, emissions regulations for passenger vehicles, CO_2 levy, emissions trading system, compensation requirement for fuels, etc.) that contribute to reducing CO_2 emissions. Aviation fuels are also to be covered in the future within the framework of an international agreement.

The gases with the greatest global warming impact are CO_2, CH_4 (methane) and N_2O (nitrous oxide). In addition, various chlorinated and fluorinated hydrocarbons (CFCs, HCFCs, HFCs, PFCs) and SF_6 have a direct radiative forcing effect. While the global warming impact of the latter substances per kilogram can be several thousand times greater than that of CO_2, their contribution to the overall emissions inventory of Switzerland is between 2 and 3% (see tab. 7).

9.2.2 Characterization

Greenhouse gases comprise the substances that contribute to global climate change. To exert their effect as greenhouse gases, they must enter the atmosphere.

Global warming potential according to Kyoto and IPCC

The updated publication by the IPCC (2007) provides reference information for the global warming potentials (GWPs) of the various gases. The reference substance is carbon dioxide (CO_2). When the need arises, the potentials are adjusted to new scientific findings, and new substances are characterized. The values vary depending on the period of time over which the effects are summated. It is common practice to apply the GWP_{100} values (integrated over 100 years; see tab. 6, and the full list in A2), which is why this is also applied to the characterization used in the method described in this report.

Tab. 6 > Global warming potentials of the substances regulated under the Kyoto and Montreal Protocols

		GWP_{100}	
		Used in this report (IPCC 2007) (kg CO_2-eq./kg)	Used in the Kyoto Protocol (Houghton et al. 1996) (kg CO_2-eq./kg)
Carbon dioxide	CO_2	1	1
Methane	CH_4	25	21
Nitrous oxide	N_2O	298	310
Chlorofluorocarbons*	CFCs/HCFCs	77–14 400	90–8 100
Partially halogenated fluorocarbons	HFCs	12–14 800	140–11 700
Perfluorinated hydrocarbons	PFCs	7 390–12 200	6 500–9 200
Sulphur hexafluoride	SF_6	22 800	23 900

* These substances are regulated under the Montreal Protocol (UNEP 2007).

The current IPCC report (IPCC 2007) rates the relative radiative forcing of individual gases somewhat differently than was the case in the Second Assessment Report of 1996 (Houghton et al. 1996). The GWP values of the latter are the basis on which national greenhouse gas emissions inventories are built. The changes in the GWPs are due above all to advances in the radiative forcing model.

Airplanes cause various effects that can lead to an increased greenhouse gas effect. The IPCC and other organisations quantify this effect with a radiative forcing index (RFI) (see, for example, Penner et al. (2000)), though they have made no uniform recommendation as of yet. The IPCC (2007, WG I, Section 2.10.4, p. 215) recommends not using the RFI factors for measurement, as the various retention times of the various elements affecting the climate are not taken into account. The IPCC (2009, p.1) confirms that the current calculation of the GWP values has certain shortcomings, but it currently lacks the scientific basis to correct them. According to the IPCC (2009, Subsection 4.4, p.17), scientific consensus has yet to be achieved on quantitative evidence of effects linked to flight altitude. Therefore, airplane emissions at cruising altitude are not more heavily weighted in the ecological scarcity method than emissions at ground level.

Some greenhouse gases also damage the ozone layer, which is why their ozone depletion potential is also assessed, and the higher of the resulting eco-factors is used in each case. Other environmental impacts of greenhouse gases (such as the herbicidal effect of the decomposition products of fluorocarbons) are not taken into account here.

9.2.3 Normalization

By signing the Kyoto Protocol, Switzerland has committed to reducing its greenhouse gas emissions. The amended CO_2 Act, which came into force on 1 January 2014 (CO_2-Gesetz 2013), includes all greenhouse gases that were set out in the Kyoto Protocol and international negotiations on a successive protocol, in contrast to the previous version of the CO_2 Act (CO_2-Gesetz 2012). The Swiss Federal Council also made it clear in its Sustainable Development Strategy (Schweizerischer Bundesrat 2012) that the goal of Swiss climate policy is to reduce the emissions of all greenhouse gases.

Just as characterization is performed using the current GWPs (IPCC 2007), the normalization flow is calculated with current global warming potentials. This leads to a normalization flow of approximately 53 million t CO_2-eq./a (see tab. 7).

Tab. 7 > Greenhouse gas emissions in Switzerland

according to the FOEN (BAFU 2012b), weighted with the GWP 100 in accordance with the IPCC (2007)

	GWP_{100} (IPCC 2007) (CO_2-eq.)	Emissions 2009 (1000 t CO_2-eq.)	Percentage in overall greenhouse gas emissions
CO_2	1	44 257	83 %
CH_4	25	4 543	8.6 %
N_2O	298	3 028	5.7 %
HFCs	12–14 800	991	1.9 %
PFCs	7 390–12 200	42	0.1 %
SF_6	22 800	178	0.3 %
Total		**53 040**	**100 %**

9.2.4 Weighting

Current flow

At 53 million t CO_2-eq (tab. 7), the current flow is identical to the normalization flow.

Critical flow

There are medium and long-term political targets for reducing greenhouse gases in Switzerland. The goal of reducing domestic greenhouse gas emissions 20% under their 1990 levels by 2020 was set out in the amended CO_2 Act (Federal Act of 23 December 2011 on the Reduction of CO_2 Emissions, CO_2-Gesetz 2013). Accordingly, efforts will be made to limit the increase in global temperature to less than 2° C. In its Sustainable Development Strategy 2012–2015 (Schweizerischer Bundesrat 2012), the Swiss Federal Council states that for industrial nations to reach the 2° C target by 2050, it will be necessary to reduce greenhouse gases by 80% to 95% under their 1990 emission levels (Schweizerischer Bundesrat 2012). Subsequently, the Federal Council set more extensive reduction targets of between 50% and 85% for 2050. After consulting with the FOEN, a reduction target of 80% was set in this report. This is within the upper range of the Swiss reduction target and within the scope of the reduction that is required to reach the 2° C target.

Reducing greenhouse gases by 80% under their 1990 levels will result in a critical flow of approximately 10.8 million t CO_2-eq. This includes all sources, except those in the land-use change and forestry sector (e.g. the sink effect of forests).

9.2.5 Eco-factor for greenhouse gases

The eco-factor for greenhouse gases is determined on the basis of the widely accepted “2 degree target”, which corresponds to the reduction of greenhouse gas emissions in Switzerland by 80% under their 1990 levels.

Tab. 8 > Eco-factor for CO_2 and other greenhouse gases in UBP/g CO_2-equivalents

	Edition 2013	Q	Notes	Edition 2006
Normalization (1000 t CO_2-eq./a)	53 040	A	2009 emissions according to the FOEN (2012d), but with GWPs according to the IPCC (2007)	53 034
Current flow (1000 t CO2-eq./a)	53 040	A	2009 emissions according to the FOEN (2012d), but with GWPs according to the IPCC (2007)	-
Critical flow (1000 t CO2-eq./a)	10 766		80% reduction from 1990 levels	-
Weighting (-)	24.3			16.5
Eco-factor (UBP/g CO_2-eq.)	**0.46**			0.31

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor has risen by roughly 50% in comparison to 2006.

9.2.6 Eco-factors of other greenhouse gases

The other greenhouse gases together contribute around 17% of the global warming impact attributable to Swiss emissions (tab. 7). Their eco-factors are determined through characterization using global warming potential (GWP_{100} values according to IPCC 2007; cf. tab. 9 and the detailed list in A2).

Eco-factors of other greenhouse gases

In cases where substances contribute to both global warming and ozone depletion, both eco-factors are calculated and the higher of the two is used.

Tab. 9 > Eco-factors for selected greenhouse gases, calculated from the eco-factor for CO_2

	Formula	GWP	Eco-factor 2013 (UBP/g)	Basis in 2013	Eco-factor 2006 (UBP/g)	Basis in 2006
Carbon dioxide	CO_2	1	**0.46**	GWP	0.31	GWP
Methane	CH_4	25	**12**	GWP	7.1	GWP
Nitrous oxide	N_2O	298	**140**	GWP	92	GWP
HCFC-22	$CHClF_2$	1 810	**830**	ODP*	610	GWP
HCFC-142b	CH_3CF_2Cl	2 310	**1 100**	GWP*	740	GWP
HFC-125	CHF_2CF_3	3 500	**1 600**	GWP	1 100	GWP
HFC-134a	CH_2FCF_3	1 430	**660**	GWP	400	GWP
Sulphur hexafluoride	SF_6	22 800	**10 000**	GWP	6 900	GWP

The detailed list is in A2.

* The eco-factor can be derived on the basis of GWP and ODP; the higher of the two is used and listed here.

9.2.7 Eco-factors from global warming for carbon monoxide (CO) and diesel soot (black carbon)

In 2010, carbon monoxide emissions amounted to 249 949 t (BAFU 2012a). For carbon (C), an eco-factor can be derived on the basis of the indirect global warming potential of carbon monoxide. The IPCC (2001) mentions a range of 1 to 3 kg CO_2-eq./kg CO for the GWP_{100} of CO. In stoichiometric terms, 1.57 kg of CO_2 are formed from 1 kg of

CO. This value is taken for the GWP_{100} of CO. An eco-factor of 0.66 UBP/g CO results.

Diesel soot (termed “black carbon” by the IPCC) also has a global warming impact, as do all aerosols. The GWP for black carbon is 800 to 2000 (IPCC 2001, Chapter 5). The resulting eco-factor is, however, substantially lower than the eco-factor derived from human health effects (cf. Part 3, Section 9.8.4).

9.3 Ozone-depleting substances

9.3.1 Environmental impact

Depletion of the stratospheric ozone layer is caused by volatile substances that contain chlorine and/or bromine atoms.

The ozone layer protects the biosphere from a part of the ultraviolet radiation of the sun. Depletion of the ozone therefore increases, among other things, the rate of humans and animals with skin cancer and eye diseases and the rate of mutation in all organisms. In addition, it accelerates aging in plastic polymers.

The most important ozone-depleting substances are CFCs (chlorofluorocarbons), halons and carbon tetrachloride (CCl_4). HCFCs (partially halogenated CFCs) have the same effect, but in a significantly weaker form, as they are less stable. tab. 11 shows that their ozone depletion potential is substantially lower than that of the CFCs, while the quantities of emissions are in the same order of magnitude.

At the same time, CFCs and HCFCs are both contributors to human-induced climate change (see Part 3, Section 9.2).

9.3.2 Characterization

The intensity of the ozone-depleting effect is stated in terms of the Ozone Depletion Potential (ODP), a dimensionless quantity, whereby the ODP of CFC-11 (R-11) is set at 1.0. ODP values are internationally binding, as they are set out in the Montreal Protocol. tab. 10 presents a selection of them, while A2 gives the entire list. This list is expanded to include new substances as required. The status of the year 2007 is used for characterization (UNEP 2007).

Halogenated hydrocarbons that contain no chlorine or bromine atoms, but contain fluorine (HFCs), for instance, have no ozone-depleting effect. Most ozone-depleting substances also have a global warming potential. Following the principles of the ecological scarcity method, the higher of the resulting eco-factors is used (see Part 2, Section 4.11).

Tab. 10 > Ozone depletion potentials (ODPs) of a number of important substances

		ODP (kg R11-eq./kg)
CFCs	R11	1
	R12	1
	R115	0.6
HCFCs	R22	0.055
	R124	0.022
	R141b	0.11
Halons	Halon 1211	3
	Halon 1301	10
	Methane, bromo-	0.6
Solvents	1,1,1-trichlorethane	0.1
	Methane, tetrachloro-	1.1

cf. also A2

9.3.3 Normalization

The ozone-depleting substances are characterized. As the environmental target is based on the characterized values, the normalization flow is identical to the characterized current flow.

9.3.4 Weighting

Current flow

The Montreal Protocol on Substances that Deplete the Ozone bans the production and use of these substances. This ban has been in effect in industrial countries since 1996 and in developing countries since 2010, except for HCFCs and bromomethane (methane, bromo-). Some exceptions still apply to certain limited uses of CFCs, tetrachloromethane (methane, tetrachloro-; CCl_4) and halons.

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

1. Diffuse emissions from foam insulation materials containing CFCs and HCFCs that are already in place in buildings and refrigeration systems.
2. Losses of CFCs and HCFCs as refrigerants in refrigeration and air conditioning systems and heat pumps.
3. Releases from the disposal of insulation material, equipment and systems that contain CFCs or HCFCs (e.g. refrigeration equipment, refrigerators).
4. Halon emissions resulting from the use of fire control equipment and systems.

The emissions of ozone-depleting substances were determined by FOEN[2] experts on the basis of the stocks and annual depletion rates, exemptions, expert estimations, available registers and import statistics (see tab. 11). This results in a current flow of 191 t R11-eq.

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[2] Written communication, Norbert Egli, BAFU, 2 September 2013

Critical flow

The Swiss Chemicals Risk Reduction Ordinance (ChemRRV 2013) prohibits the production, importation and use of ozone-depleting substances. Exemptions regarding importation and use are currently only in place for recycled HCFCs for the maintenance of existing HCFC refrigeration equipment (transitional period until 2015), for halons in specific areas of military, nuclear energy and aviation use and for special technical applications.

The provisions of the Chemicals Risk Reduction Ordinance have led to a sharp reduction in emissions of ozone-depleting substances. However, the stocks formed mainly in building insulations materials (primarily CFC-11) will release considerable amounts in the coming decades. Emissions will therefore only drop slowly.

The Chemical Risk Reduction Ordinance thus regulates the use of ozone-depleting substances, but not their emission. No critical flow can therefore be derived directly from the wide-ranging ban on the consumption of ozone-depleting substances.

The tolerated emissions are taken as a basis for determining the critical flow. As these decline gradually, the choice of reference year is decisive. Stocks (industrial application) of the most important substance in Switzerland (CFC-11) will be almost fully depleted by 2020. Hence, the following estimation is performed for the emissions of ozone-depleting substances that are to be anticipated in 2020 (see tab. 11). Accordingly, the emissions to be anticipated in 2020, i.e. the critical flow, amount to 150 t R11-eq.

Tab. 11 > Swiss emissions of ozone-depleting substances that are relevant to Switzerland in t/a and as R11-eq./a in 2011 and 2020

		ODP (kg R11-eq./kg)	Use	Emissions 2011		Emissions 2020		Notes/source
				(t/a)	(t R11-eq/a)	(t/a)	(t R11-eq/a)	
CFCs								
R-11	CCl_3F	1	Foam	120	120	120	120	HALCLIM project, based on stocks in 1995 (6000 t), which will be depleted by 2020 (industrial use). 50% of the foam is disposed of without emissions
R-12	CCl_2F_2	1	Refrigerant	35	35	17	17	Based on stocks in 2010 (500 t) according to the personal estimate of Blaise Horisberger, FOEN, and the annual emission rate of 7.5%
HCFCs								
R-22	$CHClF_2$	0.055	Refrigerant, foam	180	9.9	70	3.85	Based on stocks in 2010 (2000 t) and the annual emission rate of 10%
R-141b	$C_2H_3Cl_2F$	0.11	Extin-guishign agent	0.1	0.011	0.1	0.011	Based on annual use with exemption
R-141b	$C_2H_3Cl_2F$	0.11	Foam	180	19.8	70	7.67	HALCLIM project, based on stocks in 2010 (2000 t) and the annual emission rate of 10%

		ODP (kg R11-eq./kg)	Use	Emissions 2011		Emissions 2020		Notes/source
				(t/a)	(t R11-eq/a)	(t/a)	(t R11-eq/a)	
Halons								
Halon 1211	$CBrClF_2$	3	Extinguishing agent	0.1	0.3	0.0	0.0	Oral communication by halon experts
Halon 1301	$CBrF_3$	10	Extinguishing agent	0.5	5	0.0	0.0	Swiss halon register
Bromomethane (Methane, bromo-)	CH_3Br	0.6	Solvent	0.3	0.18	0.3	0.18	Since 2006 also banned as a fumigation product (pest control). Until further notice, max. 300 kg of annual emission from chemical synthesis with exemption.
Solvents								
Methane, tetrachloro	CCl_4	1.1	Solvent	1.0	1.1	1.0	1.1	Import statistical information
Total								
Air emissions					**191**		**150**	

Source: personal communication, Norbert Egli, FOEN, 2 Septemer 2013

9.3.5 Eco-factor for ozone-depleting substances

Tab. 12 > Eco-factor for R11-equivalents in UBP/g R11-eq

	Edition 2013	Q	Notes	Edition 2006
Normalization (t R11-eq./a)	191	B		391
Current flow (t R11-eq./a)	191	B	Estimate by FOEN experts	391
Critical flow (t R 11-eq./a)	150	b	Estimate by FOEN experts	188
Weighting (-)	1.63			4.33
Eco-factor (UBP/g R11-eq.)	**8 500**			11 000

Q = data quality; for explanation, see Part 2, Chapter 6

The new eco-factor is lower than the one for 2006. Because of the falling emissions resulting from the bans, the weighting factor and the normalization flow have both become smaller.

9.3.6 Eco-factor for other ozone-depleting substances

The eco-factor for other ozone-depleting substances can be derived from the characterization values for the ozone depletion potential (ODP) and the eco-factor for R11-equivalents derived in Section 9.3.5.

Many ozone-depleting substances also contribute to global warming. For these, both the eco-factor resulting from global warming and the eco-factor resulting from their ozone-depleting effect was calculated. A2 lists all substances and their respective dominant impacts.

No separate eco-factors are calculated for refrigerant blends. The values for blends can be calculated from the eco-factors of the individual components, weighted according to their respective share in mass.

Tab. 13 > Eco-factors for ozone-depleting substances, stated in UBP/g of substance

	Formula	ODP (kg R11-eq./kg)	Eco-factor 2013 (UBP/g)	Basis 2013	Eco-factor 2006 (UBP/g)	Basis 2006
CFC-11	CCl_3F	1	**8 500**	ODP*	11 000	ODP*
CFC-12	CCl_2F_2	1	**8 500**	ODP*	11 000	ODP*
HCFC-123	$CHCl_2CF_3$	0.02	**170**	ODP*	220	ODP*
HCFC-142b	CH_3CF_2Cl	0.065	**1 100**	GWP*	740	GWP*
HCFC-225ca	$CF_3CF_2CHCl_2$	0.025	**210**	ODP*	280	ODP*
Halon 1211	$CBrClF_2$	3	**26 000**	ODP*	33 000	ODP*
Halon 1301	$CBrF_3$	10	**85 000**	ODP*	110 000	ODP*
Methane, bromo-	CH_3Br	0.6	**5 100**	ODP*	6600	ODP*

* Data available for GWP and ODP, the higher value is used

9.3.7 Implementation in the ecoinvent v2.2 database

Inventory data on plastic production published by PlasticsEurope and used in ecoinvent database v2.2 do not show emissions of ozone depleting substances, but rather emissions of Organo-Cl. Therefore, ecoinvent introduced the substance “hydrocarbons, chlorinated”. This substance is assessed with the eco-factor of HCFC-22 (R-22; cf. in A2).

9.4 Non-methane volatile organic compounds (NMVOCs)

9.4.1 Environmental impact

Volatile organic compounds (VOCs) are a group comprising a range of non-toxic to highly toxic and carcinogenic compounds. The Swiss VOC Ordinance (VOCV 2013) defines VOCs as “organic compounds with a vapour pressure of at least 0.1 mbar at 20° C or with a boiling point of at most 240° C at 1013.25 mbar”. NMVOCs (non-methane volatile organic compounds) are VOCs excluding the gas methane.

Along with nitrogen oxides, NMVOCs are important precursors for photochemical oxidants (giving rise to tropospheric ozone or “summer smog”), which can harm human health and flora. In addition, many VOCs lead to further undesirable impacts on humans and flora and fauna. These further effects are not, however, taken into account in the eco-factor calculation, which is why individual VOCs (benzene and dioxins) are assessed with separate eco-factors.

9.4.2 Characterization

Photochemical ozone creation potential (POCP) is a measure of the contribution of a molecule to ozone formation and could provide a starting point for characterization. As the Swiss VOC Ordinance (VOCV 2013) intentionally makes no distinction between different NMVOC substances, characterization is not appropriate.

9.4.3 Normalization

The current flow already relates to all of Switzerland. For that reason, normalization is identical to the current flow.

9.4.4 Weighting

Current flow

Annual NMVOC emissions in Switzerland rose from 70 000 to 324 000 tonnes during the period from 1950 to 1985. Emissions have been declining since 1985. In 1995, they amounted to 200 000 tonnes (BAFU 2012a, Table 2–1). The introduction of the VOC levy in 2000, in combination with increasingly stricter regulations for vehicles, has contributed to further reducing current emissions to 89 000 t/a (BAFU 2012a; BUWAL 2003b).

Critical flow

The Swiss Federal Air Pollution Control Ordinance sets ambient limit values for ozone (O_3). These are often still exceeded in the summer months. In general, the peak ozone values in the Southern Alps are higher than in the northern Alps (BAFU 2012c).

In order to comply with the ambient limit values, and specifically to reduce the maximum 1-hour mean value for O_3 to the range of limit values, the Swiss Federal Council (Schweizerischer Bundesrat 2009, Table 2) states that NMVOC emissions need to be reduced by 20% to 30% from their 2005 levels. This matches the previous critical flow of 81 000 t/a for NMVOCs.

9.4.5 Eco-factor for NMVOCs

Tab. 14 > Eco-factor for volatile organic compounds (excluding methane, CFCs) in UBP/g NMVOC

	Edition 2013	Q	Notes	Edition 2006
Normalization (t NMVOC/a)	89 025	A		116 000
Current flow (t NMVOC/a)	89 025	A	(BAFU 2012c)	116 000
Critical flow (t NMVOC/a)	81 000	a	(Schweizerischer Bundesrat 2009)	81 000
Weighting (-)	1.21			2.05
Eco-factor (UB/g NMVOC)	**14**			18

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor has dropped since 2006, as the current flow has been reduced thanks to the measures taken. It can be assumed that emissions will continue to drop in the future.

9.5 Nitrogen oxides (NO_x)

9.5.1 Environmental impact

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

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

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

9.5.2 Normalization

The given target is to reduce the quantity of NO_2 emitted (stated as NO_2), and no characterization is performed. For that reason, normalization is identical to the current flow.

9.5.3 Weighting

Current flow

Nitrogen oxides are formed primarily when fossil energy carriers are burnt. Transportation is the main source, accounting for 53% of emissions in 2010. Other anthropogenic sources of nitrogen oxides include construction, agricultural and silvicultural machines (10%) and certain commercial and industrial processes (27%) (BAFU 2012a).

Annual NO_x emissions in Switzerland (measured as NO_2) rose from 31 300 t to 179 000 t in the period from 1950 and 1985. Emissions have been declining since 1985. Thanks to the measures taken, NO_x emissions have dropped substantially. The current flow is roughly 78 700 t/a (BAFU 2012a).

Critical flow

The Swiss Air Pollution Control Ordinance (LVR 2010) stipulates ambient limit values for nitrogen dioxide (NO_2) and ozone (O_3). These were set so that when they are complied with, no danger arises to humans, animals, plants, their biotic communities or their habitats. At present, the limit values for nitrogen dioxide are exceeded everywhere in urban centres, and in some cases substantially, while in rural areas they are generally complied with. In contrast, the ambient limit values for ozone are frequently exceeded above all in rural areas and conurbations (Schweizerischer Bundesrat 2009, Table 1).

Substantial emissions reductions are therefore essential in order to comply with the ambient limit values. The Swiss Federal Council (2009) seeks to reduce NO_x emissions by around 50% from their 2005 level in order to comply with the ambient limit values of O_3 and the limits for acidic depositions. This reduction also has the effect of reducing the contribution to over-fertilization to an acceptable level over the longer term (BUWAL 1996). This reduction corresponds to the previous critical flow of 45 000 t/a for NO_x emissions.

9.5.4 Eco-factor for NOx

Tab. 15 > Eco-factor for nitrogen oxide in UBP/g NO_X as NO_2

	Edition 2013	Q	Notes	Edition 2006
Normalization (t NO_x as NO_2/a)	78 704	A		91 000
Current flow (t NO_x as NO_2/a)	78 704	A	(BAFU 2012a)	91 000
Critical flow (t NO_x as NO_2/a)	45 000	a	(Schweizerischer Bundesrat 2009)	45 000
Weighting (-)	3.06			4.09
Eco-factor (UBP/g NO_x as NO_2)	**39**			45

Q = data quality; for explanation, see Part 2, Chapter 6

The decline in the current flow leads to a somewhat lower eco-factor than the situation in 2006. The planned further tightening of emission standards in the transportation sector can be expected to produce a further drop.

9.6 Ammonia (NH_3)

9.6.1 Sources and environmental impact

Agriculture is the main source of ammonia emissions, accounting for 92% of it. Ammonia forms as a result of livestock management (animal housing, farmyard manure storage and field application) and is emitted when mineral nitrogen fertilizers are applied. Overall, livestock rearing specifically accounts for 62% (BAFU 2012a).

Ammonia also contributes to acidification and over-fertilization of aquatic and terrestrial ecosystems, which causes longer-term direct and indirect changes to ecosystems. Because of the complexity of the processes, the effects of elevated nitrogen loads are difficult to predict. They include increased sprout growth and greater susceptibility to parasites, and the promotion of nitrophilous plants, which displace endemic plant species. Ecosystems recover very slowly from over-fertilization, and when they do, this can be expected only over a very lengthy period of time (BUWAL 1996; 2005).

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

9.6.2 Normalization

The reduction target relates to the over-fertilizing impact and the acidifying impact of ammonia. No characterization is performed. For that reason, the normalization flow is identical to the current flow.

9.6.3 Weighting

Current flow

Ammonia emissions rose gradually from the early 20th century onwards and peaked in 1980. Since then, emissions have dropped. In 2010, they totalled 51 500 t NH_3-N/a (corresponding to 62 600 t NH_3/a; BAFU 2012a).

Critical flow

The Swiss Federal Council (2009, Table 2) seeks to reduce ammonia emissions by 40% under the 2005 level in order to comply with the load limit for nitrogen. The Swiss Federal Commission for Air Hygiene states a reduction target of 25 000 t NH_3-N (i.e. 30 400 t NH_3) (BUWAL 2005, p. 129). According to the FOEN and the FOAG (BAFU & BLW 2008), the environmental target for ammonia, and therefore its critical flow, is 25 000 t NH_3-N per year.

9.6.4 Eco-factor for NH_3

Tab. 16 > Eco-factor for ammonia in UBP/g NH_3-N and in UBP/g NH_3

	Edition 2013	Q	Notes	Edition 2006
Normalization (t NH_3-N/a)	51 463	A		44 000
Current flow (t NH_3-N/a)	51 463	A	(BAFU 2012a)	44 000
Critical flow (t NH_3-N/a)	25 000	a	(BAFU & BLW 2008)	25 000
Weighting (-)	4.24			3.098
Eco-factor (UBP/g NH_3-N)	**82**			70
Eco-factor (UBP/g NH_3)	67			57.65

Q = data quality; for explanation, see Part 2, Chapter 6

Another way to derive an eco-factor for ammonia is characterization using the acidification potential, which results in an eco-factor of 40 UBP/g NH_3 (cf. Part 3, Section 9.7.6). The eco-factor derived from the direct reduction target is higher and therefore applied.

Major reduction potential is possible in agriculture, among other areas, through low-emission animal housing and slurry storage, as well as optimised slurry application to fields. If these and other technical options are exploited, it is possible to reduce emissions by 30–40% (BUWAL 2004b).

9.7 Sulphur dioxide (SO_2) and other acidifying substances

9.7.1 Environmental impact

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

9.7.2 Characterization

Sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3) are the most important acidifying air pollutants. The acidification potential (AP) is stated in SO_2-equivalents using sulphur dioxide as a reference substance. The "generic APs" given by Guinée et al. were adopted as characterization factors (2001b, as per April 2004).

Tab. 17 > Characterization factors for acidification potential in accordance with Guinée et al. (2001b, as per April 2004, "generic AP") in relation to SO_2

		Acidification potential (SO_2-eq.)
Ammonia	NH_3	1.88
Hydrogen fluoride	HF	1.6
Phosphoric acid	H_3O_4P	0.98
Nitric acid	HNO_3	0.51
Hydrochloric acid	HCl	0.88
Sulphur dioxide	SO_2	1.0
Sulphuric acid	H_2SO_4	0.65
Hydrogen sulphide	H_2S	1.88
Nitrogen oxides	NO_x (as NO_2)	0.7

9.7.3 Normalization

The target for sulphur dioxide is based on its acidifying effect. The other acidifying substances (cf. tab. 19 in Part 3, Section 9.7.6) would also need to be taken into account for the normalization flow. Separate targets have been established for NO_x and NH_3, which is why these two substances are not included in the normalization. Due to a lack of data, however, the other acidifying substances could not be taken into account for the calculation of the normalization flow. It can be assumed that sulphur dioxide makes by far the largest contribution and that the stated normalization flow of around 12 900 t SO_2-eq./a only slightly underestimates the real situation (see tab. 19).

9.7.4 Weighting

Current flow

Annual SO_2 emissions in Switzerland rose from 46 200 to 116 000 tonnes in the period from 1950 to 1980. Emissions have been declining since 1980. In 2010, they amounted to around 12 900 t/a (BAFU 2012a)

Critical flow

The Swiss Federal Council (2009) seeks to use pre-emptive measures to prevent a recovery of SO_2 emissions from their 2005 level and to comply with the ambient limit values for SO_2 set out in the Swiss Air Pollution Control Ordinance (LRV 2010) as well as the limits for acidic deposition. This corresponds to the previous critical flow of 25 000 t/a.

The protection of ecosystems against acidification is also regulated by the UN/ECE (United Nations/Economic Commission for Europe). The Swiss parliament ratified the second sulphur protocol in 1997. In Article 2, it establishes the long-term target that sulphur loads are to remain below the critical loads for ecosystems (UN/ECE 1994; UNECE 1999).

9.7.5 Eco-factor for $SO2_2$

Tab. 18 > Eco-factor for sulphur dioxide in UBP/g SO_2-eq.

	Edition 2013	Q	Notes	Edition 2006
Normalization (t SO_2-eq./a)	12 861	A	see text	19 000
Current flow (t SO_2/a)	12 861	A	(BAFU 2012a)	19 000
Critical flow (t SO_2/a)	25 000	a	(Schweizerischer Bundesrat 2009)	25 000
Weighting (-)	0.265			0.578
Eco-factor (UBP/g SO_2-eq.)	**21**			30

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor for SO_2 is 30% lower than it was in 2006. This is attributable to a lower normalization flow and current flow.

9.7.6 Eco-factors for other acids

Other substances in addition to sulphur dioxide are responsible for the acidification of ecosystems. An eco-factor can be derived for other substances by using the acidification potential, which characterizes the relative acidification attributable to a substance in relation to SO_2 (see Part 3, Section 9.7.2).

The eco-factors only assess the acidifying effect, as they are linked to SO_2 through characterization. Other effects of individual acids are not taken into account. Nitrogen oxide and ammonia are weighted more heavily due to their specific reduction targets (cf. Part 3, Sections 9.5 & 9.6), which is why their eco-factor applies in this case.

Tab. 19 > Eco-factors for substances with acidifying potential in UBP/g acid, characterized in reference to sulphur dioxide

		Acidification potential (kg SO_2-eq./kg)	Eco-factor 2013 (UBP/g)	Notes	Eco-factor 2006 (UBP/g)
Ammonia	NH_3	1.88		Eco-factor from direct derivation is higher (cf. Sect. 9.6)	
Hydrogen fluoride	HF	1.6	**34**		48
Phosphoric acid	H_3O_4P	0.98	**21**		29
Nitric acid	HNO_3	0.51	**11**		15
Hydrochloric acid	HCl	0.88	**18**		26
Sulphuric acid	H_2SO_4	0.65	**14**		20
Hydrogen sulphide	H_2S	1.88	**39**		56
Nitrogen oxides	NO_x	0.7		Eco-factor from direct derivation is higher (cf. Sect. 9.5)	

For weighting and normalization, see Tab. 18

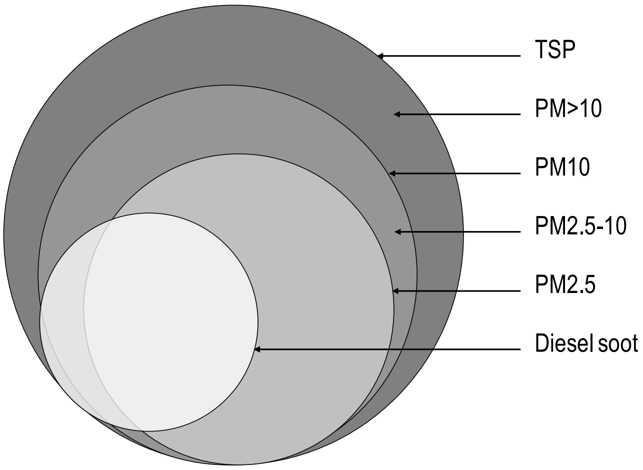
9.8 Particulate matter (I): PM10, PM2.5 and PM2.5–10

9.8.1 Environmental impact

Particulate matter (PM) is a mixture that is complex in both physical and chemical terms. It comprises, among other things, soot, geological material, heavy metals, abrasion particles, biological material (e. g. spores) and particles formed in secondary processes in the air (sulphate, nitrate, ammonium, organic carbon) (BAFU 2011c).

The harmfulness of particles depends on their size and composition. Their size is taken into account by determining eco-factors for PM2.5 and PM2.5–10 in addition to the eco-factor for PM10. However, legislators have not yet introduced this differentiation. In contrast, the derivation of the eco-factor for diesel root is determined primarily by the composition, i.e. the carcinogenicity, of the particles. Furthermore, it is thought that toxicity correlates more closely with the particle number than the absolute mass, particularly in the case of diesel soot.

Fig. 5 > Schematic representation of particle sizes and their relationships



TSP: Total Suspended Particles

Epidemiological studies have shown that the particles with a diameter of less than 10 micrometres (**PM10**) correlate closely with the observed human health impacts of air pollution. PM10 comprises those particles that can move beyond the larynx and enter the lungs. PM10 is a mixture of primary emissions (particles from combustion processes, resuspended road dust and particles from the abrasion of pavings and tyres) and aerosols formed in secondary processes (BAFU 2011c). For instance, National Research Programme 26 (People, Health, Environment) has shown that if long-term exposure increases by 10 micrograms of PM10 per m^3, the risk of various diseases of the respiratory tract rises by 30 to 60%.

Scientific findings show that the risk presented by different aerosols varies in magnitude. Above all, **diesel soot emissions** are currently considered carcinogenic and very hazardous to health. Diesel soot particles consist of tiny spherical tar particles. Typical diesel soot particles have a diameter of 0.1–0.2 μm, but can also be larger. Other carcinogenic organic substances absorb on the particle surface, but their carcinogenicity is negligible compared to that of the particles (Yetergil 1997, p. 38ff). Soot particles also have a global warming impact (termed “black carbon” by the IPCC (2001)), which is small compared to the hazard to health (see Part 3, Section 9.2.7).

The “coarse” fraction of suspended particulate matter **(PM2.5–10)** is associated more closely with coughing, asthma attacks and other diseases of the respiratory tract. These larger aerosols can be coughed out of the lung. The fine fractions (**PM2.5)** correlate more with cardiac dysrhythmia and an increased incidence of cardiovascular diseases. These fine particles remain much longer in the lungs and accumulate there, as they are difficult to cough up. Ultrafine particles (PM0.1) – **diesel soot particles** are on this scale – can enter the bloodstream and lymphatic system through the lungs. Over time, they are decomposed by the immune system and excreted (BUWAL 2011c).

Building upon these more recent findings, more detailed eco-factors are derived below for particles of different sizes and properties. The fact that the “total particulate” emissions previously listed in some inventory analyses cannot be converted directly into the new categories is tolerated.

At present, there are two reduction targets for particles: 1) for PM10 and 2) for diesel soot. Although it is to be assumed that the health impacts of PM2.5 are more severe than those of PM10, no corresponding differentiation has yet been performed at the political or statutory level.

9.8.2 Normalization

Due to a lack of robust data, no characterization is performed. PM2.5–10 and PM2.5 are subgroups with the same environmental policy target. Therefore, the normalization flow for the entire PM10 group and for the PM2.5–10 and PM2.5 subgroups is identical to the current flow of PM10.

9.8.3 Weighting

Current flow

The current flow of 20 500 t/a for **PM10** is based on the FOEN (2012a). **PM10** emissions from abrasion and resuspension are difficult to quantify. As the update is partially based on estimated values, a degree of uncertainty remains in this regard. The current flow for **PM2.5** is 9700 t/a (BAFU 2012a). The current flow for **PM2.5–10** results from the difference of the annual loads for PM2.5 and PM10 and is 10 700 t.

Critical flow

The Swiss Air Pollution Control Ordinance (LRV 2010) has stipulated ambient limit values for **PM10** (annual mean µg/m³; 24-h mean 50 µg/m³) since 1 March 1998. These were adopted at the recommendation of the Swiss Federal Commission for Air Hygiene based on the health impacts of fine particulate exposure (BUWAL 1996b). According to the Swiss Federal Council (Schweizerischer Bundesrat 2009), the emission target is to reduce **PM10** emissions by 45% under the 2005 level, which corresponds to the previous critical flow of 12 000 t/a.

There is no limit value for **PM2.5** in Switzerland. However, as it is a subgroup of PM10, the same target can be applied (minus 45%), i.e. the critical flow is 5700 t/a.

The reduction target for PM10 (minus 45%) is also taken for the **PM2.5–10** fraction, i.e. the critical flow is 6300 t/a.

9.8.4 Eco-factors for PM10, PM2.5 and PM2.5–10

Tab. 20 > Eco-factor for PM10 in UBP/g PM10

	Edition 2013	Q	Notes	Edition 2006
Normalization (t PM10/a)	20 470	A		22 000
Current flow (t PM10/a)	20 470	A	PM10 emissions including diesel soot (BAFU 2012c)	22 000
Critical flow (t PM10/a)	12 000	a	(Schweizerischer Bundesrat 2009)	12 000
Weighting (-)	2.91			3.36
Eco-factor (UBP/g PM10.)	**140**			150

Q = data quality; for explanation, see Part 2, Chapter 6

Tab. 21 > Eco-factor for PM2.5 in UBP/g PM2.5

	Edition 2013	Q	Notes	Edition 2006
Normalization (t PM2.5/a)	20 470	A	Applying target for PM10	22 000
Current flow (t PM2.5/a)	9 741	A	PM2.5 emissions including diesel soot (BAFU 2012c)	12 745
Critical flow (t PM2.5/a)	5 710	a		6 952
Weighting (-)	2.91			3.36
Eco-factor (UBP/g PM2.5)	**140**			150

Q = data quality; for explanation, see Part 2, Chapter 6

Tab. 22 > Eco-factor for PM2.5–10 in UBP/g PM2.5–10

	Edition 2013	Q	Notes	Edition 2006
Normalization (t PM2.5–10/a)	20 470	A	Applying target for PM10	22 000
Current flow (t PM2.5–10/a)	10 729	A	Difference between PM2.5 and PM10, emissions including diesel soot	9 255
Critical flow (t PM2.–5–10/a)	6 290	a		5 048
Weighting (-)	2.91			3.36
Eco-factor (UBP/g PM2.5–10)	**140**			150

Q = data quality; for explanation, see Part 2, Chapter 6

Due to the decline in PM10 emissions compared to the situation in 2006, the eco-factors are now somewhat lower. The eco-factors for PM2.5 and PM2.5–10 are identical to that of PM10, as the same (relative) reduction target is applied in each case.

9.8.5 Guidelines for application

If the eco-factor for diesel soot is also used, care must be taken so that the particles are not double weighted (see Part 3, Section 9.9.4), as the particle groups overlap (Fig. 5).

9.9 Particulate matter (II): Diesel soot

9.9.1 Introduction

The sources and impacts of diesel soot are described in Part 3, Section 9.8.1.

There are indications that the toxic effect correlates more closely with the particle number than the mass, particularly in the case of diesel soot. If that is the case, the eco-factor would need to relate to the particle number. The requisite measurement technology, however, is not yet mature and derivation based on particle number is therefore not (yet) possible.

9.9.2 Normalization

The normalization flow is identical to the current flow, as no characterization is applied and the target directly concerns diesel soot.

9.9.3 Weighting

Current flow

Although the Swiss Air Pollution Control Ordinance (LRV) expressly uses the term "diesel soot", heating oil combustion processes will also be considered below, as the ensuing soot emissions scarcely differ from diesel soot. However, gas and petrol engines are still not included, as the fraction of EC (elemental carbon) in their PM emissions is low and thus negligible at this time. A total current flow of 1700 t/a[3] results for 2010.

Critical flow

There is no threshold value for the carcinogenic effect of **diesel soot**. Diesel soot is the most important component of particulate emissions in motor combustion processes. Therefore, when applying the minimization rule for the emissions of carcinogenic substances (LRV, Annex 1 (82), para 1), the technological and operational feasibility, as well as economic viability, of reducing emissions should be required (Precautionary principle, Part 2, Section 4.3). The precautionary minimization rule can be deemed to be observed based on the following assumptions:

1. Euro-6 and Euro-VI road vehicle emissions standards
2. Construction machine equipment with particle filters in accordance with the requirements of the Swiss Air Pollution Control Ordinance (LRV)
3. Other machines in accordance with EU Directive 97/68/EC.

Diesel soot is a complex mixture. Similar to the prescriptions for diesel engines in underground mining by the Swiss Accident Insurance Fund (SUVA), diesel soot is measured as an elemental carbon in Frischknecht et al. (2008). In comparison to the Frischknecht et al. (2008) report, the problem is once again that due to particle filters, the PM emissions of diesel engines included in the publications have an extremely low EC fraction and consist mostly of incinerated residues. According to estimates by the FOEN[3], these PM emissions from engines with particle filters will be approximately

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[3] «Kritische Flüsse Luftreinhaltung Aktualsierung Ökofaktoren UBP 2012 Stand März 2013.xlsx» data file submitted by Harald Jenk, Federal Office for the Environment, on 28 March 2013

115 t by 2035, and may not actually be taken into account in the determination of the critical flow (as they are incinerated residues and not elemental carbon). Other calculations show that non-filtered diesel soot emissions calculated as elemental carbon will drop to approximately 92 t by 2035.

As the statistics do not discuss the elemental carbon fraction separately and petrol and gas engines are not included, the PM emissions from engines with particle filters are once again used for the diesel soot emission flows. This results in a critical flow of 208 t per year[3].

9.9.4 Eco-factor for diesel soot

Tab. 23 > Eco-factor for diesel soot in UBP/g diesel soot

To be applied when the life cycle inventory contains correspondingly adjusted PM10 and PM2.5 data.

	Edition 2013	Q	Notes	Edition 2006
Normalization (t diesel soot/a)	1661	B	Base year 2010	3400
Current flow (t diesel soot/a)	1661	B	Base year 2010	3400
Critical flow (t diesel soot/a)	208	a	LRV, precautionary principle	450
Weighting (-)	63.8			57.1
Eco-factor (UBP/g diesel soot)	**38 000**			17 000

Q = data quality; for explanation, see Part 2, Chapter 6,
Source: "Kritische Flüsse Luftreinhaltung Aktualsierung Ökofaktoren UBP 2012 Stand März 2013.xlsx" file[3]

The eco-factor for diesel soot is higher by a factor of 270 than the eco-factor for PM10 or PM2.5. This reflects the fact that diesel soot particles have a far more harmful impact on human health than other particles. Particle filters effectively eliminate soot particles. A considerable reduction of other air pollutants has already been achieved by deploying catalytic converters for cars with gasoline engines. Current assessments of transportation and combustion processes therefore depend greatly upon diesel soot emissions.

Diesel soot also has a global warming impact (see Part 3, Section 9.2.7). The eco-factor calculated for the impact, however, is much lower than the eco-factor derived here for the human health impact.

9.10 Carbon monoxide (CO)

Carbon monoxide is an air pollutant that is formed in incomplete combustion processes. CO emissions can also arise naturally from the chemical transformation processes of microorganisms (e.g. oxidation of methane). Motor vehicle traffic generates more than 60% of anthropogenic CO emissions (BAFU 2012a).

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

In Switzerland, there are statutory provisions governing maximum permissible concentrations, but not for loads. Therefore, the carbon monoxide eco-factor is derived on the basis of its global warming potential (Part 3, Section 9.2.7).

9.11 Carcinogenic pollutants: benzene, dioxins & furans (PCDD/PCDF) and polycyclic aromatic hydrocarbons (PAHs)

9.11.1 Sources and environmental impact

Benzene, dioxins and furans, and polycyclic aromatic hydrocarbons (PAHs) are carcinogenic substances and characterized in similar ways. That is why these substances are discussed in the same section.

Benzene

Small quantities of *benzene* are present in crude oil and are formed when mineral oil is refined or organic matter is burnt incompletely (e.g. in forest fires). Benzene emissions to the atmosphere result primarily from combustion processes. In Switzerland, motorised transportation is the source of three-fourths of all benzene emissions. The remainder is attributable to wood and oil-fired heating systems, and to losses in fuel handling and storage (BUWAL 2003b). Inhalation is the main exposure route for benzene. Benzene is soluble in fat and therefore stored in the fatty tissue of the body. As women have a higher body fat ratio than men, the impacts of benzene are greater for women. Individuals living or working near to highly travelled roads or near petrol stations are also more greatly exposed. Uptake through the skin is only relevant when benzene is handled directly (BUWAL 2003b). Benzene is toxic to blood formation and chronic exposure can lead to leukaemia. There is unequivocal evidence that benzene is carcinogenic and strong indications that it is mutagenic. There is no threshold below which exposure to benzene is not a hazard to human health (BUWAL 2003b).

Dioxins and furans

Dioxins and furans (PCDD and PCDF) are chlorinated aromatic hydrocarbons, and some of them are highly toxic to humans and animals. There are a total of 76 dioxins and 135 furans. They are formed in technological and natural combustion processes in the presence of chlorine. These processes always generate a mixture of various individual substances, expressed as a “dioxins and furans” aggregate parameter (PCDD/F) in international toxicity equivalents (I-TEQ[4]). They accumulate in the food chain and are also embryotoxic. Dioxins impair embryonal development in several ways. In particular, they appear to give rise to miscarriage, deformity of the (genital) organs, and intellectual deficits (BUWAL 1995; Lippmann 2000). Dioxins and furans are scarcely volatile; their dispersal is mainly through attachment to particles. The main exposure route is the ingestion of foods containing fat. In 2001, the WHO (2002), together with the FAO, recommended a PTMI (provisional tolerable monthly intake) of 70 pg I-TEQ/kg per body weight and month. Based on the precautionary principle, the target is a value of less than 1 pg I-TEQ per kilogram of body weight and day. This also corresponds to the German position (UBA 2012).

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

PAHs

Polycyclic aromatic hydrocarbons (PAHs) is the term used for a group of different compounds. PAHs have some carcinogenic effect in mammals. The various PAH substances are aggregated, similar to dioxins, with toxicity equivalents (TEQ) in accordance with EPA (1993) (see tab. 24).

Tab. 24 > Characterization of specific polycyclic aromatic hydrocarbons (PAHs) according to EPA (1993)

	Characterization (g BaP-eq./g)
Benzo(a)pyrene	1.000
Benzo(a)anthracene	0.100
Benzo(b)fluoranthene	0.100
Benzo(k)fluoranthene	0.010
Chrysene	0.001
Dibenz(a,h)anthracene	1.000
Indeno(1,2,3-cd)pyrene	0.100

9.11.2 Characterization

The individual substances are characterized (see tab. 25). For that purpose, the characterization factors for carcinogenic, toxic substances (human toxicity, carcinogenic effects, recommended+interim) according to USEtox (Henderson et al. 2011) are used and expressed in “Comparative Toxic Units[5] (CTUh)”.

9.11.3 Normalization

The normalization flow corresponds to the characterized quantity of emissions of the PAH substances, dioxins and furans, and benzene concerned and is identical to the current flow (see tab. 25).

9.11.4 Weighting

Current flow

The current flow corresponds to the characterized quantity of the emissions of the PAH substances concerned, dioxins and furans, and benzene and is 0.90 CTUh/a (see tab. 25).

Current flow of benzene

Measurements of the actual emissions of road vehicles have shown that earlier prognoses for benzene emissions were too low. Furthermore, benzene emissions at stationary facilities were reported in greater detail, which also leads to higher benzene emissions compared to earlier estimates. However, the benzene emissions of engines in off-road vehicles dropped, as conveyed in the FOEN report on fuel emissions and pollutant emissions in the off-road sector (“Treibstoffemissionen und Schadstoffemissionen des Off-Road-Sektors”). According to EMIS (as per 10 February 2012), the current flow for benzene is 1626 t/a.

Current flow of dioxins

Prior to 1955, dioxin and furan emissions were under 40 g I-TEQ/a. They rose to 485 g I-TEQ/a in the period from 1955 to 1980. Due to better exhaust purification

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[5] For human toxicity, this corresponds to the probability of a form of cancer per kilogram of emitted chemical

technology, they have since dropped again, as today all municipal waste incineration plants are fitted with a flue gas purification system (BUWAL 2002b). Annual emissions were reduced to 14 g I-TEQ/a by 2010 (BAFU 2012a).

Current flow of PAHs

According to the FOEN (2012a), benzo(a)pyrene emissions in 2010 were 145 kg, benzo(b)fluoranthene emissions 184 kg, benzo(k)fluoranthene emissions 201 kg and indeno(1,2,3-cd)pyrene emissions 202 kg.

Tab. 25 > Characterization factors according to USEtox (human toxicity, carcinogenic effects, recommended), emitted quantities according to the FOEN (2012a) and calculated characterized quantities

Substance	Characterization factor (CTUh/kg)	Emitted quantities 2010 (kg/a)	Characterized quantities (CTUh/a)
Benzo(a)pyrene	$3.5*10^{-5}$	144.5	0.0050
[a]Benzo(b) fluoranthene	$3.5*10^{-6}$	184.1	0.0006
[a]Benzo(k) fluoranthene	$3.5*10^{-7}$	200.8	0.0001
[a]Indeno (1,2,3-cd) pyrene	$3.5*10^{-6}$	201.5	0.0007
[a]Benz(a)anthracene	$3.5*10^{-6}$	n.a	0.0004[b]
[a]Chrysene	$3.5*10^{-8}$	n.a	$4.0*10^{-6}$[b]
[a]Dibenz(a,h)anthracene	$3.5*10^{-5}$	n.a	0.0012[b]
Dioxins and furans	29	0.014	0.41
Benzene	$3.0*10^{-7}$	1626000	0.48
Total			**0.90**

[a]The characterization factors were calculated using the characterization factor in USEtox for benzo(a)pyrene and the TEQ factors according to EPA (1993)

[b]Estimate based on Yanxu & Shu (2009)

Critical flow

The critical flow is individually derived and summated for each substance group. The sum of the characterized critical flows is 0.58 CTUh.

Critical flow of benzene

There is no threshold value for the carcinogenic effect of benzene. In accordance with the minimization rule for emissions of carcinogenic substances (LRV 2010, Annex 1 (82), para 1), the precautionary principle should be applied (Part 2, Section 4.3). This means that all technologically and operationally feasible and economically viable measures must be taken.

Engines in line with Euro-6 standards are the state of the art in road transportation. In Switzerland, the EU standards for small, petrol-driven equipment have been in effect since 1 January 2011. The figures projected by the EMIS database for 2035 are used here for fuel handling and storage and for combustion processes.

Benzene emissions from road transportation were projected to be 467 t in the year 2035 (BAFU 2010c). Boat motors/equipment generate 17 t/a, while 466 t/a will be released by 2035 due to the handling and storage of fuels and combustion processes (EMIS, as per 10 February 2012). In total, this corresponds to a critical flow of 950 t/a for benzene.

According to a report on benzene in Switzerland (“Benzol in der Schweiz”, BUWAL 2003d), benzene emissions would need to be reduced to 100 t per year so as not to exceed an acceptable risk.[6] Such a target, however, would go substantially beyond what technology and operating conditions and economic viability would allow today.

Critical flow of dioxins

As dioxins and furans accumulate in the food chain, their formation needs to be prevented wherever possible. In comparison to the situation in 2006, emissions have been reduced from 68 g I-TEQ/a to 14 g I-TEQ/a. For the period to 2020, emissions are expected to drop again to 9.95 g I-TEQ/a. Therefore, in line with the precautionary principle, the critical flow corresponds to 9.95 g I-TEQ/a.[7]

Critical flow of PAHs

According to the Swiss Federal Council (2009), carcinogenic substances should be reduced “to the extent technologically possible and proportionately”. According to the Federal Office for the Environment, a maximum of 50% of current benzo(a)pyrene emissions can be prevented. This corresponds to a critical flow of 72 kg of benzo(a)pyrene.[8] The target for benzo(a)pyrene is applied to all PAH substances concerned.

Tab. 26 > Characterization factors according to USEtox (human toxicity, carcinogenic effects, recommended), targets based on text and resulting characterized critical flow

Substance	Characterization factor (CTUh/kg)	Target (kg/a)	Characterized quantities (CTUh/a)
Benzo(a)pyrene	$3.5*10^{-5}$	72	0.0025
[a]Benzo(b) fluoranthene	$3.5*10^{-6}$	92	0.00032
[a]Benzo(k) fluoranthene	$3.5*10^{-7}$	100	0.000035
[a]Indeno (1,2,3-cd) pyrene	$3.5*10^{-6}$	101	0.00035
[a]Benz(a)anthracene	$3.5*10^{-6}$	n.a	0.00020[b]
[a]Chrysene	$3.5*10^{-8}$	n.a	0.0000020[b]
[a]Dibenz(a,h)anthracene	$3.5*10^{-5}$	n.a	0.00059[b]
Dioxins and furans	29	0.00995	0.29
Benzene	$3.0*10^{-7}$	950 000	0.28
Critical flow			**0.576**

[a] The characterization factors were calculated using the characterization factor in USEtox for benzo(a)pyrene and the TEQ factors according to EPA (1993)

[b] Estimate based on Yanxu & Shu (2009)

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[6] The term «permitted risk» is defined in a legal opinion developed at the request of BUWAL (now the FOEN). It concludes that the constitutional right to protection and the absence of risk to human health caused by the anthropogenic effects of individual substances is guaranteed for a lifetime risk of 1/1000 000, as such a risk is scarcely detectable and practically indiscernible from zero (BUWAL 2003d: Sect. 6.1)

[7] Personal communication, Harald Jenk, Federal Office for the Environment, 5 November 2012

[8] Personal communication, Peter Straehl, Research Assistant, Federal Office for the Environment, 14 May 2012

9.11.5 Eco-factor for benzene, dioxins and furans, and PAHs

Tab. 27 > Eco-factor for benzene, dioxins and furans, and PAHS in UBP/CTUh

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (CTUh/a)	0.90	B	see text	
Current flow (CTUh/a)	0.90	B	see text	
Critical flow (CTUh/a)	0.576	b	see text	
Weighting factor (-)	2.46			
Eco-factor (UBP/CTUh)	$2.7 * 10^{12}$			

Q = data quality; for explanation, see Part 2, Chapter 6

tab. 28 below shows the resulting eco-factors in UBP per gram of substance.

Tab. 28 > Eco-factors for benzene, dioxins and furans, and PAHs in UBP/g substance

Substance	Eco-factor 2013 (UBP/g)	Eco-factor 2006 (UBP/g)
Benzo(a)pyrene	**95 000**	
*Benzo(b) fluoranthene	**9 500**	
*Benzo(k) fluoranthene	**9 500**	
*Indeno (1,2,3-cd) pyrene	**950**	
*Benz(a)anthracene	**95**	
*Chrysene	**95 000**	
*Dibenz(a,h)anthracene	**9 500**	
Dioxins and furans	**$7.9 * 10^{10}$**	$5.7 * 10^{10}$
Benzene	**810**	3 800

The eco-factor for PAHs is introduced for the first time in this version of the ecological scarcity method. The eco-factor for dioxin is somewhat higher than it was in 2006. The 2013 eco-factor for dioxins and furans is very high. This not only reflects the lower emission levels (a few grams per year), but also the high degree of damage caused by these substances. The eco-factor for benzene has dropped compared to 2006, as not only the current flow is higher, but the critical flow also turns out to be higher than it was.

9.11.6 Regionally specific eco-factors for PAHs

The composition of PAHs varies according to the region in which they are emitted (Yanxu & Shu 2009). Therefore, specific eco-factors are calculated for the average PAH emissions on individual continents, while one eco-factor is assigned to the global PAH average The eco-factors for the regional PAH compositions are substantially lower than those of the individually listed PAH substances, as the regional PAH compositions are a mixture of 16 substances, of which 9 have no characterization factor for carcinogenic effect (characterization factor = 0). Global PAH emissions are dominated by the burning of biomass (including bioenergy use and uncontrolled fires). In contrast, PAH emissions in North and Central America are generated primarily by the use of consumer goods and the burning of fuels (Yanxu & Shu 2009). Both processes generate primarily naphthalene emissions. As naphthalene accounts for 74% of the emissions and has a characterization factor for carcinogenic effect of zero in North and Central America according to Yanxu and Shu (2009), the average PAH emissions in this region have the lowest characterization factor and thus the lowest eco-factor.

Tab. 29 > Characterization and eco-factors of PAHs for regional average values

Regional average values	Characterization (g BaP-eq./g)	Eco-factors 2013 (UBP/g)
PAHs global average	0.014	**1 400**
PAHs Africa	0.012	**1 100**
PAHs Asia	0.017	**1 600**
PAHs Europe	0.012	**1 100**
PAHs North & Central America	0.0067	**630**
PAHs Oceania	0.012	**1 200**
PAHs South America	0.013	**1 300**

9.11.7 Eco-factors for other carcinogenic substances under the Swiss Air Pollution Control Ordinance (LRV)

Table 83 in Annex 1 Art. 3 (1) 1 of the Swiss Air Pollution Control Ordinance (LRV) lists other carcinogenic substances (LRV 2010). An eco-factor is calculated for these substances, provided characterization factors are indicated in USEtox (Henderson et al. 2011, human toxicity, carcinogenic effects, recommended+interim).

Tab. 30 > Substances that are classified in LRV (2010) Table 83 as carcinogenic and assessed with USEtox, as well their characterization factors and eco-factors in UBP/g

Assessed substances in LRV table 83		CAS	Characterization factor (CTUh/kg)	Eco-factor 2013 (UBP/g)
Acrylonitrile	C_3H_3N	107-13-1	$2.02 * 10^{-6}$	**5 500**
1,3 Butadiene	C_4H_6	000106-99-0	$5.71 * 10^{-7}$	**1 600 ***
1-Chloro-2,3-epoxypropane	C_3H_5ClO	000106-89-8	$5.26 * 10^{-7}$	**1 400 ***
1,2-Dibromoethane	$C_2H_4Br_2$	000106-93-4	$1.96 * 10^{-5}$	**53 000**
3,3-Dichlorobenzidine	$C_{12}H_{10}N_2Cl_2$	91-94-1	$6.31 * 10^{-6}$	**17 000**
1,4 Dichlorobenzene	$C_6H_4Cl_2$	000106-46-7	$2.15 * 10^{-7}$	**590**
1,2-Dichloroethane	$C_2H_4Cl_2$	107-06-2	$4.15 * 10^{-7}$	**1 100 ***
1,2 Epoxypropane	C_3H_6O	75-56-9	$2.65 * 10^{-7}$	**720 ***
Ethylene oxide	C_2H_4O	75-21-8	$8.30 * 10^{-7}$	**2 300 ***
2-Naphthylamine	$C_{10}H_9N$	91-59-8	$4.84 * 10^{-7}$	**1 300**
2-Nitrotoluene	$C_7H_7NO_2$	88-72-2	$6.03 * 10^{-6}$	**16 000**
Vinyl chloride	C_2H_3Cl	75-01-4	$2.75 * 10^{-6}$	**7 500 ***
N-Vinyl-2-pyrrolidone	C_6H_9NO	88-12-0	$1.25 * 10^{-6}$	**3 400**

* An eco-factor is also derived for these substances through NMVOCs (cf. Part 3, Section 9.2.7), which is nevertheless lower than the eco-factor derived here. According to the methodological principles, the highest of the resulting eco-factors is applied in each case.

9.11.8 Implementation in the ecoinvent v.2.2 database

The ecoinvent v.2.2 database includes the following PAH elementary flows in air:

- Acenaphthene
- Benzo(a)pyrene
- PAHs (polycyclic aromatic hydrocarbons)

No carcinogenic effect is detected in acenaphthene, which is why this substance has no eco-factor (eco-factor = 0). PAHs are not further specified PAHs, which is why they are assessed with the eco-factor for PAHs according to the global average.

9.12 Lead (Pb)

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

9.12.1 Normalization

As the various lead compounds are not characterized, the normalization flow is the quantity emitted to air across Switzerland.

9.12.2 Weighting

Current flow

Because lead was blended into petrol, lead emissions have risen sharply since the 1950s. They peaked at 2160 t/a in 1970. Thanks to the introduction of unleaded petrol, emissions have since dropped. Other uses of lead include batteries, paints and lead for bullets. Total emissions were 23 t/a (BAFU 2012a) in 2010. These 23 tonnes are generated mainly by waste incineration plants, industrial combustion processes and the steel industry.

Critical flow

The Swiss Air Pollution Control Ordinance (LRV 2010) stipulates ambient limit values (annual mean values) for lead in dust deposition. However, no critical flow can be derived from this. Yet, a theoretical critical flow can be derived from the weighting factor for soil, as described below.

Weighting factor

The purpose of the Swiss Air Pollution Control Ordinance is to "[…] protect humans, animals, plants, their biotic communities and habitats as well as soil from air pollution that is harmful or noxious" (LRV, Art. 1). Soil protection is thus a stated goal of the Swiss Air Pollution Control Ordinance. It is therefore possible to apply the targets established for soils to air emissions as well, i.e. to make use of the weighting factors for emissions to soils. If soil is taken to be a target of protection in its own right, the ratio of current to critical flow for heavy metal emissions to air that ultimately enter the soil through deposition must be the same as that for direct emissions to soil. The weighting factor for lead in the soil, as described in Part 3, Section 4.2, is therefore used.

9.12.3 Eco-factor for lead

Tab. 31 > Eco-factor for lead emissions to air in UBP/g lead

	Edition 2013	Q	Notes	Edition 2006
Normalization (t Pb/a)	23	B		91
Current flow (t Pb/a)	23	B	(BAFU 2012a)	91
Critical flow (t Pb/a)	(32)		Theoretical value calculated from weighting	(58)
Weighting (-)	0.51		Corresponds to weighting factor for lead loading of soil	2.44
Eco-factor (UBP/g Pb)	**22 000**			27 000

Q = data quality; for explanation, see Part 2, Sect. 6

The eco-factor is slightly lower than in 2006. The lower current flow leads to both a new weighting factor below 1 and a lower normalization flow.

9.13 Cadmium (Cd)

9.13.1 Environmental impact

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

9.13.2 Normalization

As the various cadmium compounds are not characterized, the normalization flow is the quantity emitted to air across Switzerland.

9.13.3 Weighting

Current flow

Cadmium emissions peaked at 7 t/a around 1970. As a result of measures taken in waste incineration and the metal industry, they have dropped substantially since 1980. The main applications of cadmium are alloys and the production of dry batteries and colouring pigments. In 1995, emissions amounted to approximately 2.5 t/a. (BUWAL 1995, p. 90). According to the FOEN (2012a), cadmium emissions were about 1.3 t/a in 2010.

Critical flow

The Swiss Air Pollution Control Ordinance (LRV 2010) stipulates ambient limit values (annual mean values) for cadmium in dust deposition. However, no critical flow can be derived from this. Yet, a theoretical critical flow can be derived by using the weighting factor for soil, as described in the next section.

Weighting factor

The purpose of the Swiss Air Pollution Control Ordinance is to "[…] protect humans, animals, plants, their biotic communities and habitats as well as soil from air pollution that is harmful or noxious" (LRV, Art. 1). Soil protection is thus a stated goal of the Swiss Air Pollution Control Ordinance. It is therefore possible to apply the targets established for soils to air emissions as well, i.e. to make use of the weighting factors for emissions to soils. If soil is taken to be a target of protection in its own right, the ratio of current to critical flow for heavy metal emissions to air that ultimately enter the soil through deposition must be the same as that for direct emissions to soil. The weighting factor for cadmium in the soil, as described in Part 3, Section 4.2, is therefore used.

9.13.4 Eco-factor for cadmium

Tab. 32 > Eco-factor for cadmium emissions to air in UBP/g cadmium

	Edition 2013	Q	Notes	Edition 2006
Normalization (t Cd/a)	1.26	B		2.00
Current flow (t Cd/a)	1.26	B	(BAFU 2012a)	2.00
Critical flow (t Cd/a)	(1.65)		Theoretical value calculated from weighting	(2.08)
Weighting (-)	0.580		Corresponds to weighting factor for cadmium loading of soil	0.925
Eco-factor 2013 (UBP/g Cd)	**460 000**			460 000

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor has not changed since 2006. The current flow, the weighting factor and the normalization flow have all decreased. Due to the ban on cadmium-containing accumulators and their resulting replacement by modern, cadmium-free alternatives, a further decrease can be expected in the future.

9.14 Mercury (Hg)

9.14.1 Environmental impact

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

9.14.2 Normalization

No characterization is performed. The normalization flow amounts to the quantity of emissions to air produced by all of Switzerland and is identical to the current flow.

9.14.3 Weighting

Current flow

The principal generators of mercury emissions are the steel industry and municipal waste incineration plants. According to the FOEN (BAFU 2012a), mercury emissions were 1050 kg/a in 2010.

Critical flow

As mercury is not addressed by the study on heavy metal inventories (Keller et al. 2005b), an eco-factor cannot be derived for mercury from the rate of accumulation in the soil. Mercury is, however, addressed by the NABO standard measurement programme. It has found major dynamics with regard to mercury concentration changes. Yet, the guideline value of 0.5 mg/kg was only exceeded at 3 of 102 sites (BUWAL 2000b).

The strictest target of the Swiss air pollution control strategy is to reduce emissions to their levels in 1950 (Schweizerischer Bundesrat 1999). In the case of mercury, emissions in 1950 amounted to 2220 kg Hg. This value is considered the critical flow.

9.14.4 Eco-factor for mercury

Tab. 33 > Eco-factor for mercury emissions to air in UBP/g mercury

	Edition 2013	Q	Notes	Edition 2006
Normalization (kg Hg/a)	1 054	B		1 020
Current flow (kg Hg/a)	1 054	B	(BAFU 2012a)	1 020
Critical flow (kg Hg/a)	2 220	b		2 220
Weighting (-)	0.21			0.21
Eco-factor (UBP/g Hg)	**210 000**			210 000

Q = data quality; for explanation, see Part 2, Chapter 6

As the current flow has risen only slightly compared to the situation in 2006, the eco-factor remains unchanged after rounding.

9.15 Zinc (Zn)

9.15.1 Environmental impact

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

9.15.2 Normalization

As the various zinc compounds are not characterized, the normalization flow is the quantity emitted to air across Switzerland.

9.15.3 Weighting

Current flow

Until the 1970s, zinc emissions came mainly from steelworks and the unfiltered burning of waste. Total emissions peaked in 1970 at 1750 t/a. In 1995, approximately 630 t were still emitted, whereby falling emissions in industry and commerce were partly offset by rising zinc emissions from road traffic (tyre and road abrasion).

According to the FOEN (BAFU 2012a), zinc emissions were 380 t/a in 2010,whereby their main source was the transportation sector, which accounted for 87% of the emissions. If the trend towards increasing zinc emissions from transportation persists, overall zinc emissions can be expected to rise again, as no further significant reductions are anticipated in industry.[9]

Critical flow

The Swiss Air Pollution Control Ordinance (LRV 2010) stipulates ambient limit values (annual mean values) for zinc in dust deposition. However, no critical flow can be derived from this. Yet, a theoretical critical flow can be derived by using the weighting factor for soil.

Weighting factor

The purpose of the Swiss Air Pollution Control Ordinance is to "[…] protect humans, animals, plants, their biotic communities and habitats as well as soil from air pollution that is harmful or noxious" (LRV, Art. 1). Soil protection is thus a stated goal of the Swiss Air Pollution Control Ordinance. It is therefore possible to apply the targets established for soils to air emissions as well, i.e. to make use of the weighting factors for emissions to soils. If soil is taken to be a target of protection in its own right, the ratio of current to critical flow for heavy metal emissions to air that ultimately enter the soil through deposition must be the same as that for direct emissions to soil. The weighting factor for zinc in soil, as described in Part 3, Section 4.2, is therefore used.

9.15.4 Eco-factor for zinc

Tab. 34 > Eco-factor for zinc emissions to air in UBP/g zinc

	Edition 2013	Q	Notes	Edition 2006
Normalization (t Zn/a)	378	B		560
Current flow (t Zn/a)	378	B	(BAFU 2012a)	560
Critical flow (t Zn/a)	(260)		Theoretical value calculated from weighting	(359)
Weighting (-)	2.12		Corresponds to weighting factor for zinc loading of soil	2.44
Eco-factor (UBP/g Zn)	**5 600**			4 400

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor for zinc is higher compared to 2006, as the current flow and the normalization flow have dropped.

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[9] Personal communication, S. Hoehn, FOEN, 25 February 2012

9.16 Radioactive emissions to air

9.16.1 Introduction

Until now, radioactive emissions to air have been excluded from assessments using the ecological scarcity method, as the quantity of emissions from nuclear power plants in Switzerland is well below statutory limits. However, the system was not fully represented because an assessment of radioactive emissions to air had not been carried out. For this reason, these emissions are now being assessed.

9.16.2 Environmental impact

Exposure to radiation transfers energy into human tissue, and in doing so, can interfere with the molecular structure. This can disturb or destroy cell functions in living organisms (somatic effects, i.e. fatal or non-fatal cancer), or it can alter the genetic code of the cells (mutagenic effects).

The characterization factors take both of these effects into account. The impact of radiation on ecosystems is not considered here, nor are the potential impacts of accident-related releases of large quantities of radioactive substances.

9.16.3 Characterization

The environmental impact of the emission of radioactive elements is characterized according to its carcinogenic impact on humans. Impacts on ecosystems are not considered.

The characterization of emissions to air is based on the work of ExternE (1999). Carbon-14 serves as the reference substance. The characterization factors according to Frischknecht et al. are listed in tab. 35 (2000).

Tab. 35 > Characterization factors for the carcinogenic potential of radioactive emissions to air, according to Frischknecht et al. (2000), reference element C-14

		Carcinogenic potential of radioactive elements (kBq C-14-eq./kBq)
Carbon-14	C-14	1.0
Cobald-58	Co-58	0.002
Cobalt-60	Co-60	0.076
Cesium-134	Cs-134	0.057
Cesium-137	Cs-137	0.062
Tritium	H-3	0.000067
Iodine-129	I-129	4.5
Iodine-131	I-131	0.00076
Iodine-133	I-133	0.000045
Krypton	Kr-85	$6.7*10^{-7}$
Lead-210	Pb-210	0.0071
Polonium-210	Po-210	0.0071
Plutonium-alpha	Pu alpha	0.40
Plutonium-238	Pu-238	0.32
Radium-226	Ra-226	0.0043
Radon-222	Rn-222	0.00011
Thorium-230	Th-230	0.21
Uranium-234	U-234	0.46
Uranium-235	U-235	0.10
Uranium-238	U-238	0.039
Xenon-133	Xe-133	$6.7 *10^{-7}$

9.16.4 Normalization

Data on emissions from radioactive substances from nuclear power plants are compiled by the Swiss Federal Nuclear Safety Inspectorate (ENSI 2010). The characterization of the corresponding nuclides as set out in Part 3, Section 9.16.3 resulted in a total volume of emissions of 1.08 TBq C-14-eq. for 2009. In the abovementioned case of radioactive emissions to air, the current flow corresponds to the normalization flow.

9.16.5 Weighting

Current flow

Emissions from Swiss nuclear power plants were 1.08 TBq C-14-eq. in 2009 (ENSI 2010).

Critical flow

The emissions limits of radioactive substances from Swiss nuclear power plants are set for individual plants, but they differ when it comes to noble gases, aerosols and Iodine-131 for nuclear power plants and β-/γ-aerosols, α-aerosols, Tritium and Carbon-14 for interim storage facilities. The emission limits correspond to those authorised for each nuclear power plant. For nuclear power plants, the limit is set so that the dose for individuals in the vicinity is under 0.3 mSv/year. For the central interim storage facility in Würenlingen, the limit for the dose is 0.05 Sv/year, while it is 0.15 Sv/year for the Paul Scherrer Institute (ENSI 2010). Hospitals emit no isotopes to the air.

A separate limit has not been set for nuclide C-14 from nuclear power plants (ENSI 2010). The real emissions are used to set approximate limits for individual nuclear power plants in line with the ratio of permitted annual dose to actual annual dose.

Through characterization and addition of the emissions of all facilities, the limits are aggregated to one single value. This results in a characterized critical flow of 1160 TBq C-14-eq. per year.

9.16.6 Eco-factor for radioactive emissions to air

Tab. 36 > Eco-factor for radioactive emissions to air in UBP/MBq C14-eq.

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (TBq C-14-eq./a)	1.08	A	Emissions from nuclear power plants (ENSI 2010)	
Current flow (TBq C-14-eq./a)	1.08	A	Emissions from nuclear power plants (ENSI 2010)	
Critical flow (TBq C-14-eq./a)	1 164	b	Based on the annual dose for individuals in the vicinity (ENSI 2010)	
Weighting factor (-)	$8.6*10^{-7}$			
Eco-factor (UBP/MBq C-14-eq)	**0.80**			

Q = data quality; for explanation, see Part 2, Chapter 6

9.16.7 Eco-factors for individual isotopes

Using the characterization described in Part 3, Section 9.16.3, it is possible to calculate eco-factors for selected isotopes. These are listed in tab. 37 and apply to the emissions of these substances to air. Because of the way these eco-factors have been derived, they should not be used for loads in other compartments.

Tab. 37 > Eco-factors for the discharge of radioactive isotopes into air, deduced from their impact potential according to Frischknecht et al. (2000)

		Carcinogenic potential of radioactive elements (kBq C-14-eq./kBq)	Eco-factor 2013 (UBP/MBq)
Carbon-14	C-14	1.0	**0.80**
Cobald-58	Co-58	0.0020	**0.0016**
Cobalt-60	Co-60	0.076	**0.061**
Cesium-134	Cs-134	0.057	**0.046**
Cesium-137	Cs-137	0.062	**0.050**
Tritium	H-3	0.000067	**0.000054**
Iodine-129	I-129	4.5	**3.6**
Iodine-131	I-131	0.00076	**0.00061**
Iodine-133	I-133	0.000045	**0.000036**
Krypton	Kr-85	0.00000067	**5.40*10^{-7}**
Lead-210	Pb-210	0.0071	**0.0057**
Polonium-210	Po-210	0.0071	**0.0057**
Plutonium-alpha	Pu alpha	0.40	**0.32**
Plutonium-238	Pu-238	0.32	**0.26**
Radium-226	Ra-226	0.0043	**0.0035**
Radon-222	Rn-222	0.00011	**0.000092**
Thorium-230	Th-230	0.21	**0.17**
Uranium-234	U-234	0.46	**0.37**
Uranium-235	U-235	0.10	**0.080**
Uranium-238	U-238	0.039	**0.032**
Xenon-133	Xe-133	0.00000067	**5.40*10^{-7}**
Radioactive species, other beta emitters	*	0.027	**0.021**
Noble gases, radioactive, unspecified	*	0.00000016	**1.25*10^{-7}**
Aerosols, radioactive, unspecified	*	0.029	**0.023**

* For explanation, see Part 3, Section 9.16.8

9.16.8 Guidelines for using the ecoinvent v.2.2 database

In the current ecoinvent v2.2 database, the data on emissions of individual nuclides are non-exhaustive. The compositions of the mixtures are determined from the data on radioactive emissions from European nuclear power plants and reprocessing plants (Van der Stricht & Janssens 2005; 2010). The eco-factor for the mixture is determined using the eco-factors of the individual nuclides (see tab. 37). The resulting eco-factors are conservative values, as not all components of the mixtures are characterized.

10 > Emissions to surface waters

10.1 Introduction

10.1.1 Preliminary remarks

The eco-factors for the weighting of emissions to waters are based on the loads for all of Switzerland and therefore apply to the "average" situation in the country. Regional conditions are only taken into account in the case of phosphorus. For example, substances that pose a problem in individual small bodies of water still present levels in the Rhine below the required concentration limit for bodies of water, due to dilution. Ideally, graded eco-factors should be made available to reflect the situation in different bodies of water. This has not been done on economic grounds, but if need be, it could be undertaken at any time, as set out in the chapter on methodology (Part 2, Chapter 4).

The derivation of eco-factors for emissions to bodies of water is based on simplifications that do not take ecological conditions fully into account. The aim of determining eco-factors is not to be able to make an ecological assessment of individual pollutant emissions, but to produce a comparative weighting across all environmental media within life cycle assessments.

As explained in the chapter on groundwater (see Part 3, Section 11.1), the eco-factors for surface waters should *not* be applied to pollutants emitted to groundwater.

10.1.2 Selection of substances

Due to the effluent purification measures that have been taken, the emissions to surface waters of a number of substances have been reduced significantly. Therefore, some of the remaining emissions are of subordinate importance for the ecology of Swiss waters. This poses the question as to what extent eco-factors should be assigned to such substances. The fact that eco-factors are applied not only to emissions within Switzerland, but also outside the country should be taken into consideration. An eco-factor is therefore provided, wherever possible, for substances that may be unproblematic in Switzerland, but have the potential to be environmentally relevant abroad.

Annex 2 of the Swiss Waters Protection Ordinance (GSchV 2011) sets out water quality requirements for watercourses. The list of numerical requirements under Paragraph 12 (5) of the Swiss Waters Protection Ordinance represents a starting point for the selection of eco-factors for substances that pollute waters. Additions to the list include phosphorus, on account of its significant impact on water quality in lakes, the aggregate parameter AOX (absorbable organic halogens), endocrine disruptors, radioactive emissions (in Switzerland and from reprocessing spent fuel), oil emissions to the sea and persistent organic pollutants (POPs).

The water pollutants weighted with an eco-factor are listed in tab. 38. The impacts of the pollutants are also outlined, and those that are critical in determining the eco-factor are indicated. In many instances, the quality target set by the ICPR (International Commission for the Protection of the Rhine), which does not relate only to the environmental impact, has been used.

10.1.3 Guidelines for application

Substances from Switzerland reach the sea through the Rhine, the Rhone, the Ticino and the Inn Rivers. Two-thirds of the water flowing out of Switzerland reaches the North Sea through the Rhine. Due to the import of products from countries located on seas, further direct emissions are discharged into them. The eco-factors for nitrogen, radioactive emissions and oil are already based to some extent on marine protection targets. For that reason, the eco-factors derived in this chapter should be applied to emissions to the sea. One exception is the newly developed eco-factor for oil emissions to the sea. This eco-factor refers exclusively to emissions to the sea and may not be applied to other water compartments (e.g. rivers, etc.).

Tab. 38 > Impact mechanisms of the assessed water pollutants

	Environmental				Human						Notes
	Eutrophication	Oxygen consumption	Toxicity in fish	Bioaccumulation	Metabolic disturbances	Carcinogenicity	Mutagenesis	Embryonal damage	Other/further types of damage	Characterization	
Nitrogen	#		(x)							-	
Phosphorus	#									-	
Organic matter (BOD, COD, DOC, TOC)		#								-	
Arsenic (As)				x	x	x		(x)		-	As per ICPR Rhine quality target
Lead (Pb)				x	x					-	As per ICPR Rhine quality target
Cadmium (Cd)				x	x	x		(x)		-	As per ICPR Rhine quality target
Chromium (Cr)				x	x					-	As per ICPR Rhine quality target
Copper (Cu)				x	x					-	As per ICPR Rhine quality target
Nickel (Ni)				x	x					-	As per ICPR Rhine target
Mercury (Hg)				x	x					-	As per ICPR Rhine target
Zinc (Zn)				x	x					-	As per ICPR Rhine target
Radioactive emissions to domestic waters						x	x		x	U235-eq.	Emission limits according to the FOPH
Radioactive emissions to seas						x	x		x	C14-eq.	Reduction to natural background levels
Oil emissions to the sea			x								As per OSPAR target
AOXs				x	x				x	-	As per ICPR Rhine target
Chloroform						(x)			x	-	As per ICPR Rhine target
PAHs						x				-	As per ICPR Rhine target
Benzo(a)pyrene						(x)				-	As per ICPR Rhine target
Endocrine disruptors					#			x	x	E2-eq.	
Persistent organic pollutants (POPs)			x	#		x	x		x	2,4,6-T-eq	

x = Impact or link proven; (x) = Impact or link presumed; # = Impact significant to determining the eco-factor

10.2 Nitrogen (N)

10.2.1 Environmental impact

Over 90% of anthropogenic total nitrogen in surface waters consists of nitrate and ammonium or ammonia. Sources of nitrogen in bodies of water are agricultural fertilizers and industrial, commercial and household effluents. The eco-factors in this chapter evaluate only the nitrogen loads in surface waters. Nitrogen compounds (particularly nitrate), which are first released into groundwater and enter surface waters from there, are assessed separately in the chapter on groundwater (see Part 3, Section 11.2).

Current levels of individual nitrogen species such as nitrate or ammonium no longer pose a general problem for the ecology of the surface waters in Switzerland, although local problems may persist. However, the nitrogen load in the North Sea and other shallow seas is of great importance as regards eutrophication. Therefore, the aim is to achieve a marked reduction in the nitrogen discharged into the North Sea, such as by reducing nitrogen loads in the Rhine, among other measures (BAFU 2010a).

10.2.2 Normalization

No characterization is performed. The anthropogenic nitrogen load for the Rhine catchment amounts to 28 700 t N/a (OSPAR Commission 2008a). Runoff via the Rhine amounts to a long-term mean of around 38 billion m^3/a, while the total for Switzerland comes to 48 billion m^3/a. This produces an extrapolated load of 36 200 t N/a for all of Switzerland.

10.2.3 Weighting

Current flow

Since the reduction target refers only to emissions in the Rhine catchment within Switzerland (see below for the critical flow), the current flow must cover the same area. According to the OSPAR Commission (2008a), the current flow amounts to 28 700 t N/a.

Critical flow

In 1987, as a result of the over-use of fertilizers, which became evident during the 1980s, the countries bordering the North Sea issued a declaration of intent.[10] Its aim was to reduce loads of phosphorus and nitrogen to 50% of 1985 levels by 1995. Although it is responsible for only a small amount of the total discharge into the Rhine, Switzerland has contributed to these efforts (BUWAL 1996, p. 36). In the case of nitrogen, the target has still not been reached, but 28% of the loads were reduced by 2005 (OSPAR Commission 2008a).

This target is used as a basis for establishing the critical flow for total nitrogen emissions (N_{tot}). The nitrogen load in the Rhine catchment from 1985 was updated in the submission of 2008 and now amounts to 39 700 t N/a (OSPAR Commission 2008a). As a result, the critical flow is 19 900 t N/a. The derivation of the critical flow from the Swiss Waters Protection Ordinance would result in a significantly higher critical flow[11], which is why it is not used.

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[10] Second International Conference on the Protection of the North Sea, London, 24–25 November 1987

[11] Assuming a mean runoff via the Rhine of 1000 m^3/s and taking the required value of 5.6 mg NO_3-N/l, a critical flow of 176 600 t NO_3-N/a would result for the Rhine catchment alone.

10.2.4 Eco-factor for nitrogen in surface waters

Tab. 39 > Eco-factor for nitrogen in surface waters in UBP/g N

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t N/a)	36 197	B	OSPAR Commission (2008a) and extrapolated to all of Switzerland using NADUF runoff data (2011b)	31 360
Current flow (t N/a)	28 656	A	Rhine catchment only (OSPAR Commission 2008a)	24 827
Critical flow (t N/a)	19 875	a	50% reduction target in Rhine catchment from 1985 levels (OSPAR Commission 2008a)	17 510
Weighting factor (-)	2.08			2.01
Eco-factor (UBP/g N)	**57**			64

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor for nitrogen has dropped by around 10% compared to the previous situation. The nitrogen discharged into the Rhine catchment has risen slightly from 24 800 t N/a in 2006 to 28 700 t N/a. The critical flow was adjusted due to the fact that nitrogen emissions from diffuse sources in 1985 were recalculated, resulting in 39 749 t N/a (OSPAR Commission 2008a, p. 23).

10.3 Phosphorus (P)

10.3.1 Environmental impact

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

The phosphorus load in lakes varies greatly depending on the location. Alpine lakes (e. g. Lake Lucerne, Lake Thun) exhibit very low concentrations of phosphorus, whereas lakes in areas of intensive farming can still be severely polluted by the phosphorus that is applied to the fields in the form of manure and synthetic fertilizers. Soil erosion and phosphorus discharged by urban drainage can contribute to higher phosphorus loads. The connection of households and businesses to sewage treatment works and the ban on phosphates in textile detergents led to a marked drop in the phosphorus load in the 80s and 90s (BLW & BUWAL 1998; BUWAL 2004a).

Phosphorus is released into bodies of water as particle-bound phosphate, mainly through erosion and leaching from cropland. Agriculture’s continuing substantial contribution to the loads is also a consequence of the liberal use of fertilizers in the past. Thus, pastures and agricultural land in Switzerland register a phosphorus content that greatly exceeds the annual requirements of plants. The Waters Protection Act (GSchG 2011) requires a balanced quantity of fertilizers so that bodies of water are not adversely affected by runoff and quantities of fertilizer washed into them. Consequently, it is now only permitted to use as much phosphorus as the crops can take up. Moreover, the Chemical Risk Reduction Ordinance (ChemRRV, 2013) contains regulations on permitted applications of fertilizers. Thus, fertilizer guidelines, plant stocks, nutrient levels in soil, weather conditions, among other factors, must all be taken into consideration.

10.3.2 Normalization

No characterization is performed. The amount of phosphorus discharged into surface waters across Switzerland can only be estimated, as the runoff from agricultural land, which accounts for a significant proportion, is impossible to measure directly. Therefore, phosphorus is equated with discharge through watercourses. Phosphorus entering the bodies of water is absorbed by algae and aquatic plants and eventually deposited through sedimentation of the biomass in lakes or released back into the water when biomass decomposes.

The phosphorus load from anthropogenic sources for the Rhine catchment amounts to 1500 t P/a (OSPAR Commission 2008a). Runoff via the Rhine amounts to a long-term mean of around 38 billion m^3/a, while the total runoff for Switzerland comes to 48 billion m^3/a. This results in a phosphorus discharge through watercourses of 1900 t P/a for all of Switzerland.

10.3.3 Weighting: protecting the North Sea

Current flow

The current flow differs from the normalization flow, as the reduction target only applies to the Rhine catchment. According to the OSPAR Commission (2008a), the phosphorus load amounts to 1500 t P/a.

Critical flow

The countries bordering the North Sea have issued a ministerial declaration aimed at reducing phosphorus and nitrogen loads to 50% of their 1985 levels. Switzerland has also signed this declaration. The phosphorus target has already been achieved. At 1500 t P/a, the critical flow is slightly higher than the current flow (OSPAR Commission 2008a).

10.3.4 Weighting: phosphorus content in Swiss lakes

The numerical limit set out in the Waters Protection Ordinance does not apply to phosphorus, but rather to the oxygen required by organisms. The general environmental target for lakes is an oxygen content of 4 mg per litre at each depth of a lake (GSchV 2011, Annex 2, Paragraph 13). Furthermore, the nutrient content must permit at most an average production of biomass (GSchV 2011, Annex 2, Paragraph 13). Each lake is a special case due to its morphology and geographical location or weather exposure. The nutrient content requirements for average production at most can therefore be determined with one single value that applies in the same way to all lakes. According to the FOAG and the FOEN (BAFU & BLW 2008), this requirement is met in many lakes, if the average content or concentration value of spring circulation is less than 20 mg of total phosphorus per cubic meter (20 µg P per litre) for several years. This corresponds to the environmental target for agriculture, in which the total phosphorus content in lakes, whose phosphorus loads mainly come from agriculture, should be less than 20 µg of phosphorus per litre (BAFU & BLW 2008).

Regional weighting factors

The weighting factor (and the resulting eco-factor) for phosphorus can also be calculated separately for each lake in Switzerland (tab. 40). For lakes with an average phosphorus concentration above 20 mg/m³, the target value is the same as the target for agriculture, while for lakes with a concentration under 20 mg/m³, the target is the average phosphorus concentration from the period from 2008 to 2010. Some lakes have a measured value that is well below 20 mg/m³ (Walensee), while others exceed it quite considerably (Lake Zug and the north basin of Lake Lugano). The ecological scarcity of the large Swiss lakes is thus extremely varied when it comes to phosphorus.

To determine the average ecological scarcity of phosphorus in Switzerland, both the individual phosphorus concentrations and the volume of water in the lakes are relevant. The lakes' capacity to absorb phosphorus is dependent upon these two parameters. As the weighting factor has the effect of squaring the ratio of the current to the target concentration, the average weighting factor is determined on the basis of the sum of the weighting factors of each lake, weighted with their respective volumes (see tab. 40).

Tab. 40 > Calculation of the weighting factor for Swiss lakes based on the current and critical concentrations

Only lakes with reliable values for 2010 based on testing frequency have been included

	Volume of lake m³ (millions)	Total concentration of phosphorus mg/m³	Derived target value* mg/m³	Weighting factor (-)
Lake Geneva	89 900	22	20	1.25
Lake Constance	48 000	6.0	6.7	0.81
Lake Neuchâtel	14 170	7.0	7.7	0.83
Lake Maggiore	37 100	10	10	1.00
Lake Lucerne	11 800	5.0	4.3	1.33
Lake Zurich	3 900	21	20	1.10
Lake Lugano, north basin	4 690	73	20	13.3
Lake Lugano, south basin	1 140	42	20	4.41
Lake Thun	6 500	4.0	3.3	1.44
Lake Biel	1 240	18	20	0.81
Lake Zug	3 210	94	20	22.1
Lake Brienz	5 170	5.0	4.7	1.15
Walensee	2 490	3.0	3.3	0.81
Lake Murten	600	21	18	1.31
Lake Sempach	660	23	20	1.32
Lake Hallwil	215	19	20	0.90
Lake Greifensee	161	48	20	5.76
Lake Baldegg	178	26	20	1.69
Lake Pfäffikon	58	16	16	1.00
Weighting factor for Switzerland				**1.65**

Source: "Phosphor in den Seen 2010_2011.xls" data file[12]

*The Waters Protection Act requires that nutrient content allow for average biomass production at most. Therefore, the environmental target for agriculture has been selected for lakes with an average phosphorus concentration above 20 mgP/m³, while the target for the other lakes is the average concentration of the last 3 years (2008–2010).

10.3.5 Eco-factor for phosphorus

In Sections 10.3.3 and 10.3.4, the weighting has been derived by two different methods: in one instance, from the 50% reduction target for emissions to the North Sea and in the second, from the derived target values (environmental target for agriculture and average phosphorus concentration of the last 3 years) for Swiss lakes. The calculation of the eco-factor from the derived target values for Swiss lakes leads to higher values. The eco-factor derived from the 50% reduction target will therefore not be included in tab. 41.

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[12] Data on phosphorus in lakes transmitted by Jean-Philippe Houriet, Federal Office for the Environment, on 23 September 2011. The data were collected by international water commissions (CIPEL, CIPAIS, IGKB), cantonal water protection authorities, Eawag and Wasserversorgung Zürich (WVZ, Zurich water utility for Zurich and the Walensee).

Tab. 41 > Eco-factor for phosphorus in UBP/g P

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t P/a)	1854	B	Extrapolated using NADUF runoff data (BAFU 2011a) from the loads for the Rhine catchment according to the OSPAR Commission (2008a)	1694
Current flow (t P/a)	-			-
Critical flow (t P/a)	-			-
Weighting factor (-)	1.65		Calculated from the lake protection target	2.04
Eco-factor (UBP/g P)	**890**			1200

Q = data quality; for explanation, see Part 2, Chapter 6

The lower eco-factor reflects the easing of the phosphorus problem and the effect of the measures taken. As shown in tab. 40, some lakes are still subject to severe pollution. However, concentrations have also fallen compared to previous years.

10.4 Organic matter (BOD, COD, DOC, TOC)

10.4.1 Environmental impact

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

Due to measures to improve effluent treatment, the pollution of Swiss bodies of water by organic substances has fallen in recent decades. Moreover, the legislation (GSchV) requires the implementation of measures to reduce organic matter in effluent to a level at which there is no ecological detriment to bodies of water. In most cases, the residual load from effluent treatment works is non-critical in terms of the total oxygen available. For that reason, persistent, bioaccumulative and toxic organic substances are of foremost environmental importance (see POPs, Part 3, Section 10.14). However, the specific impacts of the substances encompassed by the aggregate parameter “organic matter” cannot be considered here.

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

- **BOD (biochemical oxygen demand)**
  BOD_x expresses the amount of oxygen consumed by biological activity in water in x days. Incubation takes place in the dark, at 20° C and normally over a period of 5 days (BOD_5). The proportion of hydrocarbons that break down readily, particularly

through microbial degradation, is determined from this. The BOD value is always lower than the COD value. Usually, BOD_5 is determined.

- **COD (chemical oxygen demand)**
  COD expresses the amount of oxygen required to oxidize organic compounds. In Switzerland, COD is used mainly to determine the quality of the discharge from water treatment works (effluent parameter). In most other countries, water pollution by organic matter is assessed in terms of COD. Many life cycle inventories contain figures for COD emissions.
- **DOC (dissolved organic carbon)**
  DOC measures the bound organic carbon content of dissolved organic compounds. This measurement produces more exact results than the COD test when dealing with small concentrations such as those in Swiss watercourses (clean water parameter).
- **TOC (total organic carbon)**
  TOC is a measure of the total carbon bound in organic molecules. It is made up of dissolved organic carbon and particle-bound organic carbon.

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

10.4.2 Normalization

No characterization is performed. The total load cannot be extrapolated from the COD concentrations at the places where the large rivers flow out of Switzerland, as some of the organic substances are of natural origin and degrade to some extent relatively quickly in water courses, which means that they do not reach the measuring stations at these runoff points.

The data collected by the VSA (2011) covers over 80% of Switzerland's inhabitants who are connected to a sewage disposal system and are thus good data for the extrapolation of organic matter emissions from wastewater treatment plants. The annual runoff loads of COD amount to 37 000 tonnes.

10.4.3 Weighting

The current flow is identical to the normalization flow, since the reduction target is also based on the total load for Switzerland. **Current flow**

The Waters Protection Ordinance (GSchV 2011) sets out a purification capacity of 85% for dissolved organic carbon when it comes to the disposal of communal effluents discharged into bodies of water. When applied to an annual incoming load of 490 000 tonnes of COD, this results in a critical flow of about 74 000 tonnes of COD per year. **Critical flow**

10.4.4 Eco-factors for BOD, COD, DOC and TOC

As all of these factors measure the same thing – organic carbon – care must be taken not to count them twice. It is preferable only to assess COD, for which the eco-factor has been derived directly from the current and critical flows. In inventory analyses, missing COD values can then be derived from the other values using the rule of thumb in Part 3, Section 10.4.1.

Tab. 42 > Eco-factor for COD (chemical oxygen demand) in UBP/g COD

The eco-factors for BOD, DOC and TOC can be calculated using the general rules of thumb BOD ≈ COD, COD ≈ 3 DOC and DOC ≈ TOC, if no inventory analysis data is available for COD – see also the text regarding counting twice.

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t COD/a)	37 002	B	Total runoff loads for Switzerland (VSA 2011)	47 700
Current flow (t COD/a)	37 002	B	Total runoff loads for Switzerland (VSA 2011)	47 700
Critical flow (t COD/a)	73 527	b	Derived from GSchV 2011	144 000
Weighting factor (-)	0.25			0.11
Eco-factor (UBP/g COD)	**6.8**			2.30
Eco-factor (UBP/g BOD)	6.8		Rough approximation: BOD ≈ COD	2.30
Eco-factor (UBP/g DOC)	21		Derived from the eco-factor for COD with COD ≈ 3 DOC	6.90
Eco-factor (UBP/g TOC)	21		Rough approximation: COD ≈ 3 DOC ≈ 3 TOC	6.90

Q = data quality; for explanation, see Part 2, Chapter 6

The resulting eco-factor is higher than in the situation in 2006. This was the first time that data were accessible for all of Switzerland. Both the current and critical flows are substantially lower than previously determined.

The weighting of specific impacts of persistent bioaccumulative substances is not possible with the eco-factor for COD. These substances are assessed separately (see Part 3, Section 10.14).

10.5 Heavy metals and arsenic

10.5.1 Environmental impact

Heavy metals and arsenic damage the aquatic ecosystem by accumulating in organisms, where they can cause growth impairments and metabolic disturbances. They are able to propagate extensively through the food chain.

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

Cadmium is an ingredient of phosphorus fertilizers and pesticides. For that reason, agriculture is another source of heavy metals. Chromium arises mainly from the corrosion of chromium steel products. Since the use of leaded petrol has declined and industrial effluent discharges have been cleaned up, these have now become the predominant diffuse sources of heavy metals (BUWAL 2002a).

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

10.5.2 Normalization

No characterization is performed. The total load of heavy metals entering surface waters in Switzerland can be extrapolated from the concentration values measured in the Rhine.

In Weil am Rhein, heavy metal concentrations in the water are determined in accordance with NADUF guidelines (BAFU 2011a), and the heavy metal content of suspended matter is measured according to the International Commission for the Protection of the Rhine (AUE 2009). The NADUF values have been used to determine the normalization, as these include dissolved heavy metals. In order to compensate for the occasional extreme variations in concentration from one year to another and obtain more representative values, the mean value for the years 2006 to 2009 has been used in each case (tab. 43).

The following factors may account for a difference between the actual situation and the extrapolated flow:

> the total concentration of heavy metals rises with the concentration of suspended matter, since the metals accumulate there. In the Rhone, which registers comparatively high particle concentrations, concentrations of heavy metals may therefore exceed those in the Rhine.
> Between entering the water and being measured in Basel, the heavy metals undergo some degree of exchange with the sediment. Depending on the concentration ratios in the river and the sediment, net heavy metals are either dissolved or deposited.

Tab. 43 > Calculation of the normalization flow for heavy metals based on NADUF concentration figures (mean value for the years 2006 to 2009) at Weil am Rhein monitoring station

	Mean load in the Rhine (g/s)	Normalization flow (t/a)
Arsenic (As)	0.231*	10.7*
Lead (Pb)	0.590	27.4
Cadmium (Cd)	0.014	0.66
Chromium (Cr)	0.485	22.6
Copper (Cu)	1.74	81.1
Nickel (Ni)	1.34	62.4
Mercury (Hg)	0.004	0.20
Zinc (Zn)	2.65	123

* Arsenic values calculated from ICPR (2004) concentration figures and the assumption of 17.5 kg of suspended solids/s (mean value for the years 2006 to 2009 based on NADUF)

10.5.3 Weighting

Weighting factor

Seven heavy metals with implications for the environment are listed in the Swiss Waters Protection Ordinance (GSchV 2011). They are mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu), zinc (Zn) and nickel (Ni). The Waters Protection Ordinance sets out quality requirements for watercourses in the form of required and guideline values and for the discharge of effluent into sewers and bodies of water.

In addition, the Convention on the Protection of the Rhine (IKSR 1999), which was renewed in 1999 and signed by Switzerland, came into force in 2003. The ICPR (International Commission for the Protection of the Rhine), like the Swiss Waters Protection Ordinance, sets water quality targets in the form of concentrations limits, which include limits for heavy metals.

The ratio of the heavy metal content in the suspended solids to the target values according to AUE (2009) is substantially higher than the ratio of the total concentration of heavy metals in water to the concentration limits under the Swiss Waters Protection Ordinance. Therefore, the more stringent targets, and thus higher eco-factors based on ICPR data, are used for the weighting. To produce the weighting factor, the concentrations in the suspended solids (rather than the rivers) are compared directly with each other (tab. 44). The data on current concentrations is taken from the annual reports of the Rhine monitoring station at Weil am Rhein (AUE 2007; 2008; 2009), which give the most recent figures.

Tab. 44 > Weighting factors for heavy metals calculated from current and critical concentrations

	Current concentration (measured value) (mg/kg suspended matter)	Critical concentration (target value) mg/kg suspended matter)	Weighting (-)
Arsenic (As)	13.2	40	0.11
Lead (Pb)	33.8	100	0.11
Cadmium (Cd)	0.41	1.00	0.17
Chromium (Cr)	53.1	100	0.28
Copper (Cu)	51.2	50	1.05
Nickel (Ni)	42.3	50	0.72
Mercury (Hg)	0.21	1	0.17
Zinc (Zn)	176	200	0.77
Source:	(AUE 2007, 2008, 2009)	(AUE 2009)	

10.5.4 Eco-factors for heavy metals and arsenic in surface waters

Tab. 45 > Eco-factors for heavy metals in surface waters in UBP/g of each heavy metal

	Normalization (t/a)	Q	Current concentration (mg/kg)	Q	Critical concentration (mg/kg)	Q	Weighting (-)	Eco-factor 2013 (UBP/g)	Eco-factor 2006 (UBP/g)
Arsenic (As)	10.7	B	13.2	A	40	a	0.109	**10 000**	8 000
Lead (Pb)	27.4	B	33.8	A	100	a	0.11	**4 200**	4 400
Cadmium (Cd)	0.66	B	0.41	A	1.00	a	0.17	**250 000**	290 000
Chromium (Cr)	22.6	B	53.1	A	100	a	0.28	**12 000**	7 600
Copper (Cu)	81.1	B	51.2	A	50	a	1.05	**13 000**	14 000
Nickel (Ni)	62.4	B	42.3	A	50	a	0.72	**11 000**	6 800
Mercury (Hg)	0.20	B	0.21	A	0.50	a	0.17	**860 000**	880 000
Zinc (Zn)	123	B	176	A	200	a	0.77	**6 200**	5 000

Q = data quality; for explanation, see Part 2, Chapter 6

The values required by the Waters Protection Ordinance have not altered since being used in Brand et al. (1998), which would have resulted in the eco-factors staying more or less the same. A higher eco-factor is derived by using Rhine and Rhine water ecosystem targets (ICPR targets) instead of watercourse ecosystem limit values (limits for water quality under the Swiss Waters Protection Ordinance). By using the more stringent targets from the ICPR, political developments are taken into account. The resulting eco-factors are just as high as those in 2006. In particular, the eco-factors for chromium and nickel are significantly higher than the eco-factors in 2006.

10.6 Radioactive emissions to domestic waters

10.6.1 Introduction

Until now, radioactive emissions to rivers have been excluded from assessments using the ecological scarcity method, as the quantity of emissions from nuclear power plants and hospitals in Switzerland is well below statutory limits. The system was not fully represented due to the lacking assessment of radioactive emissions to rivers. For this reason, these emissions are now being assessed.

10.6.2 Environmental impact

Exposure to radiation transfers energy into human tissue, and in doing so, can interfere with the molecular structure. This can disturb or destroy cell functions in living organisms (somatic effects, i.e. fatal or non-fatal cancer), or it can alter the genetic code of the cells (mutagenic effects).

The characterization factors take both of these effects into account. The impact of radiation on ecosystems is not considered here, nor are the potential impacts of accident-related releases of large quantities of radioactive substances.

10.6.3 Characterization

The environmental impact of the emission of radioactive elements is characterized according to its carcinogenic impact on humans. Impacts on ecosystems are not considered. Uranium-235 is the reference substance. tab. 46 lists the characterization factors according to Frischknecht et al. (2000).

Tab. 46 > Characterization factors for the carcinogenic potential of radioactive emissions to rivers, according to Frischknecht et al. (2000), reference element u-235

		Carcinogenic potential of radioactive elements (kBq U-235-eq./kBq)
Silver-110m	Ag-110m	0.22
Cobalt-58	Co-58	0.018
Cobalt-60	Co-60	20
Cesium-134	Cs-134	6.1
Cesium-137	Cs-137	74
Tritium	H-3	$1.91*10^{-4}$
Iodine-131	I-131	0.22
Manganese-54	Mn-54	0.13
Radon-226	Ra-226	0.056
Antimony-124	Sb-124	0.36
Uranium-234	U-234	1.04
Uranium-235	U-235	1.0
Uranium-238	U-238	1.0

10.6.4 Normalization

Data on emissions of radioactive substances from nuclear power plants and hospitals are recorded by the Swiss Federal Nuclear Safety Inspectorate (ENSI 2010; BAG 2010). The characterization of the corresponding nuclides as set out in Part 3, Section 10.6.2 results in a total volume of emissions of 0.29 TBq U-235-eq. for 2009. In the case of radioactive emissions to rivers, the current flow corresponds to the normalization flow.

10.6.5 Weighting

Current flow

The actual emissions from Swiss nuclear power plants and hospitals amounted to about 0.29 TBq U-235-eq. in 2009. These flows are documented by ENSI (2010) and the FOPH (BAG 2010).

Critical flow

Emission limits for radioactive substances from Swiss nuclear power plants and hospitals are set for individual facilities and differ when it comes to Tritium and the nuclide mixture, as they do not include Tritium for nuclear power plants and Iodine-131 for hospitals. The emission limits correspond to those authorised for each nuclear power plant. For nuclear power plants, the limit is set so that the dose for individuals in the vicinity is under 0.3 mSv/year. For the central interim storage facility in Würenlingen, the specific dose limit is 0.05 Sv/year, and for the Paul Scherrer Institute (ENSI 2010), it is 0.15 Sv/year. Effluent discharged from hospitals may not exceed the activity concentration of 1/50 of the permitted limit for Iodine-131 on a weekly average basis (BAG 2010). Through the characterization and addition of all facilities, the limits are aggregated to one single value. This results in a characterized critical flow of 36 TBq U-235-eq. per year.

10.6.6 Eco-factor for radioactive emissions to surface waters

Tab. 47 > Eco-factor for radioactive emissions to rivers in UBP/MBq U235-eq

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (TBq U235-eq./a)	0.289	A	Emission from Swiss nuclear power plants	
Current flow (TBq U235-eq./a)	0.289	A	(BAG 2010; ENSI 2010)	
Critical flow (TBq U235-eq./a)	36.14	a	(BAG 2010; ENSI 2010)	
Weighting factor (-)	6.37»10^{-5}			
Eco-factor (UBP/MBq U235-eq.)	**220**			

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor for radioactive emissions is a new addition.

10.6.7 Eco-factors for individual isotopes

Using the characterization described in Part 3, Section 10.6.2, it is possible to calculate eco-factors for selected isotopes. These are listed in tab. 48. They apply to the load of these substances discharged into rivers. Because of the way these eco-factors have been derived, they may not be used for discharges into other compartments.

Tab. 48 > Eco-factors for the discharge of radioactive isotopes into rivers, deduced from their impact potential according to Frischknecht et al. (2000)

		Carcinogenic potential of radioactive elements (kBq U-235-eq./kBq)	Eco-factor 2013 (UBP/MBq)
Silver-110m	Ag-110m	0.22	**48**
Cobalt-58	Co-58	0.018	**4.0**
Cobalt-60	Co-60	20	**4 200**
Cesium-134	Cs-134	6.1	**14 000**
Cesium-137	Cs-137	74	**17 000**
Tritium	H-3	1.91*10^{-4}	**0.042**
Iodine-131	I-131	0.22	**48**
Manganese-54	Mn-54	0.13	**30**
Radon-226	Ra-226	0.056	**13**
Antimony-124	Sb-124	0.36	**78**
Uranium-234	U-234	1.04	**230**
Uranium-235	U-235	1.0	**220**
Uranium-238	U-238	1.0	**220**
Radioactive species, nuclides, unspecified	*	13	**2 800**
Radioactive species, alpha-emitters	*	0.014	**30**

* For explanation, see Part 3, Section 10.6.8

10.6.8 Guidelines for using the ecoinvent v.2.2 database

In the current ecoinvent v2.2 database, emissions of individual nuclides are indicated in summary form. The composition of the “radioactive species, nuclides, unspecified” mixture is specified in the ecoinvent report (Dones 2007, p. 209). The “radioactive species, alpha-emitters” mixture includes the emissions of alpha emitters from nuclear power plants. The composition of these mixtures is determined on the basis of available data on radioactive emissions from European nuclear power plants (Van der Stricht & Janssens 2010).

The characterization and the eco-factors for the summary parameter were averaged based on the eco-factors of emitted single nuclides. The resulting eco-factors of the mixtures are conservative, as not all single nuclides are characterized. This primarily concerns the alpha-emitter mixture.

10.7 Radioactive emissions to seas

10.7.1 Introduction

The reason why radioactive emissions to seas are assessed lies in the OSPAR Conventions for the protection of the North Sea. The OSPAR member states have agreed to substantially reduce the loads of radioactive substances from reprocessing plants that end up in the Irish and North Seas.

Because of this, an eco-factor is derived on the basis of emissions occurring outside Switzerland. The reduction targets are based on international agreements that Switzerland supports. (A similar procedure is applied in Part 3, Section 13.6 in relation to freshwater use in arid countries.)

The moratorium on reprocessing spent fuel elements, which came into effect on 1 July 2006, has no influence on the scarcity formula produced here. This is an exceptional situation, which will last for a limited period of time. The cessation of reprocessing and its associated emissions of radioactive elements to seas will nonetheless have an impact on future inventory analyses of electricity generation at Swiss nuclear power plants. Indeed, the inventory analyses of French nuclear energy, for instance, remain uninfluenced, in line with France’s strategy for the disposal of spent fuel elements. Emissions generated by French nuclear energy are still relevant to Switzerland because of the electricity Switzerland imports from France.

10.7.2 Environmental impact

Exposure to radiation transfers energy into human tissue, and in doing so, can interfere with the molecular structure. This can disturb or destroy cell functions in living organisms (somatic effects, i.e. fatal or non-fatal cancer), or it can alter the genetic code of the cells (mutagenic effects).

The characterization factors take both of these effects into account. The impact of radiation on ecosystems is not considered here, nor are the potential impacts of accident-related releases of large quantities of radioactive substances.

10.7.3 Characterization

The environmental impact of the emission of radioactive elements is characterized according to their carcinogenic effect on humans. Impacts on ecosystems are not considered. The reduction targets for discharges into the Irish and North Seas are stipulated under the OSPAR Convention. Therefore, the characterization values of pollutant discharges into seas are of interest here. Carbon-14 has been chosen as the reference substance. The characterization factors are determined on the basis of Frischknecht et al. (2000) and listed in tab. 49.

Tab. 49 > Characterization factors for the carcinogenic potential of radioactive emissions to seas, according to Frischknecht et al. (2000), reference element C-14

		Carcinogenic potential of radioactive elements (kBq C-14-eq. /kBq)
Americum-241	Am-241	25.8
Carbon-14	C-14	1.00
Curium-alpha	Cm alpha	47.5
Cobalt-60	Co-60	0.325
Cesium-134	Cs-134	0.066
Cesium-137	Cs-137	0.066
Tritium	H-3	$5.75*10^{-5}$
Iodine-129	I-129	83.3
Plutonium-alpha	Pu alpha	6.17
Ruthenium-106	Ru-106	0.117
Antimony-125	Sb-125	0.0125
Strontium-90	Sr-90	0.0033
Uranium-234	U-234	0.0192
Uranium-235	U-235	0.0208
Uranium-238	U-238	0.0192

10.7.4 Normalization

The annual emissions classified by isotopes are documented by the OSPAR Commission (2008b; 2009b; 2010; 2011). The radionuclides listed there are assigned characterization factors in accordance with tab. 49 in Section 10.7.3. The quantity of characterized emissions amounts to an average of 130 TBq C-14-eq./a for the years 2006 to 2009.

Switzerland’s share of Europe’s electricity production from nuclear power plants is around 2.9% (Itten et al. 2012). This percentage is used for normalization, resulting in a normalization value of 3.9 TBq C-14-eq./a.

At both of the La Hage and Sellafield reprocessing plants, around 2500 tonnes of spent fuel rods are reprocessed annually (Select Committee on Science and Technology 1999). Since the OSPAR Convention stipulates the target in absolute terms, the quantity of spent fuel rods is not relevant to the calculation.

10.7.5 Weighting

Current flow

OSPAR targets are defined separately for alpha and beta emitters (see next paragraph). These two separate targets have been amalgamated here to a single goal by means of characterization. As the French reprocessing plant at La Hage does not set any quantitative targets, it is assumed that the Sellafield target is also applicable to the French facility. Based on this assumption, it is sufficient to look at the emissions from the Sellafield reprocessing plant to determine the weighting factor.

The emissions from the Sellafield plant fluctuate from year to year, following a downward trend (see OSPAR Commission 2008b; 2009b; 2010; 2011). In order to exclude random values, a sliding average over four years (2006–2009) is used. This four-year average value of the current emissions from Sellafield amounts to 26 TBq C14-eq. (1.9 TBq C14-eq. alpha and 24.2 TBq C14-eq. beta emitters).

Critical flow

The OSPAR decision in 2000 aims to prevent pollution of the North Sea from ionising radiation by substantially reducing the disposal, emission and loss of radioactive substances. The goal is to reduce the concentrations of natural isotopes in the seas to background pollution levels and synthetic isotopes to practically zero (OSPAR Convention 2000).

This general demand was put in more concrete terms in the progress report (OSPAR Convention 2003, p.15). Whereas no specific targets have been set for France, the emission targets for the British plant have been concisely defined. By 2020, the emissions from alpha emitters should be reduced to 0.2 TBq per year, and the beta emitters to 50 TBq per year (OSPAR Convention 2003). This corresponds to a characterized quantity of emissions totalling 47 TBq C14-eq. (2.3 TBq C14-eq alpha and 44.3 TBq C14-eq beta emitters).

10.7.6 Eco-factor for radioactive emissions to seas

Tab. 50 > Eco-factor for radioactive emission to seas in UBP/kBq C14-eq

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (TBq c14-eq./a)	3.85	C		2.00
Current flow (TBq c14-eq./a)	26.0	B	Four-year average (2006–2009) of beta emitter emissions from the Sellafield plant	96.0
Critical flow (TBq c14-eq./a)	46.6	b	Characterized emissions target for 2020 for the Sellafield plant (OSPAR Convention 2003)	64.1
Weighting factor (-)	0.31			2.24
Eco-factor (UBP/kBq C14-eq.)	**81**			1 100

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor for radioactive emissions is significantly lower than in the 2006 version. This is attributable to a substantial reduction in emissions to seas, which are now well below the emission target (critical flow).

10.7.7 Eco-factors for individual isotopes

Using the characterization described in Part 3, Section 10.7.3, it is possible to calculate eco-factors for selected isotopes. These are listed in tab. 51. They apply to the load of these substances that is discharged into seas. Due to the method of deriving these eco-factors, they should not be used for loads discharged into other bodies of water.

Tab. 51 > Eco-factors for the discharge of radioactive isotopes into seas, deduced from their impact potential according to Frischknecht et al. (2000)

		Carcinogenic potential of radioactive elements (kBq C-14-eq./kBq)	Eco-factor 2013 (UBP/kBq)
Americum-241	Am-241	25.8	**2100**
Carbon-14	C-14	1	**81**
Curium-alpha	Cm alpha	47.5	**3900**
Cobalt-60	Co-60	0.325	**26**
Cesium-134	Cs-134	0.066	**5**
Cesium-137	Cs-137	0.066	**5**
Tritium	H-3	$5.75*10^{-5}$	**0.005**
Iodine-129	I-129	83.3	**6800**
Plutonium-alpha	Pu alpha	6.17	**500**
Ruthenium-106	Ru-106	0.117	**10**
Antimony-125	Sb-125	0.0125	**1**
Strontium-90	Sr-90	0.0033	**0.3**
Uranium-234	U-234	0.0192	**2**
Uranium-235	U-235	0.0208	**2**
Uranium-238	U-238	0.0192	**2**
Actinides, radioactive, unspecified	*	10.25	**830**
Radioactive species, Nuclides, unspecified	*	4.06	**330**

* For explanation, see Part 3, Section 10.7.8

10.7.8 Guidelines for using the ecoinvent v.2.2 database

With the exception of tritium, cesium-134 and 137 and strontium-90, emissions of radioactive isotopes are given only in summary form in the current ecoinvent v2.2 database. The alpha emitters (Am-241, Cm-alpha, Pu-alpha and uranium) are listed under “actinides, radioactive, unspecified”. Cobalt, caesium, antimony, strontium and other isotopes are listed under “radioactive species, Nuclides, unspecified”.

Isotopes with very different impacts are aggregated within these two groups. The eco-factors for both of these aggregate parameters were averaged on the basis of the eco-factors for the isotopes emitted, whereby each individual eco-factor was weighted with its three-year average value for the emissions from Sellafield plus La Hague.

In the case of actinides, plutonium determines the eco-factor, whereas for the other substances, the emission ratio of iodine-129 to the other isotopes is decisive in deducing the level of the average eco-factor.

10.8 Oil emissions to the sea

10.8.1 Environmental impact

The accident that occurred at the oil platform in the Gulf of Mexico in 2010 and the resulting oil spill brought the issue of crude oil pollution in the sea back into the spotlight. However, oil is also discharged into the sea during the normal operations of offshore platforms in the oil and gas industry, as well as by tankers.

In seas, oil sticks to seabird plumage and animal fur, causing animals to drown or freeze to death. It sticks to coral, plants (leaves and roots) and fish gills. It impedes or inhibits photosynthesis and suffocates fish. Oil is acutely toxic when swallowed, inhaled or filtered (mussels, shrimp). Individual components of oil can also trigger allergic reactions in humans (rashes, burns) if they come into contact with skin. Fluid components (benzene, toluene, etc.) can irritate the eyes and respiratory tracts and cause nausea and headaches upon inhalation. Lipophilic components accumulate in the food chain and can, for instance, be absorbed by fish and humans when consumed (Kienle & Bryner 2010).

10.8.2 Normalization

No characterization is performed. The normalization flow is composed of the oil emissions of offshore platforms, tankers and other sources (refineries near the sea, recreational watercraft, etc.). Emissions resulting from operations and some unforeseeable events are taken into account in the normalization flow.

The OSPAR Commission (OSPAR Commission 2009b) reports on the oil emissions of offshore platforms in the North-East Atlantic Ocean at regular intervals. In 2007, a total of 10 000 tonnes of oil were emitted. Based on the quantity of transported goods to ports in the OSPAR region (approximately 2.6 billion tonnes (EUROSTAT 2011)) and global oil emissions of oil transportation by sea according to GESAMP (2007), the oil load is estimated at 152 000 tonnes. “Other sources” in the OSPAR region emitted 56 000 tonnes of oil (GESAMP 2007). This results in a total of roughly 220 000 tonnes of oil emitted by various sources in the OSPAR region. Tab. 52 shows the oil emissions caused by OSPAR members.

Switzerland’s share in the OSPAR members’ total demand for crude oil is 3%. Thus, the normalization flow is 6200 tonnes.

Tab. 52 > Estimated oil emissions to the sea by all OSPAR members. Figures in tonnes per year

	Oil emissions (t/a)	Notes
Offshore platforms	10 053	(OSPAR Commission 2009a)
Ships	152 180	GESAMP (2007) and EUROSTAT (2011)
Other sources (refineries near to the sea, recreational watercraft, etc.)	55 900	(GESAMP 2007)
Total	**218 133**	

10.8.3 Weighting

Current flow

The current flow amounts to 9600 tonnes for 2007 (OSPAR Commission 2009a). This value, as well as the target (see below), is based on the oil emissions from produced water, which is discharged into the sea when crude oil is produced on offshore platforms.

Critical flow

Switzerland is a Contracting Party to the OSPAR Convention and therefore supports its decisions, recommendations and agreements. The OSPAR Commission set the target of reducing oil emissions from produced water by 15% under the 2000 emission level (OSPAR Convention 2001). According to the calculations of the OSPAR Commission (2003), the oil emissions from produced water amounted to 8700 tonnes in 2000. Thus, the 15% reduction target means a permitted annual load of 7400 tonnes of oil.

10.8.4 Eco-factor for oil emissions to the sea

The eco-factor for oil emissions to the sea is introduced for the first time in this version of the ecological scarcity method. tab. 53 shows the resulting eco-factor.

Tab. 53 > Eco-factor for oil emissions to the sea in UBP/g oil

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t oil/a)	6 210	B	Emissions from offshore platforms, ships and other sources in reference to Switzerland	
Current flow (t oil/a)	9 596	A	Emissions through the produced water of all OSPAR countries	
Critical flow (t oil/a)	7 403	a	Reduction of oil emissions in produced water by 15% under the 2000 level (8709 tonnes)	
Weighting factor (-)	1.68			
Eco-factor (UBP/g oil)	**270**			

Q = data quality; for explanation, see Part 2, Chapter 6

This eco-factor is applied to all oil emissions to the sea. However, it should not be used for oil emissions to other bodies of water (lakes, rivers, etc.) due to its derivation method.

10.9 Adsorbable organic halogenated compounds (AOX)

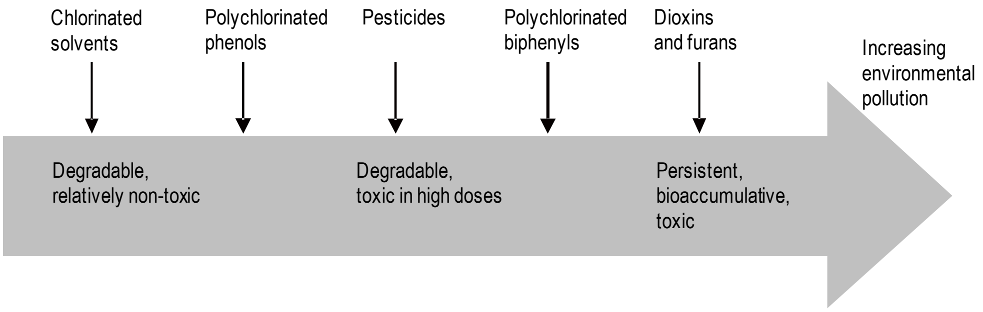
10.9.1 Environmental impact

Adsorbable organic halogenated compounds (AOX) are materials of both anthropogenic and natural origin, such as chlorinated non-aromatic hydrocarbons (e. g. chloroform), chlorinated aromatic hydrocarbons, polychlorinated biphenyls (PCBs) and certain pesticides.

The toxicity and environmental impact of the compounds in the AOX group varies widely. An important criterion for toxicity is the ability of the substance to accumulate in an organism. This is possible for fat-soluble substances. The greater the chlorination, the more toxic the substances, as they are fat-soluble and thus bioavailable. For that reason, the eco-factor below is determined in relation to chlorine so that the eco-factor of a substance rises in proportion to the number of chlorine atoms.

Tab. 54 shows a rough classification of the AOXs according to their environmental impacts.

Tab. 54 > Rough classification of various AOXs according to their environmental impacts



AOX pollution of surface waters in Switzerland has fallen significantly in recent years and lost much of its importance in water protection efforts. Furthermore, AOXs are also no longer a parameter in the Rhine substance list maintained by the International Rhine Protection Commission. In addition, the creation of an eco-factor for AOXs is a compromise. The weighting of very different toxic substances with a common eco-factor can lead to inaccurate statements in respect of environment pollution. Nevertheless, an eco-factor is derived for AOXs, partly because life cycle inventories often still state this value, but also because subdividing AOXs into distinct, homogenous substance classes or even individual substances is feasible only to a limited extent. A separate eco-factor is derived below only for chloroform and persistent organic pollutants (Part 3, Section 10.10 and Section 10.14). In this case, there has also been a marked drop in pollution in the intervening period due to a ban on its use.

10.9.2 Normalization

No characterization is performed. Measurements taken at the Rhine monitoring station at Weil am Rhein (AUE 2009) present AOX concentrations between 3.9 to 6.7 µg Cl^-/l with a mean value of 5.2 µg Cl^-/l. The substances included in the AOX aggregate parameter degrade by widely varying degrees. Extrapolating the measured concentrations to total Swiss loads[13] produces a lower limit of 250 µg Cl^-/l for the measured loads.

10.9.3 Weighting

Current flow

The current flow corresponds to the normalization flow, as the reduction target also applies to all of Switzerland.

Critical flow

The Swiss Waters Protection Ordinance (GSchV 2011) contains various regulations concerning AOXs. One of these stipulates that a limit of 10 µg/l applies in groundwater used for drinking water. However, there is no quality target in Switzerland for AOX concentrations in surface waters.

Nevertheless, the international association of waterworks in the Rhine catchment (IAWR) has established a target value of 25 µg/l for surface waters (IAWR 2003). This target meets the requirements of the drinking water supply. This recommendation is in no way legally binding. If this quality target is taken as the basis for a rough estimate of the critical flow of AOXs for Switzerland, it results in critical flow of approximately 1200 t Cl^-/a for AOXs. Due to degradability, this is also a lower limit.

10.9.4 Eco-factor for AOXs

Tab. 55 > Eco-factor for AOXs in UBP/g Cl^-

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t AOX as Cl^-/a)	249.6	B		288
Current flow (t AOX as Cl-/a)	249.6	B	Calculated using concentration readings (AUE 2009)	288
Critical flow (t AOX as Cl-/a)	1 200	a	Quality target for surface waters (IAWR 2003)	1 200
Weighting factor (-)	0.043			0.058
Eco-factor (UBP/g AOX as Cl^-)	**170**			200

Q = data quality; for explanation, see Part 2, Chapter 6

The AOX group is made up of various individual substances with widely differing environmental impacts. The eco-factor represents an average composition and is therefore a rough estimate. Since AOXs are now only of minor importance in water protection, a more accurate determination of this aggregate parameter is not a prime concern. Where possible, a specific eco-factor should be derived for environmentally significant substances that would fall under the AOX category. Persistent organic

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[13] Assumption for the total Swiss runoff of 48 billion m³/a

substances that also belong to the AOX group are assessed in the section on POPs (persistent organic pollutants, Part 3, Section 10.14).

10.9.5 Eco-factor for individual chlorinated substances

An eco-factor is derived for individual AOX substances contained in the ecoinvent v2.2 database (tab. 56). The greater the chlorination, the more toxic the substances, as they are fat-soluble and thus bioavailable. For this reason, the characterization factor is derived using the number of chlorine atoms.

Tab. 56 > Eco-factor for various chlorinated substances in UBP/g Cl^-

		CAS	Characterization (kg Cl^-/kg)	Eco-factor 2013 (UBP/g)
AOX			1.0	**170**
Benzene, chloro-	C_6H_5Cl	000108-90-7	0.315	**54**
Chlorinated solvents, unspecified			1.0	**170**
Chloroform	$CHCl_3$	000067-66-3	0.891	**(150)**[1]
Ethane, 1,1,1-trichloro-, HCFC-140	$C_2H_3Cl_3$	000071-55-6	0.798	**140**
Ethane, 1,2-dichloro-	$C_2H_4Cl_2$	000107-06-2	0.717	**(120)**[2]
Ethane, hexachloro-	C_2Cl_6	000067-72-1	0.899	**150**
Ethene, chloro-	CH_2CHCl	000075-01-4	0.568	**97**
Ethene, tetrachloro-	C_2Cl_4	000127-18-4	0.855	**(150)**[2]
Ethene, trichloro-	C_2HCl_3	000079-01-6	0.810	**140**
Methane, dichloro-, HCC-30	CH_2Cl_2	000075-09-2	0.835	**140**
Methane, tetrachloro-, CFC-10	$CHCl_2F$	000075-43-4	0.689	**120**

[1] Direct derivation (see Part 3, Section 10.10) results in a higher factor

[2] Derivation using POPs (see Part 3, Section 10.14) results in higher factors

10.10 Chloroform

10.10.1 Environmental impact

Chloroform is a substance in the AOX group (see Part 3, Section 10.9), which was formerly in widespread use in dry cleaning as a solvent and a disinfectant. The Swiss Chemical Risk Reduction Ordinance (ChemRRV 2013) prohibits both the distribution and use of chloroform. Exceptions to this include its use in closed industrial processes, such as in the manufacture of CFC-22. Chloroform is produced as a by-product of chlorination of drinking water, for example (EPA 2000; IARC 1999; Lippmann 2000).

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

10.10.2 Normalization

No characterization is performed. The total load for Switzerland is estimated from the total Swiss runoff (48 billion m³) and the concentration readings at Weil am Rhein (0.06 µg/l) according to the Basel department for energy and the environment (AUE) (2009). Based on these values, the load amounts to around 2.9 t chloroform/a.

10.10.3 Weighting

Weighting factor

The weighting factor is determined from the measured (current) concentration and the ICPR target value (critical concentration) (2011). The former amounts to 0.06 µg/l, the latter to 0.6 µg/l.

10.10.4 Eco-factor for chloroform

Tab. 57 > Eco-factor for chloroform ($CHCl_3$) in UBP/g $CHCl_3$

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t $CHCl_3$/a)	2.9	B		1.5
Current concentration (µg $CHCl_3$/l)	0.06	B	Concentration readings as per AUE (2009)	0.04
Critical concentration (µg $CHCl_3$/l)	0.60	b	ICPR quality target for surface waters (IKSR 2004)	0.60
Weighting factor (-)	0.010			0.0028
Eco-factor (UBP/g $CHCl_3$)	**3 400**			1 500

Q = data quality; For explanation, see Chapter 6

The eco-factor for chloroform is higher than the eco-factor derived for AOXs (see Part 3, Section 10.9) and POPs (Part 3, Section 10.14). However, the pollution situation is similar and chloroform generally no longer presents a problem.

10.11 Polycyclic aromatic hydrocarbons (PAHs)

10.11.1 Environmental impact

Polycyclic aromatic hydrocarbons (PAHs) is the term used for a group of different compounds. PAHs have some carcinogenic effect in mammals. They occur mainly in suspended matter. For that reason, the PAH concentration is dependent upon the concentration of suspended matter in bodies of water. Their sources are combustion processes and runoff from roads. The most common PAHs (including CAS numbers and synonyms) are listed in A3.

10.11.2 Normalization

A characterization is not performed. The calculation of Switzerland's total discharge into bodies of water is extrapolated from the concentration in the Rhine at the Weil am Rhein monitoring station. Since 2007, the Weil am Rhein monitoring station has been taking readings for 16 PAHs[14] (AUE 2007; 2008; 2009; 2010). In most cases, the PAH concentrations fall under the detection limit and can only be determined in individual samples. Every year, 13 samples are taken. For the purposes of establishing a mean value, PAH concentrations that fall under the detection limit equal zero. The mean value of the measured values from 2007 to 2010 is used. The mean concentration amounts to 0.0068 µg/l. In combination with the Swiss runoff of 48 billion m³/a, this results in a load of 330 kg/a.

10.11.3 Weighting

Weighting factor

The weighting factor is determined from the concentration readings and the target values in exactly the same ways as for heavy metals. The measured concentration of PAHs amounts to 0.0068 µg/l. The ICPR target (IKSR 2011) is set at 0.1 µg/l and therefore substantially higher.

10.11.4 Eco-factor for PAHs

Tab. 58 > Eco-factor for PAHs in UBP/g PAH

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (kg PAH/a)	328	B		144
Current concentration (µg PAH/l)	0.0068	B	Calculation from concentration readings (AUE 2007; 2008; 2009; 2010)	0.004
Critical concentration (µg PAH/l)	0.1	a	Target for surface waters (IKSR 2009)	0.1
Weighting factor (-)	0.0047			0.0016
Eco-factor (EP/g PAH)	**14 000**			11 000

Q = data quality; for explanation, see Part 2, Chapter 6

The newly derived eco-factor is somewhat higher than in 2006. This is primarily due to the higher concentration readings, especially in 2009, which are included in the four-year average value.

There is insufficient data available for a characterization of individual PAHs. That is why individual substances are assessed with the same eco-factor. A separate eco-factor is derived only for benz(a)pyrene in the next section. A3 has a non-exhaustive list of other PAH substances.

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[14] Acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene,chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene.

10.12 Benzo(a)pyrene (BaP)

10.12.1 Environmental impact

Benzo(a)pyrene (BaP) belongs to the PAH group (see Part 3, Section 10.11). BaP is not produced commercially, but is nevertheless widespread, as it is formed in the incomplete combustion of organic material, e. g. in furnaces and engines, but also in cigarettes. The carcinogenicity of BaP has long been proven in experiments on animals, and is probably the case in humans too (IARC Group 2A, EPA 2006; IARC 1983; UGZ 2003).

Sources relevant to bodies of water are wood preservatives containing creosote, which is used on railway sleepers, for example. Creosote contains benzo(a)pyrene, which is washed out over time and enters bodies of water. The Chemical Risk Reduction Ordinance (ChemRRV) now prohibits the use of creosote in wood preservatives for domestic purposes. However, it is permitted for commercial use, provided that the benzo(a)pyrene content is less than 50 mg/kg.

10.12.2 Normalization

A characterization is not performed. The calculation of Switzerland's total discharge into bodies of water is extrapolated from the concentration in the Rhine at the Weil am Rhein monitoring station. Since 2007, the Weil am Rhein monitoring station has been taking readings for benzo(a)pyrene (AUE 2007; 2008; 2009; 2010). In most cases, the concentrations fall under the detection limit and could only be determined in individual samples. From 2007 to 2010, PAHs were detected in 2 out of 52 samples. Every year, 13 samples are taken. For the purposes of establishing a mean value, the concentrations that fall under the detection limit equal zero. The mean value of the measured values from 2007 to 2010 is used. The mean concentration amounts to 0.00033 µg/l. In combination with Switzerland's runoff of 48 billion m^3/a, this results in a load of 16 kg/a.

10.12.3 Weighting

Weighting factor

The weighting factor is derived from the concentrations in exactly the same way as for the PAHs. The mean value of the concentrations measured between 2007 and 2010 is 0.00033 µg/l. The critical concentration is 0.01 µg/l (IKSR 2009).

10.12.4 Eco-factor for benzo(a)pyrene

Tab. 59 > Eco-factor for benzo(a)pyrene (BaP) in UBP/g BaP

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (kg BaP/a)	15.7	B		48
Current concentration (µg BaP/l)	0.00033	B	Concentration readings as per AUE (2009)	0.001
Critical concentration (µg BaP/l)	0.01	b	Quality target for surface waters (IKSR 2009)	0.01
Weighting factor (-)	0.001			0.010
Eco-factor 2013 (UBP/g BaP)	**(68 000)***			210 000

Q = data quality; for explanation, see Part 2, Chapter 6

* The directly derived eco-factor is lower than the one that was determined using the POPs (cf. Part 3, Section 10.14.6). In accordance with the methodological principles, the highest of the resulting eco-factors is applied in each case

The separate benzo(a)pyrene eco-factor is substantially higher than the aggregate parameter for PAHs. This takes account of the above-average toxicity and carcinogenicity of this substance within the PAH group. However, a higher eco-factor for benzo(a)pyrene results from using the POPs (cf. Part 3, Section 10.14.6).

10.13 Endocrine disruptors

10.13.1 Environmental impact

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

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

Endocrine substances can operate in two ways:

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

Female and male sex hormones (oestrogen and androgen) can attack the reproductive endocrine system and potentially cause oestrogenous and androgenous effects, as well as anti-oestrogenous and anti-androgenous effects (BUWAL 1999).

In humans, endocrine disruptors are principally absorbed through the digestive tract, the skin or the lungs. Aquatic organisms absorb them mainly from the water. As certain types of hormone receptors occur throughout the animal kingdom, a very large number of species can be affected by a single endocrine disruptor (SNF 2002).

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

Hormonal effects have been proven in the case of the following substances and substance groups (BUWAL 1999; ECHA 2012a; SNF 2002):

> natural (e. g. 17β-estradiol, estrone) and synthetic oestrogens (e. g. 17α-ethinylestradiol)
> phyto and myco-oestrogens (e.g. isoflavones)
> alkylphenol polyethoxylates (APEOs) and byproducts (e. g. nonylphenol, octylphenol)
> various organochlorate pesticides (e.g. DDT, methoxychlor, lindane and kepone)
> certain industrial chemicals used in plastics (e.g. PCBs, bisphenol A)
> certain phthalates are or were used as plasticizers in plastics, among other uses (confirmed in benzyl butyl phthalate (BBP), dibutyl phthalate (DBP), bis (2-Ethylhexyl) phthalate (DEHP), suspected in diisononyl phthalate (DINP)
> certain fragrances (e.g. nitrified musk compounds)
> various polychlorinated dibenzo-p-dioxins and furans (PCDDs/PCDFs)
> organotin compounds used in antifouling ship paints, among other uses (e.g. tributyltin (TBT) and triphenyltin (TPT))
> certain UV filter substances contained in suntan lotions (suspected in 4-methylbenzylidene camphor)

It should be noted here that standardized and validated tests to detect the presence of endocrine disruptors in a chemical do exist, but the appropriate tests have still not been made mandatory by the laws governing chemicals in Switzerland and the EU. Many of the chemicals currently on the market have not been tested for effects of this type.

10.13.2 Characterization

Rutishauser et al. (2004) lists the oestrogenic potential of several endocrine disruptors. This figure describes the strength of the impact of an endocrine disruptor in relation to

17β-estradiol (abbreviation E2). The equivalence factors were determined by using YES (yeast estrogen screening), as other methods can easily produce slightly inaccurate factors. The YES procedure is well accepted in scientific circles. The list includes the most important substances that are classified as critical due to their oestrogenic activity.[15]

The figures for oestrogenic potential in tab. 60 can be used as characterizations for calculating the eco-factors of individual substances. To determine the eco-factors of other endocrine substances, their oestrogenic potential must be known. It should also be noted that for reasons of comparability, the characterization factors should in each case be based on results from similar testing systems.

Tab. 60 > Characterization factors for several endocrine disruptors, based on their oestrogenic potential according to Rutishauser et al. (2004)

Name of substance	Abbr.	Oestrogenic potential	Characterization factor (kg E2-eq./kg)
Oestrone	E1	0.38	0.38
17β-oestradiol	E2	1	1
Oestriol	E3	$2.40 * 10^{-3}$	$2.40 * 10^{-3}$
17α-ethinyloestradiol	EE2	1.19	1.19
Bisphenol A	BPA	$1.10 * 10^{-4}$	$1.10 * 10^{-4}$
Nonylphenol	NP	$2.50 * 10^{-5}$	$2.50 * 10^{-5}$
4-tert-octylphenol	OP	$7.80 * 10^{-6}$	$7.80 * 10^{-6}$
Mestranol	MES	0.013	0.013
β-oestradiol-17-valerate	E2-Val	0.21	0.21

10.13.3 Normalization

The average quantity of endocrine disruptors from anthropogenic sources, which are discharged directly into surface waters through the runoff from sewage treatment plants, amount to 1 µg E2-equivalent (BAFU 2009a) per inhabitant and day. This value is based on representative measurements in Swiss surface waters and a substance model for all of Switzerland (Ort et al. 2008). With a population of 7.87 million (BfS 2011a), this results in an annual load of 2.9 kg of E2-equivalents for Switzerland.

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[15] Personal communication of Michael Schärer, Federal Office for the Environment, of 10 April 2012.

10.13.4 Weighting

Current flow

As the critical flow target refers to all of Switzerland, the current flow is identical to the normalization, i.e. 2.9 kg E2-eq./a.

Critical flow

Statutory limits or required values for an endocrine disruptor aggregate parameter do not yet exist. In the EU, the environmental quality standards for bodies of water are being discussed again. In accordance with the new draft guidelines, an annual average concentration of 0.4 ng E2/l should not be exceeded in continental bodies of water (European Commission 2012, p. 34). This value, together with Switzerland's total runoff of 48 billion m^3/a, results in a critical flow of 19 kg E2-eq./a.

10.13.5 Eco-factor for endocrine disruptors

Tab. 61 > Eco-factor for endocrine disruptors in UBP/g E2-eq

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (kg E2-eq./a)	2.9	B		5.0
Current flow (kg E2-eq./a)	2.9	B	Based on measurements in surface waters and substance flow models (BAFU 2009a)	5.0
Critical flow (kg E2-eq./a)	19.2	b	Recommended environmental quality standard for water bodies (European Commission 2012)	24.0
Weighting factor (-)	0.022			0.043
Eco-factor (UBP/g E2-eq.)	**$7.8 * 10^6$**		E2 = 17β-oestradiol	$8.7 * 10^6$

Q = data quality; for explanation, see Part 2, Chapter 6

Both the current and critical flows are lower than previously determined. The current flow is now based on representative measurements in surface waters and not on punctual measurements in the runoff from wastewater treatment plants and is around 40% lower than the previous estimate. The recommended environmental quality standard leads to a roughly 20% lower critical flow. Overall, the new eco-factor derived according to this standard is about 10% lower than the previous one.

Through characterization (see Part 3, Section 10.13.2), eco-factors can be determined for other substances for which the oestrogenic potential is known.

10.13.6 Eco-factor for individual endocrine disruptors

The characterization method using oestrogen potentials described in Part 3, Section 10.13.2 is used below to calculate other eco-factors for individual endocrine disruptors. The eco-factor in tab. 61 serves as a starting point.

Tab. 62 > Eco-factors of individual endocrine disruptors in UBP/g of the substance, calculated using oestrogen potential as the characterization factor

Name	Abbr.	Characterization factor (kg E2-eq./kg)	Eco-factor 2013 (UBP/g)	Eco-factor 2006 (UBP/g)
Oestrone	E1	0.38	**$3.0 * 10^{6}$**	$3.3 * 10^{6}$
17β-oestradiol	E2	1	**$7.8 * 10^{6}$**	$8.7 * 10^{6}$
Oestriol	E3	$2.40 * 10^{-3}$	**$1.9 * 10^{4}$**	$2.1 * 10^{4}$
17α-ethinyloestradiol	EE2	1.19	**$9.3 * 10^{6}$**	$1.0 * 10^{7}$
Bisphenol A	BPA	$1.10 * 10^{-4}$	**$8.6 * 10^{2}$**	$9.6 * 10^{2}$
Nonylphenol	NP	$2.50 * 10^{-5}$	**$2.0 * 10^{2}$**	$2.2 * 10^{2}$
4-tert-octylphenol	OP	$7.80 * 10^{-6}$	**$6.1 * 10^{1}$**	$6.8 * 10^{1}$
Mestranol	MES	0.013	**$1.0 * 10^{6}$**	$1.1 * 10^{5}$
β-oestradiol-17-valerate	E2-Val	0.21	**$1.6 * 10^{6}$**	$1.8 * 10^{6}$

Source: Rutishauser et al. 2004

10.14 Persistent organic pollutants (POPs)

10.14.1 Preliminary remark

This section was developed in close collaboration with the Safety and Environmental Technology Group[16] of the Institute of Chemical and Bioengineering of the Swiss Federal Institute of Technology Zurich. The scientific bases and the characterization factors were quantified by Ruiz et al. (2012).

10.14.2 Environmental impact

Persistent organic pollutants (POPs) are often toxic chemical substances with extremely poor degradability. Once they are discharged through the air and water, or even through the food chain, they can spread around the world and harm humans and the environment at locations far from their point of discharge. In this way, they can, for instance, cause cancer, disrupt hormones and adversely affect reproduction.

In 2003, Switzerland ratified the Stockholm Convention. The goal of the Stockholm Convention on Persistent Organic Pollutants (POPs) is to minimize the loads of these substances that are discharged into the environment (UNEP 2009).

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[16] Sandi Ruiz, Carla Ng, Martin Scheringer, Konrad Hungerbühler, Safety and Environmental Technology Group, Institute for Chemical and Bioengineering, Swiss Federal Institute of Technology Zurich

POPs are mentioned in various laws and regulations, such as in the Chemicals Ordinance (ChemV 2013), the Chemical Risk Reduction Ordinance, (ChemRRV 2013), the Ordinance on Biocidal Products (VBP 2013), the Plant Protection Products Ordinance (PSMV 2010), the Technical Ordinance on Waste (TVA 2011), and others. A overview is provided by the Swiss National Implementation Plan of POP Convention (BAFU 2006) and the amendment of 2012.

The eco-factors derived here are based on the work of the Safety and Environmental Technology Group of the Institute of Chemical and Bioengineering at ETH Zurich (Ng et al. 2012; Ruiz et al. 2012). A total of 227 substances from the PCB group (polychorinated biphenyls), HFCs (hydrofluorocarbons), PBDEs (polybrominated diphenyl ethers), industrial chemicals and plastics additives, which are discharged into bodies of water, are taken into account. The substances are defined as POPs in the Stockholm Convention, classified as persistent, bioaccumulative and toxic substances by REACH or are mentioned on the Candidate List of Substances of Very High Concern (SVHC).

According to Ruiz et al. (2012), substances with a particularly high bioaccumulative potential are emitted in small quantities in Swiss surface waters as substances with a comparatively low bioaccumulative potential.

10.14.3 Characterization

The characterization is based on the bioconcentration factor (BCF). This expresses the ratio between the concentration of a substance in fish and the concentration of the same substance in water. The BCF is an indicator of the basic toxicity of a substance, as substances accumulate in fat tissue, i.e. in the cell membranes, and inhibit metabolism there. For that reason, the BCF is a simple indicator of the ecotoxic impact of substances.

The Environmental Protection Agency (EPA) of the United States has a data base with BCF values (EPA 2013). The higher the BCF, the higher the ecotoxic impact of a substance. The BCF is expressed in litres of water per kg of body weight and is between 10^{-1} und 10^{5} l/kg for the substances concerned here. PCBs exhibit high BCFs of between $4*10^{3}$ and $2*10^{5}$ l/kg, as do flame retardants and polymer additives. 2,4,6-Tribromophenol, which has a BCF of 245 l/kg, was selected as the reference substance. The characterization factors were determined by Ruiz et al. (2012).

10.14.4 Normalization

The POPs are characterized. The normalization flow is identical to the characterized current flow. POP emissions in Swiss surface waters are determined for every substance with various models (direct emissions, extrapolated using POP concentrations in Zurich waters, extrapolated using POP emissions in Zurich air, extrapolated using POP emissions in Swedish air). The models are explained in Ruiz et al. (2012) and refer to the period from 2006 to 2010.

A normalization flow of 290 t 2,4,6-tribromophenol-eq. per year results.

10.14.5 Weighting

Current flow

The current flow is identical to the normalization flow and amounts to 290 t 2,4,6-tribromophenol-eq. per year.

Critical flow

Switzerland has signed the Stockholm Convention. Therefore, the production, distribution, import and use of the substances listed in the Stockholm Convention, except for perfluorooctane sulfonic acid (PFOS), is banned in Switzerland. The Waters Protection Ordinance (GSchV 2011 Annex 1, Article 1) governs water quality and ensures that bodies of water are not contaminated.

Under REACH, substances with persistent, bioaccumulative and toxic characteristics (PBT substances, vPvB substances) are subject to authorization. The limit criterion is a bioconcentration factor (BCF) of over 2000 l/kg for B substances or over 5000 l/kg for vB substances (ECHA 2012b). The goal of implementing the EU regulation on substances subject to authorization is to ensure the same level of protection for humans and the environment in Switzerland as in the EU (BAFU 2013).

In addition, there are no quantitative political targets for POP emissions to surface waters in Switzerland that can be directly applied here. Therefore, the following approach was taken:

- The critical flow of substances that fall under the Stockholm Convention is set at 0.
- The critical flow of substances that have a BCF of over 2000 l/kg is set at 0.
- The critical flow of all the other POP substances is equated to the present current flow.

Thus, a critical flow for all 227 substances are defined and characterized. The characterized critical flow amounts to 72 t 2,4,6-tribromophenol-eq/a.

10.14.6 Eco-factor for POPs

The eco-factor for POP emissions was first introduced in the previous version of the ecological scarcity method. tab. 63 shows the resulting eco-factor.

Tab. 63 > Eco-factor for POP emissions to surface waters in UBP/g 2,4,6-tribromophenol-eq

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t 2,4,6-tribromophenol-eq/a)	294	A	(Ruiz et al. 2012)	
Current flow (t 2,4,6-tribromophenol-eq/a)	294	A	(Ruiz et al. 2012)	
Critical flow (t 2,4,6-tribromophenol-eq/a)	72.2	a	(Ruiz et al. 2012)	
Weighting factor (-)	16.6			
Eco-factor (UBP/g 2,4,6-tribromophenol-eq)	**57 000**			

Q = data quality; for explanation, see Part 2, Chapter 6;
Source: “BCF based eco-factors_Sandi_Ruiz.xlsx” data file[17]

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[17] File transmitted by Sandi Ruiz, Swiss Federal Institute of Technology Zurich, on 26 March 2013

10.14.7 Eco-factor for individual POP substances

The characterization method using BCF described in Part 3, Section 10.14.3 is used to calculate other eco-factors for individual POP substances. The eco-factor in tab. 63 serves as a starting point. A complete list of all substances is included in A4. Tab. 64 shows eco-factors of selected POP substances.

Tab. 64 > Eco-factor of selected POP substances in UBP/g substance

Name	CAS no.	Characterization factor (kg 2,4,6-tribromophenol-eq/kg)	Eco-factor 2013 (UBP/g)
Dioxin, 2,3,7,8 tetrachlorodibenzo-p-	1746-01-6	56	**3 200 000**
Anthracene	120-12-7	11	**640 000**
Pentabromodiphenyl ether	32534-81-9	62	**3 500 000**
Benzene, pentabromomethyl-	87-83-2	78	**4 400 000**
Antioxidant MD-1024	32687-78-8	13	**750 000**
Benzo(a)pyrene	50-32-8	34	**1 900 000**
Toluol	108-88-3	0	**5 800**
Xylol	1330-20-7	0.24	**13 000**

Full list in A4

The directly derived eco-factor for benzo(a)pyrene (cf. Part 3, Section 10.12) is lower than the one that was determined using the POPs. In accordance with the methodological principles, the highest of the resulting eco-factor is applied in each case (see Part 2, Section 4.11).

11 > Emissions to groundwater

11.1 Introduction

More than 80% (1 billion m³/a) of Switzerland’s drinking water supply comes from groundwater (BUWAL 2003c). In addition, another 0.5 billion m³/a is used as process water. For that reason, groundwater is particularly important and justifies stricter quality requirements for its use than surface waters.

The boundaries between groundwater and surface water are very porous. Water that initially enters the groundwater via precipitation and drainage will sooner or later reach surface waters, either through natural processes or via groundwater use. Conversely, the most important sources of groundwater in Switzerland are definitely supplied by river water infiltration. As a result, the quality of river water in many cases also contributes to the quality of groundwater.

Not only nitrogen loads from agriculture, but also the total nitrogen loads, including nitrogen loads from effluents, contribute to the nitrogen loads in surface waters and their dissemination to seas.

Only nitrate is assessed, as it is the only substance for which relevant data is currently available.

The Waters Protection Ordinance (GSchV 2011) sets out, among other things, limit values for concentrations of plant protection products (PPPs) and VOCs in groundwater. The limit value for PPPs was exceeded by roughly one-sixth of the monitoring wells in catchment areas dominated by agriculture or settlements and transportation (BAFU 2009b). PPPs enter groundwater through the soil and are recorded and assessed in life cycle assessments as emissions (see Part 3, Section 12.3). The numerical quality requirement for VOC concentration has been exceeded at least once per year at 6% to 8% of the tested monitoring wells (BAFU 2009b). VOC concentrations in groundwater are discussed in Part 3, Section 17.1.

11.2 Nitrate (NO_3)

11.2.1 Environmental impact

Groundwater polluted by nitrate that is used as drinking water can lead to health problems (precursor of carcinogenic nitrosamines, BUWAL 1996). Nitrate concentrations in groundwater, especially in areas with intensive agriculture, often exceed the required limits for groundwater that is used or reserved for use and even the tolerance value for drinking water. Nitrogen fertilizer applied to fields can be washed from the soil into groundwater. New farming systems (crop cultivation, plant selection/crop rotations, ploughing, areas without vegetation in the winter, etc.), soil characteristics and groundwater recharge rates are decisive factors in this.

11.2.2 Normalization

No characterization is performed. According to the FOEN (BAFU 2010a), the nitrate load discharged into groundwater from agriculture amounts to 34 000 t N/a (2005 figure). As other nitrogen compounds are only present in small quantities, this normalization flow can be used not only for nitrate, but also for nitrogen loads in general.

The flows demonstrated by the FOEN are based on older estimates. No new estimates of nitrate quantities in groundwater have been made since 1994. Groundwater observations at a few monitoring wells with longer datasets show some reduction in the nitrogen content since the mid-90s. In the years after, however, a rise in nitrate concentrations was recorded, which was particularly marked at monitoring wells with catchments used by agricultural operations (BAFU 2009b).

In addition to agricultural soils, nitrate is also washed from forest (8500 t N/a) and other soils (11 000 t N/a) into the hydrosphere (BAFU 2010a). These loads are not taken into account here, as they are to a large extent attributable to landfills and not to the application of nitrogen fertilizers.

11.2.3 Weighting

Current flow

The current flow is identical to the normalization flow (34 000 t N/a), as the reduction target for nitrate also applies to all of Switzerland.

Critical flow

Based on the targets and limits for groundwater and drinking water by extension, BUWAL (1996) called for a target to reduce by half the 1994 level of nitrate washed out by agriculture. This results in a critical flow of 17 000 t NO_3-N/a for nitrate discharged into groundwater.

11.2.4 Eco-factor for nitrate in groundwater

Tab. 65 > Eco-factor for nitrate-N in groundwater in UBP/g NO_3^--N and for nitrate in groundwater in UBP/g NO_3^-

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t N/a)	34 000	B		34 000
Current flow (t N/a)	34 000	B	(BAFU 2010a)	34 000
Critical flow (t N/a)	17 000	a	(BUWAL 1996c, p. 37)	17 000
Weighting factor (-)	4.0			4.0
Eco-factor (UBP/g NO_3-N)	**120**		Eco-factor for **nitrate-N** in groundwater	120
Eco-factor (UBP/g NO_3)	27		Eco-factor for nitrate in groundwater	27.1

Q = data quality; for explanation, see Part 2, Chapter 6

As nothing has changed in either the current or critical flow, the eco-factor for nitrate in groundwater remains unchanged compared to the previous eco-factor in 2006. It is still higher than the eco-factor for the load discharged into surface waters. This is due to the fact that nitrate in groundwater, as opposed to surface waters, can still present a problem, especially as concerns the use of groundwater as drinking water.

12 > Emissions to soil

12.1 Introduction

12.1.1 Background

The quality of soils in Switzerland is impaired by various substance-related impacts (acidification, over-fertilization, contamination by heavy metals and organic pollutants). The contamination not only stems from the direct input of substances into the soil (plant protection products, fertilizer, waste landfilling), but also indirectly from the deposition of pollutants emitted to air.

The Swiss Ordinance on Soil Pollution (VBBo 2012) is not applicable to all surfaces. Thus, soils that are permanently paved over, sediment in bodies of water and soils making up land whose designated use precludes soil protection (e.g. football pitches, motocross tracks, percolation facilities, roadside drainage strips) are not covered by the Ordinance. However, it does apply to rocky soils, provided that at least sparse vegetation grows or can grow on them (BUWAL 2001a, p. 9). For that reason, soil protection is addressed not only in the Ordinance on the Pollution of Soil (VBBo), but also in other ordinances with indirect relevance to soils, such as the Swiss Federal Ordinance on Air pollution Control or the Chemical Risk Reduction Ordinance (USG, Art. 33 (1)). In each of these, the long-term conservation of soil fertility must be taken into account (BUWAL 2001a).

The partial or total destruction of soils by paving over them, erosion and mechanical damage (soil compaction) is equally important to long-term soil fertility conservation. These pressures can be assessed partly through land use and are discussed separately in Part 3, Section 13.3.

The assessment of the most important substance-related contaminations is discussed in this chapter.

12.1.2 Separating the soil and groundwater compartments

The ecological scarcity method assesses the substance flows at their point of entry into the environment, i.e. when they leave the anthroposphere. While the boundary between anthroposphere and environment is relatively easy to define (“end of pipe” concept: top of the chimney, outfall from the sewage treatment plant) in the case of emissions to air, separating the systems is more difficult when it comes to soil and groundwater. Thus, nutrients from fertilizers are available to agricultural crops and are absorbed by them to some extent as long as they remain in the root zone of the soil. In other words, nutrients absorbed by plants do not leave the agricultural production system.

However, heavy metals that enter the topmost layers of soil and accumulate there do not form part of the desired agricultural cycles. The guidelines for pollutant content of soil in the Ordinance on the Pollution of Soil (VBBo) refer to the top 20 cm of the soil. Therefore, in the meaning of the Ordinance, this soil layer belongs to the "environment", as far as heavy metals are concerned.

For that reason, the boundary between the anthroposphere and the soil/groundwater compartment is drawn at the point where substances are no longer part of agricultural use. Current and critical flows for nutrients are thus assessed when they leave the productive agricultural system, and by extension when they are washed into groundwater (nitrate), when entering surface waters through erosion or runoff (phosphate) or when emitted to the air (ammonia and nitrous oxide). Heavy metals, in contrast, are already pollutants when they enter the soil and are inventoried at that point.

12.1.3 Selection of substances

The various paths of entry should be distinguished in the case of substance-related soil contamination:

- non-point inputs of nutrients, acidifiers and heavy metals from the atmosphere
- entry via fertilizers (can contain traces of harmful substances, such as heavy metals and fluoride)
- entry via plant protection products

The non-point input of pollutants occurs either in liquid form (wet disposition) or bound to dust particles (dry deposition).

The most important non-point source pollutants include:

- heavy metals: lead, cadmium, copper, mercury and zinc
- acidifiers: SO_4^{2-}, NO_3^-, NH_4^+. With the exception of SO_4^{2-}, they also contribute to the over-fertilization of ecosystems.

Non-point airborne inputs to soils (atmospheric deposition) are inventoried and assessed at the point of their emission to air (cf. Part 3, Section 9.12 to 9.15). Separate eco-factors for non-point inputs to soil are therefore unnecessary. For that reason, only the direct inputs to soils listed in tab. 66 are assessed. However, non-point inputs to soil are necessary for determining the normalization flow.

Tab. 66 > Impact mechanisms of the assessed soil pollutants

	Environmental			Human						Notes
	Damage to flora	Impairment of soil fertility	Bioaccumulation	Metabolic disturbances	Carcinogenicity	Mutagenesis	Embryonal damage	Other / further types of damage	Characterization	
Lead (Pb)	x	#	x	x					-	
Cadmium (Cd)	x	#	x	x	x		(x)		-	
Copper (Cu)	x	#	x	x					-	
Zinc (Zn)	x	#	x	x					-	
Plant protection products (PPP)	x	x	x	x	x	x	x	x	Gly-phosate-eq	A single PPP normally only exhibits some of the impacts listed. Moreover, plant damage is an intentional effect of herbicides.

x = Impact or link proven; (x) = Impact or link presumed; # = Impact significant to determining the eco-factor

12.2 Heavy metals in the Soil

12.2.1 Environmental impact

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

12.2.2 Normalization

No characterization is performed. The normalization flow is the current flow extrapolated to the surface area in accordance with the Ordinance on Pollution of Soil (Keller et al. 2005a, adjusted to the deposition according to the FOEN (BAFU 2012a)). In accordance with the Ordinance (VBBo), the surface area was determined from the categories of wooded areas, agriculturally utilized areas and unproductive vegetation in the Swiss Land Use Statistics (BFS 2011d) and covers 3.06 million hectares (around three-quarters of Switzerland). It was also taken into account that heavy metal inputs via pesticides, fertilizers and sewage sludge occur primarily on land used for agriculture (around 1.5 million hectares, over which loads may be subject to wide regional variations), whereas deposition from the atmosphere affects all types of land under the Ordinance (VBBo) (see tab. 67).

Tab. 67 > Calculation of the normalization value for heavy metal input into soils based on the values for atmospheric deposition and on direct loading via pesticides, manure, mineral fertilizers and sewage sludge

	Deposition (g/(ha*a))	Direct input (g/(ha*a))	Normalization value (t/a)
Lead (Pb)	5.6	8.25	29.4
Cadmium (Cd)	0.4	0.55	2.16
Copper (Cu)	5.05	68.4	118
Zinc (Zn)	65.4	376	763

12.2.3 Weighting

Current flow

The current flow of heavy metals in the soil is composed of non-point input via the atmosphere and direct input through fertilizers (especially compost) and plant protection products.

Eight heavy metals and fluoride have been recorded at 105 different sites by the Swiss Soil Monitoring Network (NABO). Of the heavy metals regulated by the Ordinance on the Pollution of Soil (VBBo 2012), only molybdenum is not measured by NABO. The measurements enable an inventory and evaluation of the current heavy metal load in soils to be performed (BUWAL 2000).

Keller et al. (2005a) have compiled detailed substance inventories for lead, cadmium, copper and zinc on 48 selected representative areas of land in connection with the NABO measurement programme. The median[18] of these values was used as the current flow for heavy metals. The more up-to-date values of the FOEN (BAFU 2012a) are used for the atmospheric deposition. The values are listed in the corresponding tables of eco-factors (tab. 68 to tab. 71).

Critical flow

It is not possible to derive critical flows from the guideline values in the Ordinance on the Pollution of Soil (VBBo). However, the long-term conservation of soil fertility is stated in Art. 1 as the purpose of this Ordinance (this applies only to soil types included in the Ordinance (VBBo) – see Section 12.1.1). To achieve this, heavy metals may not accumulate in the soil, i.e. the maximum input must be only as great as the output. Keller et al. (2005a) assess only the output via plants, and this is used as a first approximation for the critical flow. The transfer of heavy metals into groundwater or their transportation through erosion were not investigated. However, except for antimony and chromium (VI), this effect is of little relevance.

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

12.2.4 Eco-factor for lead

Tab. 68 > Eco-factor for lead in the soil in UBP/g lead

	Edition 2013	Q	Notes	Edition 2006
Normalization (t Pb/a)	29.4	B	Extrapolated to the surface area based on VBBo definition	79.9
Current flow (g Pb/(ha*a))	13.9	B	Calculated from data in Keller et al. (2005b) and BAFU (2012a)	30.3
Critical flow (g Pb/(ha*a))	19.4	b	Calculated from data in Keller et al. (2005b)	19.4
Weighting (-)	0.51			2.44
Eco-factor (UBP/g Pb)	**17 000**			31 000

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor is considerably lower than the situation in 2006, as the current flow and thus the weighting factor have decreased.

12.2.5 Eco-factor for cadmium

Tab. 69 > Eco-factor for cadmium in the soil in UBP/g cadmium

	Edition 2013	Q	Notes	Edition 2006
Normalization (t Cd/a)	2.16	B	Extrapolated to the surface area based on VBBo definition	2.98
Current flow (g Cd/(ha*a))	0.99	B	Calculated from data in Keller et al. (2005b) and BAFU (2012a)	1.25
Critical flow (g Cd/(ha*a))	1.30	b	Calculated from data in Keller et al. (2005b)	1.30
Weighting (-)	0.580			0.925
Eco-factor 2013 (UBP/g Cd)	**270 000**			310 000

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor is considerably lower than the situation in 2006, as the current flow and thus the weighting factor have decreased. It can be assumed that both the problem and the eco-factor will decrease further in the future as a result of the ban on cadmium in accumulators and plastics.

12.2.6 Eco-factor for copper

Tab. 70 > Eco-factor for copper in the soil in UBP/g copper

	Edition 2013	Q	Notes	Edition 2006
Normalization (t Cu/a)	118	B	Extrapolated to the surface area based on VBBo definition	120
Current flow (g Cu/(ha*a))	73.4	B	Calculated from data in Keller et al. (2005b)	73.4
Critical flow (g Cu/(ha*a))	58.0	b	Calculated from data in Keller et al. (2005b)	58.0
Weighting (-)	1.60			1.60
Eco-factor (UBP/g Cu)	**14 000**			13 000

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor is slightly higher than the one for the situation in 2006, due to the somewhat lower normalization flow. The normalization flow has decreased slightly, as the area based on the Ordinance on the Pollution of Soil (VBBo) has shrunk from 3.06 million hectares (BFS 2001) to 3.04 million hectares (BFS 2011b).

Copper is also used for plant protection, especially in organic farming. However, the derivation of the eco-factor in accordance with Part 3, Section 12.3 (plant protection products, PPPs) results in a substantially lower eco-factor, which is why the eco-factor shown in tab. 70 is used.

12.2.7 Eco-factor for zinc

Tab. 71 > Eco-factor for zinc in soil in UBP/g zinc

	Edition 2013	Q	Notes	Edition 2006
Normalization (t Zn/a)	763	B	Extrapolated to the surface area based on VBBo definition	870
Current flow (g Zn/(ha*a))	442	B	Calculated from data in Keller et al. (2005b) and BAFU (2012a)	473
Critical flow (g Zn/(ha*a))	303	b	Calculated from data in Keller et al. (2005b)	303
Weighting (-)	2.12			2.44
Eco-factor (UBP/g Zn)	**2 800**			2 800

Q = data quality; for explanation, see Part 2, Chapter 6

The changes in the normalization flow, current flow and weighting factor do not result in a different eco-factor than the one used for the situation in 2006.

12.3 Plant protection products (PPPs)

12.3.1 Environmental impact

According to the Plant Protection Products Ordinance (PSMV 2010), plant protection products (PPPs) are crop protectants, plant development regulators and post-harvest protection products. These can be substances, organisms and preparations that are specifically developed to destroy undesirable plants or parts of plants. Safeners[19] and synergists[20] are also considered plant protection products. The eco-factor assessment mainly addresses chemical, synthetic plant protection products. The environmental problems associated with their use are a function of the primary effects, the quantities applied, the rates of degradation and dispersal behaviour (mobility) of the active agents, and the types and behaviour of degradation products and residues.

Plant protection products are applied above all in open arable farming, large farming operations, specialist fruit growing and viticulture. Their use is minimal on grassland (BLW 2000).

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[19] Substances or preparations that are added to a plant protection product in order to suppress or reduce the phytoxic effect of the plant protection product on specific plants

[20] Substances or preparations that exhibit little or no effect in accordance with Section 1 of the PSMV, but intensify the effect of the active agent or active agents in a plant production product

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

The movement of soil particles with the wind and atmospheric transportation of plant protection products has in the meantime also led to the detection of active agents in mountain lakes and rain. Human health impacts of these products arise particularly from the use of groundwater as drinking water. In Switzerland, a large quantity of pesticides is regularly analysed in groundwater in conjunction with the current NAQUA monitoring campaigns. However, measurements of several particularly mobile pesticide degradation products are still lacking (Hanke et al. 2007).

12.3.2 Characterization

The recommended dose of plant production products (PPPs) – in terms of the quantity of the active agent – varies approximately by a factor of 1 000 between traditional PPPs that are applied in quantities of several kilograms per hectare (e.g. atrazine, copper, sulphur) and modern PPPs, where in some cases a few grams per hectare suffice (e.g. triflusulfuron) (BUWAL 2003a).

It is assumed that the standard weighted dose (expressed in kg/ha) of a plant protection product provides a first approximation of the measure of its effectiveness – the higher the permitted dose, the smaller the effect per unit measured. In the absence of better information about the environmental side effects of PPPs, it is assumed that the specific effectiveness runs parallel to the intended effect and side effects. The characterization factor is therefore set in inverse proportion to the standard weighted dose.

The standard dose of a plant protection product depends on the crop to be treated and sometimes also on the pest to be controlled. In order to obtain an average standard dose, these values are weighted with the area of Switzerland under cultivation.

The data on the standard dose comes from the Swiss index of plant protection products (BLW 2012). The PPPs that are not listed in the index, for instance, because they are not permitted in Switzerland, are based on the data sheets of the PPP manufacturers, data from the EU Pesticides Database (Directorate General for Health & Consumers 2008) or from the North American pesticide database (Kegley 2011).

Glyphosate is used as the reference unit to perform the characterization. Glyphosate is widely used in Switzerland as a PPP (herbicide). All active agents sold in Switzerland, as well as the PPPs that are included in the ecoinvent v2.2 database, are characterized to the extent possible. The list of plant protection products sold[21] in Switzerland contains, among other things, substances in the surfactant, disinfectant and wound closure product categories. These substances were not taken into account, either because the standard doses cannot be determined or because they cannot be classified as active agents in the traditional sense and are thus also not listed in the Plant Protection Prod-

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[21] The document contains a list of the sold substances and reliable information about the sold quantities. The authors did not have any access to this reliable information.

ucts Ordinance. Furthermore, it should be noted that only PPPs applied on land used for agriculture are taken into account. Plant protection products that are exclusively authorised for private gardens, golf courses or silviculture are not taken into account. Tab. 73 shows the standard doses and characterization factors for selected plant protection products. The full list can be found in A5.

12.3.3 Normalization

As a characterization is performed, the normalization flow corresponds to the sum of the characterized quantities of plant protection products sold in Switzerland in 2010. Substances from the ecoinvent v2.2 database that are not sold in Switzerland are therefore excluded from the characterized normalization flow. This results in an annual flow of 8200 t glyphosate-eq[22].

12.3.4 Weighting

Current flow

The current flow corresponds to the non-characterized total of the plant protection products sold. In 2010, this amounted to approximately 2200 t (weight based on the quantity of the active agent, BLW 2011). While the sales figures for plant protection products up to 2005 are based on information from member firms of the Swiss Society of Chemical Industries (SSCI), the sales figures of all firms that sell plant protection products have been available since 2006. This has led to a spike in the sales figures (BLW 2011). The values prior to 2006 are no longer directly comparable to those after 2006.

Critical flow

The Swiss Federal Office for Agriculture set the goal of reducing the use of plant protection products by 30% from their 1990/1992 levels by 2005 (mean value, 2100 t/a) (BLW 2000). This goal was narrowly achieved in 2003 (Poiger et al. 2005). The absolute value of the critical flow must be adjusted due to the change of source data on sales figures. The quantities sold in 2005 amounted to approximately 1400 tonnes (old statistical data source) and approximately 1900 tonnes in 2006 (new statistical data source, BLW 2011). Based on the assumption that the actual quantities sold in 2006 were as high as they were in 2005, the quantities used in 1990/1992 are scaled by a factor of 1.36. This results in an average value of 2850 t/a for the quantity sold in the 1990/1992 reference period. Consequently, a 30% reduction in the use of plant protection products corresponds to a critical flow of 2000 t/a.

The resource efficiency contributions set out in the Swiss Agricultural Policy for 2014–2017 stipulate the specific and economical use of plant protection products as a means of lowering inputs of plant protection products in the environment (Schweizerischer Bundesrat 2011a). The Federal Council expects a slight reduction in plant protection product sales. At 2208 tonnes, the current flow is around 11% higher than the critical flow. As a result, the newly defined critical flow also accounts for the expectation of a slight reduction in plant protection product sales in accordance with the Federal Council's recommendation in the new Agricultural Policy for 2014–2017.

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[22] Personal communication, Norbert Egli, Federal Office for the Environment, 7 August 2012

12.3.5 Eco-factor for average plant protection product

Tab. 72 > Eco-factor for the emission of plant protection products in the soil in UBP/g glyphosate-eq

	Edition 2013	Q	Notes	Edition 2006
Normalization (t glyphosate-eq./a)	8 241	A		1 507 t PPP-eq./a
Current flow (t PPP/a)	2 208	A	Reference year 2010, BLW (2011)	1 577
Critical flow (t PPP/a)	1 995	b	30% reduction of 1990/92 levels, BLW (2000), see Part 3, Section 12.3.4	1 500
Weighting (-)	1.22			1.11
Eco-factor (UBP/g glyphosate-eq.)	**150**			730 UBP/g PPP-eq.

Q = data quality; for explanation, see Part 2, Chapter 6

A full set of data on the PPP quantities sold and the adjustment of the characterization result in a substantially higher normalization flow and thus a lower eco-factor compared to 2006.[23] The goal (30% reduction of the quantity sold) is the same as in 2006. Since 2006, plant protection product sales have been fully included in FOAG statistics. For that reason, the critical flow in the 2006 version is underestimated and was scaled up for the 2013 eco-factor (see also Part 3, Section 12.3.4). The eco-factor for glyphosate in 2006 was 660 UBP/g. The current eco-factor is therefore substantially lower. However, as far as the discharge of PPPs in Switzerland is concerned, the environmental pressure has risen slightly.

12.3.6 Eco-factors of other plant protection products

Eco-factors for individual PPPs can be calculated using the characterization based on the standard dose of PPPs described in Part 3, Section 12.3.2. Tab. 73 provides an overview of the characterization and eco-factors of selected substances. The full list can be found in A5.

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[23] The characterization factor for glyphosate is close to the average of the plant protection products used in Switzerland in 2006. Therefore, the eco-factors for 2006 and 2013 are comparable despite the different reference substance.

Tab. 73 > Eco-factors of selected PPPs

Active agent	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	Eco-factor 2006 (UBP/g)
Herbicides				
Atrazine	1000	2.4	**360**	1600
Dinitrocresol (DNOC)	18 300	0.13	**20**	88
Glyphosate	2440	1.0	**150**	660
Metsulfuron-methyl	6	420	**63 000**	250 000
Insecticides				
Bifenthrin	18	130	**20 000**	88 000
Chlorpyrifos-ethyl	403	6.1	**920**	2500
Mineral oil	5310	0.46	**69**	43
Fungicides				
Folpet	2560	0.95	**140**	880
Copper*	866	2.8	**(420)***	370*
Metconazole	89	28	**4200**	18 000

The full table can be found in A4

* The eco-factor for copper determined using heavy metal input in the soil (see Section 4.2) is 14 000 UBP/g and is thus significantly higher than the eco-factor determined using the PPP input. The applicable principle is that the highest resulting eco-factor in each instance is used.

13 > Resources

13.1 Overview

The extraction of resources from nature is also weighted with an eco-factor. Until now, only the consumption of energy resources, water, gravel and land use have been weighted in the ecological scarcity method. Other consumed resources are now included in the evaluation. In the case of energy resources (Part 3, Section 13.2), a distinction is made between an eco-factor for renewable (limited rate of replenishment) and non-renewable energies (limited supply). This makes it possible to take account of the different sustainability aspects of these types of energy. Furthermore, new eco-factors are defined for land use (Part 3, Section 13.3), for the diminishing use of primary mineral resources (Part 3, Section 13.3, newly adopted in this version), for the extraction of natural gravel (Part 3, Section 13.5) and for freshwater (Part 3, Section 13.6), as these resources are considered to be ecologically scarce.

13.2 Energy resources

13.2.1 Environmental relevance

The Federal Constitution (Bundesverfassung 2012, Art. 89) states the goal of efficient and environmentally sound energy supply in the same sentence in which it calls for a reliable and economical supply: *“Within their powers, the Confederation and the Cantons shall strive to ensure a sufficient, diversified, reliable, and economical energy supply compatible with the protection of the environment, and the economical and efficient use of energy”.*

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

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

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

For renewable and non-renewable energy resources alike, the assessed energy corresponds to the quantity of energy yielded: the energy content of the harvested biomass, the rotation energy in the case of wind and hydropower generators, the electrical energy delivered to the inverter in photovoltaic installations, the thermal energy delivered to the heat storage system in the case of solar collectors, and the energy quantity extracted from the geosphere in the form of crude oil, raw hard coal, lignite, natural gas and fissile uranium. This provides a consistent concept for evaluating the primary energy demand.

The eco-factor for energy consumption assesses the scarcity of the energy resource; the environmental impacts of energy uses caused by emissions are taken into account through the corresponding eco-factors for air, water and soil pollution.

13.2.2 Characterization

Beside reducing energy consumption, another goal of the 2000 watt society (cf. also Part 3, Section 13.2.4) is to increase the proportion of renewable energy carriers: Of the 2000 watts per person, 1500 watts should be produced from renewable sources (Schweizerischer Bundesrat 2012). Conventional energy supply with non-renewable energy carriers is the current reference (i.e. a characterization factor of 1 MJ-eq. /MJ non-renewable energy). The goal is for renewable resources to supply three times more energy than non-renewable sources, which results in a politically established characterization factor of ⅓ MJ-eq./MJ (tab. 74). In other words, 3 MJ of energy from renewable sources is rated as equivalent to 1 MJ from non-renewable sources.

Tab. 74 > Characterization factors for renewable and non-renewable energy carriers, based on Schweizerischem Bundesrat (2012)

	Characterization factor (MJ oil-eq./MJ)
Non-renewable energy	1
Renewable energy	⅓

13.2.3 Normalization

Aggregate energy statistics (BFE 2011) present the energy balance of Switzerland by energy carrier (see tab. 75). This encompasses domestic production as well as imports and exports. The final consumption of energy carrier compositions is converted into primary energy consumption in Switzerland by using the energy carrier compositions and fuel value conversion factors from Bébié et al. (2009) and primary energy factors from Frischknecht et al. (2012). The characterized primary energy demand is used for normalization. For this purpose, renewable and non-renewable energy consumption is multiplied by the corresponding characterization factors (⅓ and 1 MJ oil-eq./MJ). This results in a normalization flow of 1400 PJ-oil-eq./a.

13.2.4 Weighting

Current flow

The current flow corresponds to the primary energy consumption in Switzerland in 2010 and amounts to 1500 PJ/a (see tab. 75).

Tab. 75 > Consumption of final energy by energy carriers in Switzerland according to 2010 energy statistics (BFE 2011) and their conversion into characterized primary energy consumption

	Energy consumption (lower heating value) (TJ)	Composition	Ratio heating value/fuel value	Energy consumption (fuel value) (TJ)	Primary energy factor, total	Primary energy consumption, total (TJ)	Primary energy consumption, characterized (TJ oil-eq.)
Total						**1 537 631**	**1 428 329**
Fossil energy carriers							
Heating oil (extra light)	191 460		0.94	203 681	1.24	252 261	251 192
Heating oil (medium and heavy)	2 230		0.94	2 372	1.24	2 938	2 926
Petrol coke	1 640		0.94	1 745	1.69	2 947	2 934
Other petroleum fuels	4 190		0.94	4 457	1.24	5 521	5 497
Gas	115 510		0.90	128 344	1.12	143 446	143 137
Petrol	134 650		0.93	144 785	1.29	186 409	186 044
Diesel	98 780		0.94	105 085	1.22	127 870	127 667
Aviation fuel	61 400		0.94	65 319	1.19	77 707	77 593
Liquid propane/liquid butane	0		0.92	-	1.18	0	0
Coal	6 420						
Hard coal		72.7 %	0.96	4 862	1.21	5 862	5 839
Lignite briquets		19.4 %	0.96	1 299	1.21	1 566	1 560
Hard coal coke		7.9 %	0.96	527	1.69	890	886
Biomass							
Wood	38 090						
Timber		45.0 %	0.92	18 631	1.06	19 731	7 226
Wood chips		50.0 %	0.90	21 161	1.14	24 203	8 965
Pellets		5.0 %	0.91	2 093	1.22	2 559	1 146
Biogas	1 620		0.90	1 800	0.37	666	626

Solar/wind/geothermal energy							
Solar energy use	1 850			1 850	1.85	3 419	1 437
Ambient heat use	10 850						
Heat source: air		40.0 %		4 340	0.66 [a]	2 850	559
Heat source: brine or water		60.0 %		6 510	0.77 [a]	5 004	1 310
Other energy carriers							
Industrial waste	10 030			10 030	0.06	584	533
District heat, Swiss average	17 260			17 260	0.85	14 747	14 070
Electricity, Swiss consumption mix	215 230			215 230	3.05	656 452	587 185

[a] The proportion of electricity is subtracted, as the electricity is listed separately under “Other energy sources”. The proportion of electricity in the PEF_{total} of air as a heat source is 62.3% and in the PEF_{total} of brine or water as a heat source is 50.3%.

Critical flow

The goal of the 2000 watt society (Schweizerischer Bundesrat 2012) is used to determine the weighting factor. The 2000 watt society is a long-term goal without any specific target year for the achievement of the goal: The various studies state 2050, 2100 or 2150 (Koschenz & Pfeiffer 2005; Spreng & Semadeni 2001; Würsten 2003). Nevertheless, the goal is a long-term one. The use of a very low goal set in the distant future would greatly exaggerate the issue and urgency compared to other environmental problems. The period from 2030 to 2035 is considered the current time horizon of the policy on climate change and energy concerns. The long-term goal is taken to apply to 2050 and then interpolated to the year 2035.

The critical flow is taken to be equal to the current flow for the short term, as no specific short-term statutory or political reduction targets have been established at present. The long-term reduction target is 2000 watts per person by the year 2050. The population figure is taken from the intermediate scenario of the BFS (2010), which anticipates a resident population of 8.98 million in the year 2050.

13.2.5 Eco-factors for energy

Tab. 76 > Eco-factors for primary energy consumption in accordance with the 2013 and 2050 reference points in time, in UBP/MJ oil-eq.

Eco-factor of the reference points in time

	2013 target	Q	2 050 target	Q	Notes
Normalization (PJ oil-eq./a)	1 428	A	1 428	A	Characterized energy quantity
Current flow (PJ/a)	1 538	A	1 538	A	
Critical flow (PJ/a)	1 538	b	566	b	
Weighting (-)	1.00		7.37		
Eco-factor (UBP/MJ oil-eq.)	0.70		5.16		Basis for interpolation

Q = data quality; for explanation, see Part 2, Chapter 6

Interpolated eco-factor

The eco-factor varies by a factor of seven depending on whether the short-term or long-term target is selected as the reference point in time (tab. 76). The former would underestimate the situation, while the latter exaggerates the issue, as the target only needs to be achieved in a good 35 years. In the following, the eco-factor is interpolated to 2035, as explained above.

Tab. 77 > Eco-factor for the consumption of energy equivalents in UBP/MJ oil-eq., calculated from the targets for 2013 and 2050 and interpolated to 2035

	Edition 2013	Q	Notes	Edition 2006
Normalization (PJ oil-eq./a)	1428	A	Characterized energy quantity	1030
Current flow (PJ/a)	1538			
Critical flow (PJ/a)	693		Calculated from the interpolated weighting and current flow	
Weighting (-)	4.92	b	Interpolated weighting for 2013 and 2050	3.38
Eco-factor (UBP/MJ oil-eq.)	**3.4**		Energy eco-factor interpolated to 2035	3.3

Q = data quality; for explanation, see Part 2, Chapter 6

13.2.6 Eco-factors for renewable and non-renewable energy carriers

Tab. 78 > Eco-factors for renewable final energy and non-renewable primary energy in UBP/MJ of renewable and non-renewable energy

	Characterization (PJ oil-eq./PJ)	Normalization (PJ oil-eq./a)	Weighting (-)	Eco-factor 2013 (UBP/MJ oil-eq.)	Eco-factor 2006 (UBP/MJ oil-eq.)
Non-renewable primary energy	1	1428	4.92	**3.4**	3.3
Renewable final energy	0.33	1428	4.92	**1.1**	1.1

For the eco-factors for renewable primary energy, see Tab. 79.

The energy content of energy resources not used for energy production (feedstock energy, such as when hydrocarbons are used as refrigerants or wood is used in a building), is also assessed with a primary energy factor. However, only the consumed proportion should be assessed (see Section 13.4.7 for details).

13.2.7 Guidelines for using the ecoinvent v.2.2 database

Eco-factors of other energy carriers

Tab. 79 presents the application of the two eco-factors to the energy resources listed in the ecoinvent v.2.2 database.

If a life cycle inventory is based on other assumptions concerning energy content and transformation ratio, the eco-factors must be adjusted to that specific situation following the same method.

Tab. 79 > Eco-factors for the consumption of primary energy resources. Calculated using the eco-factors from tab. 78 and the energy values in Hischier et al. (2010)

	Energy content		Eco-factor, primary energy 2013	
Fossil energy				
Crude oil (before refining)	45.8	MJ/kg	**160**	UBP/kg
Natural gas (before refining)	38.3	MJ/Nm^3	**130**	UBP/Nm^3
Mine gas	39.8	MJ/Nm^3	**140**	UBP/Nm^3
Hard coal (in mine)	19.1	MJ/kg	**65**	UBP/kg
Lignite (in mine)	9.9	MJ/kg	**34**	UBP/kg
Nuclear energy				
Uranium (in ore)	560 000	MJ/kg	**1 900 000**	UBP/kg
Biomass				
Energy in biomass	1	MJ/MJ	**1.1**	UBP/MJ
Energy in biomass, primary forest clearcut	1	MJ/MJ	**3.4**	UBP/MJ
Hardwood, standing a)	19.6	MJ/kg	**22**	UBP/kg
Softwood, standing a)	20.4	MJ/kg	**22**	UBP/kg
Hydro				
Potential energy of water in impoundment b)	0.95	MJ_e/MJ	**1.0**	UBP/MJ
Other renewable energies				
Kinetic energy in wind b)	0.93	MJ_e/MJ	**1.0**	UBP/MJ
Solar energy in solar radiation b)	0.91	$MJ_{e\ u.\ t}$/MJ	**1.0**	UBP/MJ
Geothermal energy b)	1.00	MJ_t/MJ	**1.1**	UBP/MJ

a) Wood may only be assessed if it has not already been taken into account as energy in biomass, as otherwise double counting would occur.
b) According to the ecoinvent v2.2 database, the transformation ratio (quantity of primary energy yielded) is:
hydro = 0.95; wind = 0.93; solar = 0.91 (average of photovoltaic (0.935) and solar thermal (0.885)); geothermal = 1.00.

13.3 Land use

13.3.1 Introduction

The land-use statistics of 2004/09 (BFS 2011b) break down the area of Switzerland (41 285 km^2) into four broad types of use:

1. 7.3% settlement and urban areas (buildings, transportation areas, recreational and green urban areas, landfills, building sites)
2. 36.2% agriculturally utilized areas (grassland, arable land, orchards)
3. 30.9% wooded areas (forest, shrub forest, woods)
4. 25.5% unproductive areas (rock, ice, lakes, rivers, glaciers)

The Swiss Spatial Planning Act (RPG 2012) stipulates that soil resources should be used economically and urban sprawl should be counteracted. Nevertheless, the settlement area has been and still is expanding. According to the Swiss land-use statistics for

2004/2009, the overall settlement area is growing at a rate of around one square metre per second, mostly at the expense of agricultural land in Switzerland's Central Plateau. In remote areas, agricultural land that is no longer managed is transformed again into wooded areas. While the unproductive areas are subject to constant change, their overall area remains roughly constant (BFS 2011b).

According to the BFS (BFS 2011b), the settlement area of Switzerland (3207 km²), is composed as follows:

- 50.4% building areas
- 31.% transportation areas
- 7.3% industrial areas
- 5.2% special urban areas (utility facilities, quarries/mines and dumps, construction sites)
- 6.1% recreational and green urban areas

The settlement area is growing as a result of the growing levels of land take per person and the growing population of Switzerland. The goal of the Federal Council set out in the 2002 sustainable development strategy is to meet further demand wherever possible through inward development, i.e. improved utilization of existing settlement areas (Schweizerischer Bundesrat 2012).

13.3.2 Environmental impact

Soil is a scarce, non-renewable resource. Quantitative loss of soil, sealing, compacting, over-fertilization, pollution and loss of organic matter are the main problems that lead to the loss of biological diversity in and above the soil in Switzerland. Soils formed by nature constitute the basis for biodiversity (BAFU 2012d).

Biodiversity provides essential services to society and industry known as ecosystem services. The diversity of these services is immense: among other things, biodiversity provides food, influences the climate, maintains water and air quality, is part of soil development and offers humans space for recreation. When biodiversity is degraded, this results in less of these services and thus threatens the sustainable development of industry and society (BAFU 2012d).

13.3.3 Characterization

Biodiversity

The characterization of land use applies the method developed by de Baan et al. (2012), which assesses the various types of land use according to their biodiversity (plants, vertebrates, invertebrates). Building upon the Swiss biodiversity monitoring programme and the Globio3 database (Alkemade et al. 2009), de Baan et al. (2012) derives the characterization factors for the BDP (Biodiversity Damage Potential) of a wide variety of different types of land use in various biomes, which reflect the anticipated number of species and the actually encountered number of species for the specific type of land use.

The values for the global mean of the various types of land use according to de Baan et al. (2012) are used for the BDPs. De Baan et al. (2012) chose natural forests as the reference status for biodiversity. Consequently, the difference between the biodiversity of a specific type of land use and the biodiversity of "natural forest" land use is decisive in the determination of the decline in species diversity. "Settlement area" land use is selected as the reference "substance" for the determination of the characterization factors. The use of 1 m^2 of settlement area during a year therefore corresponds to 1 m^2a of settlement area-equivalent.

In order to obtain a degree of detail that is suitable for life cycle assessments, the land-use categories of version 2006 (Frischknecht et al. 2008) based on the selection by Köllner & Scholz (2007a; b) were adopted. The characterization factors from de Baan et al. (2012), however, are not so detailed. Missing items of data were estimated with information from publications by de Baan et al. (2012) and Köllner & Scholz (2007a; b), through equation with similar land-use types or with interpolations. Details can be found in A6 and Section 13.3.4 in Part 3.

Water surfaces and bare lands

The use of *water surfaces and bare land* (e. g. (rock) cannot be characterized at this time. These types, however, are usually of minor importance for life cycle assessments, and hence neglecting them is unlikely to have any significant effect on the outcome.

Unknown uses

For *unknown uses*, a category encountered occasionally in life cycle inventories, a suitable BDP mean value weighted with land use in Switzerland is used.

Agricultural use

The internationally applied factor for *agricultural land use* was applied to intensive types of use, as the proportion of organically farmed agricultural lands is low from a global perspective.

The characterization factors of several land categories for various biomes are listed in tab. 83. The complete list can be found in A6.

Tab. 80 > Global characterization factors (in m² SA-eq.) of selected land-use types according to de Baan et al. (2012)

CORINE+	Land use	Global BDP (-)
Settlement area		
111	Settlement, continuous	0.44
112	Settlement, discontinuous	0.26
121a	Industrial area, continuous, >80% sealed	0.44
121b	Industrial area, discontinuous, <80% sealed	0.26
Agricultural areas		
211b	Arable land, non-irrigated, conventional	0.60
221	Permanent crops, vineyards	0.42
231a	Pastures and meadows, intensive	0.33
Forest		
244	Agroforestry areas	0.20
311a	Forest, broad-leafed, plantations	0.18
312	Forest, coniferous	0.04 [1]

A6 provides the complete list and derivation of factors. [1] For derivation, see Part 3, Section 13.3.4

13.3.4 Characterization of forest management

Forest management in Switzerland

De Baan et al. (2012) list the BDPs for the “natural forest” and “managed forest” types of forest, whereby natural forest is used as a reference and its BDP is zero. The average Swiss forest must be broken down into these two types of use.

The results of the national forest inventory (Brändli 2010) show that Swiss forest is a relatively semi-natural ecosystem. Various indicators in the national forest inventory are combined on the basis of the biotope value models in order to provide a comprehensive, spatially differentiated relative evaluation of the status and development of the Swiss forest from an ecological perspective. The results of these surveys reveal that 53.9% of Switzerland’s forest area has a high biotope value. Therefore, 53.9% of the forest area is assigned the BDP for “natural forest” (corresponding to 0) and the rest of the 46.1% is assigned the BDP for “managed forest” (corresponding to 0.18).

Forest performs various functions. The Swiss forest is both a provider of wood and a place for recreation. This multifunctionality should also be taken into consideration. Only the proportion of the forest that is associated with wood use is attributed to the factor for “managed forest”. For that purpose, an economic allocation is performed between the gross value of the forest and the public’s willingness to pay to use the forest as a place for recreational activities. The gross value of the forest amounted to CHF 373 million (in 2006, BAFU 2012e), which corresponds to CHF 292/ha. The public’s willingness to pay to use the forest for recreational activities translates into an average of CHF 252/ha (calculation based on FOEN (BAFU 2008)). Therefore, recreational use accounts for 46% of the entire value created by the forest, and 56% of land use is attributed to felled wood.[24]

The result of the current situation mentioned above is that Switzerland's average forest can be represented with 25% of the BDP factor for "managed forest" (corresponding to 0.18) and 75% of the BDP factor for "natural forest" (corresponding to 0). Therefore, a BDP factor of 0.04 results for the average Swiss forest.

13.3.5 Normalization

The normalization flow corresponds to the characterized settlement area. The surface areas of the land-use types in settlement areas (excluding agricultural areas, forest areas, water surfaces and bare land) with their respective characterization factors result in a normalization flow of 2400 km² SF-eq*a.

13.3.6 Weighting

Current flow

The current flow relates to the Swiss settlement area of 3000 km² (BFS 2011b).

Critical flow

The stated goal is to stabilise the settlement area at 400 m² per inhabitant (Schweizerischer Bundesrat 2012). As this is a longer-term goal, the calculation uses the future population of 8.84 million in accordance with the intermediate scenario of the BFS (2010) for 2035. This results in a critical flow of 3500 km².

13.3.7 Eco-factor for settlement area

Tab. 81 > Eco-factor land use in UBP/m²a SA-eq. settlement area

	Edition 2013	Q	Notes	Edition 2006
Normalization (km²*a SA-eq.)	2437	A	Characterized area	3378
Current flow (km²)	3027	A	According to the interim report on 04/09 land-use statistics in (BFS 2011d)	2791
Critical flow (km²)	3535	a	Sustainability goal: 400 m² per inhabitant, (Schweizerischer Bundesrat 2002)	3224
Weighting (-)	0.73			0.749
Eco-factor (UBP/(m²*a SA-eq.))	**300**		Eco-factor for settlement area	220

Q = data quality; for explanation, see Part 2, Chapter 6;
SA-eq. = settlement area-equivalent

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[24] This concerns an aspect of the life cycle inventory of forestry. Since the current life cycle inventories of forestry attribute 100 % of the maintenance activities to the wood harvest, the allocation is performed at the level of the eco-factor for land use. Provided the multifunctionality of the forest management is reflected in the life cycle inventory data, the eco-factors for forest management must be correspondingly adjusted.

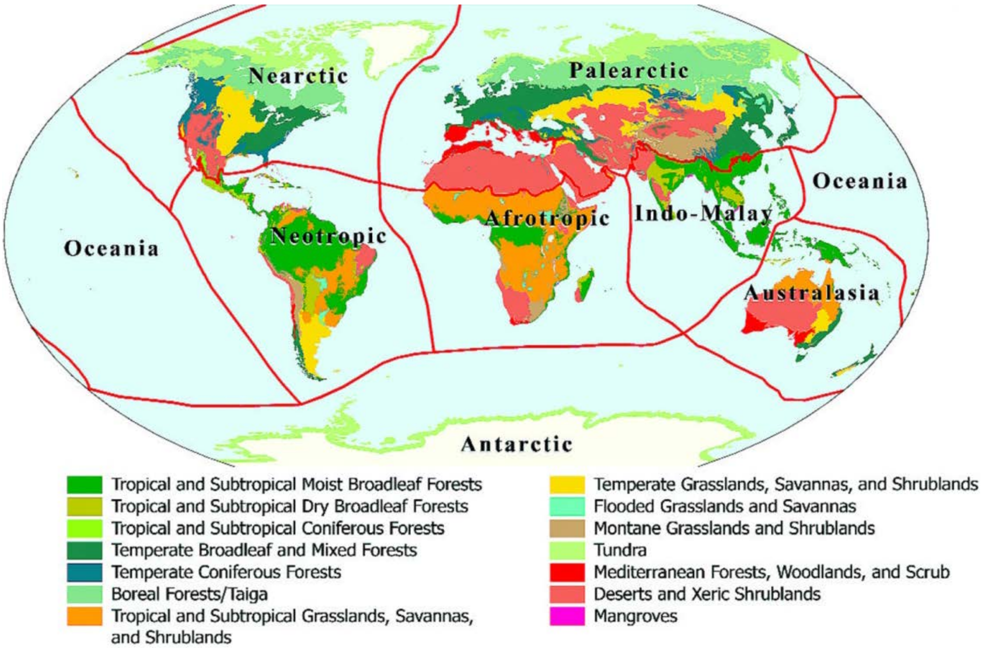
13.3.8 Land use subject to biomes

Biome-specific BDPs

Human activities can cause extensive changes in land use and thus a substantial reduction of biodiversity. One example is the clearing of primary forests for agricultural use. The land-use assessment, which up until now focused on the Swiss situation, should be expanded so that described land uses can also be assessed. The environmental impacts of various types of land use are represented using differences in observed biodiversity.

The 14 biomes according to Olson et al. (2001) are used as a reference system, as in de Baan et al. (2012) (see fig. 6).

Fig. 6 > The 14 biomes according to Olson et al. (2001)



The average plant biodiversities observed in the 14 biomes according to Kier et al. (2005) are used to extrapolate the characterization factors of biome 5 to the other biomes. These vegetation densities relate to biome areas of different sizes and are therefore normalized to 1 m² according to the mathematical relationships described in Köllner & Scholz (2007b). Switzerland is located in biomes 4 and 5 (“temperate broadleaf and mixed forests” as well as “temperate coniferous forests”). Biome 5 was selected as a reference. The internationally applied BDPs from de Baan et al. (2012) are weighted with the ratio of species densities from Kier et al. (2005) to biome 5 (see tab. 82) in order to obtain biome-specific BDPs.

Tab. 82 > Ratio of species densities of biomes 1 to 14 from Kier et al. (2005) to the species density in biome 5

		Ratio to biome 5
Biome 1	Tropical and subtropical moist broadleaf forests	1.968
Biome 2	Tropical and subtropical dry broadleaf forests	0.959
Biome 3	Tropical and subtropical coniferous forests	1.609
Biome 4	Temperate broadleaf and mixed forests	1.057
Biome 5	*Temperate coniferous forests*	**1.0**
Biome 6	Boreal forests/taiga	0.351
Biome 7	Tropical and subtropical grasslands, savannas and shrublands	0.788
Biome 8	Temperate grasslands, savannas and shrublands	0.701
Biome 9	Flooded grasslands and savannas	0.548
Biome 10	Montane grasslands and shrublands	0.839
Biome 11	Tundra	0.209
Biome 12	Mediterranean forests, woodlands and scrub	1.440
Biome 13	Deserts and xeric shrublands	0.526
Biome 14	Mangroves	0.215

Land use in the tropics

The eco-factors of several land categories for various biomes are listed in tab. 83. The complete list can be found in A6. It appears that land use in tropical regions has a higher eco-factor, by a factor of 2, than the same land use in Switzerland.

The 2006 eco-factors can be compared to the eco-factors for biome 5. It appears that the eco-factors except for agricultural land use are similarly high. The new eco-factors for agricultural use are substantially higher than in the 2006 version.

Tab. 83 > Eco-factors of selected land-use types in UBP/m^{2}a for various biomes

CORINE+	Land use	Biome 1 (UBP/m^{2}a)	Biome 4 (UBP/m^{2}a)	Biome 5 (UBP/m^{2}a)	Biome 10 (UBP/m^{2}a)	Biome 12 (UBP/m^{2}a)	Edition 2006
		Tropical and subtropical moist broadleaf forests	Temperate broadleaf and mixed forests	Temperate coniferous forests	Montane grasslands and shrublands	Mediterranean forests, woodlands and scrub	comparable to biome 5
Settlement area							
111	Urban, continuously built	600	330	**300**	250	420	260
112	Urban, discontinuously built	360	190	**180**	150	250	220
121a	Industrial area, continuous built up	600	330	**300**	250	420	260
121b	Industrial area, vegetation	360	190	**180**	150	250	210

CORINE+	Land use	Biome 1 (UBP/m²a)	Biome 4 (UBP/m²a)	Biome 5 (UBP/m²a)	Biome 10 (UBP/m²a)	Biome 12 (UBP/m²a)	Edition 2006
Agricultural areas							
211b	Arable land, non-irrigated, divers-intensive	810	420	**420**	330	600	110
221	Permanent crop, viney	570	300	**290**	240	420	29
231a	Pasture and meadow, intensive	450	240	**230**	190	330	84
Forest							
244	Agro-forestry areas	270	140	**140**	110	200	-
311a	Forest, broad-leafed, plantations	240	130	**120**	100	180	100
312	Forest, coniferous	60	33	**30**	26	45	15

A6 provides the complete list

13.3.9 Guidelines for application: assessing special land-use types

There are two possible ways to handle land uses that are not covered by the extended CORINE nomenclature (cf. also tab. 84 and Part 3, Section 16.1):

1. Increase the degree of detail: a land use can be broken down into defined types of use. The assessment problem can thus be transferred to the life cycle inventory level at which it is more readily resolved (e.g. forests managed to FSC standards can be inventoried by assigning a part to managed forest and a part to natural forest).
2. Proceed by analogy: a land use is similar to a type of use for which there is an eco-factor (e.g. the eco-factor for green urban areas can be applied to green roofs).

Tab. 84 > Recommendation for the characterization of "FSC forest" and "green roof"

Land-use type	Recommendation for classification	Notes
Forest, managed to FSC standards	a) Depending on the type of forest and management: 1) 311: Forest, broad-leafed 2) 312: Forest, coniferous 3) 313: Forest, mixed In the case of plantations, the subcategories 311a, 312a or 313c are to be used b) and, in accordance with the circumstances on the ground, proportions classified as semi-natural 1) 311b: Forest, broad-leafed, semi-natural 2) 312b: Forest, coniferous, semi-natural 3) 313: Forest, mixed	The Swiss FSC rules prescribe ecological management and the designation of at least 5% of the area as strict reserve (BUWAL 1999a). The rules are specified at the national level and may therefore differ in other countries. The inventorization of FSC forest should be performed in the life cycle inventory.
Green roof	1) 113: Urban fallow	Where plantings are ecologically valuable, e.g. oligotrophic grassland on a large flat roof
	2) 141: Green urban areas	Where roof planting is simple **Note:** areas are only counted once, either as a normal settlement area or as a green roof

13.3.10 Implementation in the ecoinvent v.2.2 database

In the ecoinvent v2.2 database, managed forests are classified as “forest, high-intensity”, which is the average form of managed forest in Europe. This would correspond to plantation forests in this categorization (cf. categories 311a, 312a and 313c in A6). This leads to an assessment that does not effectively reflect the circumstances in European forest management, but especially not in Switzerland. For the assessment of products and fuels from Swiss timber, we therefore recommend using the eco-factors for “forest, broad-leafed, “forest, coniferous”, or “forest, mixed” (see A6) for the “occupation, forest, intensive, normal” elementary flow of the ecoinvent v2.2 database. The eco-factor for “occupation, forest, broad-leafed, semi-natural”, “occupation, forest, coniferous, semi-natural” or “occupation, forest, mixed, semi-natural” (eco-factor = 0) are recommended for the “occupation, forest, extensive” and “occupation, tropical rain forest” elementary flows.

The “use, arable land, non-irrigated” should be used for the elementary flow concerning arable lands, except for organically farmed lands and fallows. Tab. 85 shows how land use categories are assigned to the elementary flows in the ecoinvent v2.2 database.

Tab. 85 > Recommended assignment of land use categories and elementary flows for forest and agricultural lands in the ecoinvent v2.2 database

Elementary flow in the ecoinvent v.2.2 database	Recommended land use category
Forest	
Occupation, forest	Occupation, forest, broad-leafed
Occupation, forest, intensive	Occupation, forest, broad-leafed
Occupation, forest, intensive, clear-cutting	Occupation, forest, broad-leafed, plantations
Occupation, forest, intensive, short-cycle	Occupation, forest, broad-leafed, plantations
Occupation, forest, intensive, normal	Occupation, forest, broad-leafed
Occupation, forest, extensive	Occupation, forest, broad-leafed, semi-natural
Occupation, tropical rainforest	Occupation, forest, broad-leafed, semi-natural
Agricultural areas	
Occupation, arable	Occupation, arable land, non-irrigated
Occupation, heterogeneous, agricultural	Occupation, arable land, non-irrigated
Occupation, arable, non-irrigated	Occupation, arable land, non-irrigated
Occupation, arable, non-irrigated, monotone-intensive	Occupation, arable land, non-irrigated
Occupation, arable, non-irrigated, diverse-intensive	Occupation, arable land, non-irrigated
Occupation, arable, organic	Occupation, arable land, non-irrigated, organic
Occupation, arable, non-irrigated, fallow	Occupation, arable land, non-irrigated, fallow

13.4 Primary mineral resources (minerals and metals)

13.4.1 Introduction

The assessment of primary mineral resources is debatable. Economists argue that resource scarcity will automatically be reflected in the prices, and that resources themselves do not cause any external effects as a result. Following this logic, they should not be assessed separately in life cycle assessment methods. The opposing argument is that current resource prices are not only affected by the demand of the generations alive right now; future generations are excluded from price formation. In this sense, the intertemporal equitable distribution of mineral and metal resources is not currently being achieved, which is why these resources need to be included in the assessment.

The Federal Council's cleantech strategy (Schweizerischer Bundesrat 2011b, p. 10) expresses the vision that Switzerland should reduce its resource consumption to sustainable levels (footprint "one"). The Federal Council's sustainable development strategy (Schweizerischer Bundesrat 2012, p. 34) postulates in the new 4–2 measures (information and communications technologies and sustainable development) that recycling activities should be developed in the field of information and communications technologies in order to close material cycles. The Swiss federal government is promoting actions within the current 4b measure (integrated product policy) to close material cycles. This also involves conserving material resources by closing material cycles.

Given the abovementioned strategies, material resources are once again included in the assessment. A broad approach (annual depletion of reserves) has been selected from the various approaches presented and compared in scientific publications to be used for the characterization. This approach quantifies the scarcity of a specific resource and is therefore very similar to the basic principle of the ecological scarcity method.

13.4.2 Characterization

The environmental impact of the dissipative use of metals and minerals is characterized by squaring the ratio of the current volume annually excavated worldwide to the available reserves (Guinée et al. 2001a). The production volumes and available reserves were updated with information from the USGS (2011) and completed with data from Angerer et al. (2009). The phosphorus reserves according to the USGS (2011) were thus adjusted using the Moroccan phosphorous reserves from the USGS (2010), as the source data for the large Moroccan reserves taken from the USGS (2011) were deemed presumptive and inconclusive by the Global Phosphorus Research Initiative (GPRI, White et al. 2010).

The production volumes and reserves of specific rare earths were determined by dividing up the data on all rare earths based on the frequency of the individual elements in the excavated ores according to Cotton (2003).

Antimony (Sb) is used as the reference substance. Tab. 86 lists a selection of the characterization factors. A7 provides a complete list of all assessed metals and minerals.

Tab. 86 > Characterization factors for selected metal and mineral resources according to their scarcity, with antimony (Sb) as the reference substance. Complete list in A7

Substance	Specification	Characterization factor (kg Sb-eq./kg)
Antimony		1.00
Chromium	25.5% in chromite, 11.6% in crude ore	0.0043
Gypsum		0.00058
Indium	0.005% in sulfide, In 0.003%, Pb, Zn, Ag, Cd, in ore	114
Lead	5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in ground	0.015
Tin	79% in cassiterite, 0.1% in crude ore	0.23
Gold	Au 2.1E-4%, Ag 2.1E-4%, in ore	23.1
Zinc	9.0% in sulfide, Zn 5.3%, Pb, Ag, Cd, In, in ore	0.0046
Silver	3.2 ppm in sulfide, Ag 1.2 ppm, Cu and Te, in crude ore	2.05
Cadmium	0.30% in sulfide, Cd 0.18%, Pb,Zn, Ag, In, in ore	1.21

It is debatable whether the volume of reserves deemed economically exploitable is dependent upon the current price level of the corresponding minerals and metals or upon the business considerations of large corporations regarding the available reserves specified in their annual reports. The characterization factors determined in such a way can vary over time as a result. However, this variation may be substantially less from the global perspective applied here than from the business perspective. For that reason, we still consider the approach applied here to be the best suited one, particularly because the information used is updated regularly by the U.S. Department of the Interior.

13.4.3 Normalization

The normalization flow is determined based on the global production of minerals and metals and the ratio of the Swiss population to the world population. In 2010, a total of 800 000 tonnes of Sb-eq. were produced globally. According to the UN Population Division, the world population was 6896 million in 2010.[25] In 2010, 7 788 500 people were living in Switzerland. This results in a total normalization flow of 900 tonnes of Sb-eq. per year.

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[25] http://esa.un.org/unpd/wpp/unpp/panel_population.htm (Accessed on 22 December 2011)

13.4.4 Weighting

Current flow

The current flow corresponds to the normalization flow.

Critical flow

The critical flow was initially approximated to be equal to the current flow.

The critical flow is equated with the current flow in a preliminary assessment based on the minimum goal. The qualitative goals chosen by the Federal Council are to reduce resource consumption, increase resource efficiency and close more material cycles (Schweizerischer Bundesrat 2012, p. 8). However, the quantitative goals, the time frames for their achievement and the system of measurement to monitor goal achievement have not yet been set out in any binding manner. In this situation, "no further deterioration", i.e. maintaining the status quo, is used as the binding minimum goal for the assessment of the critical flow. As a result, the critical flow corresponds to the current flow.

13.4.5 Eco-factor for minerals and resources, lead substance antimony

The eco-factor for the extraction of the resource antimony, the lead substance, is introduced in this version. Tab. 87 shows the resulting eco-factor, whereby the normalization flow corresponds to the proportional production quantity of all metals and minerals.

Tab. 87 > Eco-factor for metal and mineral resources, lead substance is antimony; in UBP/g Sb-eq

	Edition 2013	Q	Notes	Edition 2006
Normalization flow (t Sb-eq./a)	904	A	World production, Swiss proportion	
Current flow (t Sb-eq./a)	904	A	World production, Swiss proportion	
Critical flow (t Sb-eq./a)	904	c		
Weighting factor (-)	1.00			
Eco-factor (UBP/g Sb-eq.)	**1 100**		Characterization factor = 1	

Q = data quality; for explanation, see Part 2, Chapter 6

13.4.6 Eco-factors of other metals and minerals

The eco-factors of other metals and minerals are determined using the characterization based on the scarcity approach (cf. tab. 86 and the detailed list in A7).

Tab. 88 > Eco-factors for selected metal and mineral resources

Substance	Specification	Characterization (kg/kg Sb-eq.)	Eco-factor (UBP/kg)
Metals			
Copper	1.18 % in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore	0.0010	**1 100**
Chromium	25.5 % in chromite, 11.6% in crude ore	0.0043	**4 800**
Lead	5.0 % in sulfide, Pb 3.0%, Zn, Ag, Cd, In	0.015	**17 000**
Tantalum	81.9 % in tantalum, 1.6E-4% in crude ore	1.33	**1 500 000**
Silver	3.2 ppm in sulfide, Ag 1.2 ppm, Cu and Te, in crude ore	2.05	**2 300 000**
Gold	4.9E-5 % in ore	23.1	**26 000 000**
Minerals			
Gypsum		0.00001	**6.30**
Phosphorus	18 % in apatite, 4 % in crude ore	0.00006	**62.0**
Sulfur		0.00007	**72.0**

Complete list in A7

13.4.7 Guidelines for applying the eco-factors

The goal of the Federal Council's strategy is to close material cycles (see Section 13.4.1). From this, it can be deduced that resource extraction is not decisive in the material use of resources, but rather the amount of dissipatively, i.e. irrevocably, extracted and processed resources that are lost and no longer available for future use. The remaining portion, which can be recovered or recycled, is only "on loan" and may be used again in the future.

Hence, resource extraction, and not dissipative use, is assessed in the way the used inventories are represented. In case studies where the use of primary resources is important, it should be ensured that only dissipative use (as described above) is assessed.

The eco-factor of mineral and metal resources should therefore be applied to the difference between resource extraction and recycled resources. Alternately, it can also be applied to the proportion of dissipatively used mineral or metal resources (which comes out to the same result, but is technically easier to implement as concerns databases). These methods should also be applied to the separately derived eco-factor for gravel.

A similar assessment should now also be applied in the case of organic resources that are used for materials (plastics, wood, renewable raw materials). Resource extractions (crude oil, natural gas, coal, wood and many others) are still assessed with the primary energy eco-factor. The particular proportion of raw material that is recycled should now be assessed with a negative primary energy factor. Accordingly, the "borrowed" use of material resources is not assessed in this case either, but rather only the "dissipative use". The thermal treatment of products from organic materials (e.g. plastics or wood) at the end of their life cycle is considered dissipative use.

13.5 Gravel extraction

13.5.1 Introduction

Gravel (and sand) is a *sui generis* resource: it is both a construction material and an important material for protecting and forming ground water. Not all physical gravel occurrences are extractable; permissible land uses set limits.

Gravel and sand are mainly used in the construction industry, particularly as concrete aggregate and in road and railway subgrades. Sand is also used in mobile telephones, cosmetics and chips. The quality of gravel deposits can vary widely. High-grade alluvial gravels are found especially on valley floors, while morainic mounts often have a mixed composition, making gravel extraction more costly (Jäckli & Schindler 1986; Kündig et al. 1997). Sand is not only excavated for building purposes, but also to fill beaches. Sand is actually the most used raw material after water in terms of mass. The consequences of unlimited industrial sand use include the loss of river beds and habitats for animals (Chaton 2013).

Gravel resources replenish very slowly. Only around 1% of Switzerland's annual gravel consumption is formed anew in rivers in the same period. Moreover, the geological gravel deposits are reduced by competing demands such as housing construction, groundwater protection and, in some cases, forest protection and species diversity conservation. As a result, the extractable quantity is substantially smaller than the resource (Jäckli & Schindler 1986). In the canton of Zug, for instance, it is assumed that if extraction intensity remains at the same level, the utilizable gravel reserves will suffice for only 18 years (Raumplanungsamt Kt. Zug 2005). The above-mentioned items subject to protection are included in the "extractable gravel quantities" set by the authorities. Therefore, the ecological scarcity of this form of land use can be determined using the gravel quantities.

According to Chaton (2013), the amount of sand being excavated is equal to the sand produced by all of the world's rivers in one year.

13.5.2 Normalization

The normalization flow is identical to the current flow, as the latter relates to all of Switzerland. No characterization is performed.

13.5.3 Weighting

Current flow

The gravel production of Swiss gravel works depends on construction sector activity and has ranged between 30 and 40 million tonnes in the last 20 years, peaking around 1990. In the year 2009, 33 million tonnes of sand and gravel were extracted (BFS 2011d); this is used as the current flow.

Critical flow

The spatial planning authorities of the cantons are responsible for approving gravel extraction. Provisions governing extraction have therefore only been established, if at all, at the cantonal level. It has been clear for some time that gravel reserves will be exhausted in the foreseeable future (see e.g. Kündig et al. 1997; Raumplanungsamt Kt. Zug 2005). The volume of gravel reserves designated for extraction across Switzerland has always been sufficient for the next 15 to 20 years. Therefore, even though the resource is essentially finite, the current extraction situation is tolerated. Thus, the critical flow is taken to be equal to the current flow.

13.5.4 Eco-factor for gravel extraction

Tab. 89 > Eco-factor for gravel extraction in UBP/g gravel

	Edition 2013	Q	Notes	Edition 2006
Normalization (million t gravel/a)	33.46	A		34
Current flow (million t gravel/a)	33.46	A	(BFS 2011d)	34
Critical flow (million t gravel/a)	33.46	c		34
Weighting (-)	1.00			1.00
Eco-factor 2013 (UBP/g gravel)	**0.030**			**0.029**

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor for gravel has increased slightly. It reflects the currently tolerated extraction volume.

13.5.5 Guidelines for application

The eco-factor for gravel should be applied for gravel and sand from alluvial gravel pits. Gravel and sand excavated from rock (quarry, tunnel construction) or extracted from the bed load of rivers and lakes should not be assessed with this eco-factor.

For the assessment of gravel and sand that are recycled and reused for other purposes, see Section 13.4.7.

13.6 Freshwater consumption

13.6.1 Introduction

In some regions of the world, freshwater is scarce, while in others, there is a surplus. Switzerland is in the comfortable position of having access to more than enough clean water. Nevertheless, the Federal Council (Schweizerischer Bundesrat 2002, p. 9) demands that "*[…] natural resources be utilized with due regard to future generations*" and specifies this by demanding that, among other things, "*[…] the consumption of renewable resources (e.g. farmed biomass, water) is kept below the level at which they can regenerate or below the natural level of availability*". The same document also notes the global freshwater problem, citing the OECD. One of the measures of the Federal Council's current sustainable development strategy (Schweizerischer Bundesrat 2012) is intended to strengthen the international environmental regime with a particular focus on the issue of "water".

With this in mind, four types of eco-factors are derived for freshwater:

1. Country-specific (for Switzerland and all other countries in the world)
2. For six different scarcity situations (low, moderate, medium, high, very high and extreme)
3. For the OECD and BRIC countries (weighted average consumption) as food, if the water consumption is not differentiated in a life cycle inventory
4. For the continents of Africa, Asia, Europe, Australia, North and Central America, South America and separately for OAPEC countries

This makes it possible to differentiate – for instance, in life cycle assessments of foods or other products requiring large amounts of water for their production – between origin from arid regions where water scarcity prevails and origin from regions with ample water resources, and to take account of the aspect of water scarcity in arid regions that can be relevant in some cases. Users of the method can also derive regional or local eco-factors themselves to address specific issues.

According to the OECD (2004), the scarcity of freshwater resources can be expressed as the share of gross consumption in the available renewable water resource (precipitation plus inflows from neighbouring countries minus evaporation). This share is known as water stress.

If the share of gross consumption in the available resource is 10–20%, water stress is classed as moderate according to the OECD (2004); 20–40% is considered medium to high, and if the share is above 40%, it is high.

Term definitions

Tab. 90 shows the terms used in this report in reference to water extraction, consumption and renewable water resources.

Tab. 90 > Term definitions according to FAO (2012)

Term	Definition	Term according to FAO (2012)	Term according to FAO (2012)
Water withdrawal	Water withdrawal means not only withdrawing water for use as drinking water, but also for irrigating agricultural areas and for industrial processes. In-stream uses that are characterized by a very low net consumption rate are not taken into account. This includes turbined water, navigation, recreational activities, fishing, etc.	Annual quantity of water withdrawn for agricultural, industrial and municipal purposes. It includes renewable freshwater resources as well as potential over-abstraction of renewable groundwater or withdrawal of fossil groundwater and potential use of desalinated water or treated wastewater. It does not include in stream uses, which are characterized by a very low net consumption rate, such as recreation, navigation, hydropower, inland capture fisheries, etc.	Total water withdrawal
Water consumption (consumptive water use)	Water consumption corresponds to the proportion of water that evaporates during its use (evaporation or evapotranspiration), is embodied in products or diverted from its original catchment to a different catchment.	The part of water withdrawn from its source for use in a specific sector (e.g., for agricultural, industrial or municipal purposes) that will not become available for reuse because of evaporation, transpiration, incorporation into products, drainage directly to the sea or evaporation areas, or removal in other ways from freshwater resources.	Water consumption, consumptive water use
Renewable water supply, renewable water resources	Renewable water resources include the long-term average runoff from rivers (surface water) and the accumulation of aquifers (ground water) through precipitation. Groundwater aquifers that are practically totally isolated from the natural water cycle and thus have only an insignificantly low accumulation rate (on a human time scale) are not classified as renewable.	Total Natural Renewable Water Resources (TRWR_natural): The long-term average sum of internal renewable water resources (IRWR) and external natural renewable water resources (ERWR_natural). It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment.	Water resources: total renewable (natural)

Consumptive use

While the water stress index expresses the ratio of water withdrawal to water supply, the eco-factor developed here for product and corporate life cycle assessments is applied to consumptive water use.

13.6.2 Normalization

A characterization is not performed. The Swiss level of freshwater consumption, which is 2.6 km³/a (approximately 350 m³ per capita and year or 1000 litres per capita and day), is used as the normalization flow (FAO 2011b). This value corresponds to the current flow when assessing the eco-factor for Switzerland.

The normalization flow of Switzerland is also used for normalization when calculating country-specific eco-factors or assessing water scarcity categories. Normalization is calculated on the basis of the current flow of the region to which the eco-factor should apply, which is Switzerland in this case. A weighting factor determined for a certain region can be normalized to Switzerland and thus integrated in the assessment (cf. also Part 2, Section 3.4).

13.6.3 Weighting

Current and critical flow for Switzerland

According to FAO (2011a), the **current flow,** i.e. the quantity of freshwater consumed annually in Switzerland, is 2.6 km³/a. FAO (2011a) also reports that the available annual renewable water resource in Switzerland is about 54 km³.

According to the OECD (OECD 2003), a tolerable water stress is the withdrawal of 20% of the renewable water supply. Therefore, the **critical quantity** of freshwater use for Switzerland is about 11 km³/a.

Other OECD and non-OECD countries

Overall, the quantity of freshwater withdrawn in OECD and BRIC countries is 2500 km³/a (calculated on the basis of data from FAO (FAO 2011a). A7 has the data of the individual OECD and non-OECD countries.

Weighting according to scarcity situation

The weighting is calculated based on the scarcity situation. The OECD defines four categories of water scarcity, whereby if the ratio of renewable water supply to water withdrawal exceeds 0.4, it is assumed that water scarcity is high (OECD 2004). For the purposes of a life cycle assessment, however, cases may also arise in which very high (up to a ratio of 1) and extremely high scarcity (water withdrawal exceeds the renewable water supply) are relevant. The OECD categories are therefore complemented by two further categories: very high (0.6 to <1.0) and extreme (≥1.0).

The weighting factor is calculated by the ratio of water withdrawal to renewable water supply (without needing to know the absolute values) and based on the assumption that the critical flow is 20% of the water supply as follows:

$$Weighting = \left(\frac{current\ flow}{critical\ flow}\right)^2 \tag{10}$$

$$= \left(\frac{water\ withdrawal}{(water\ supply_{renewable} \cdot 20\%)}\right)^2 \tag{11}$$

$$= \left(\underbrace{\left(\frac{water\ withdrawal}{water\ supply_{renewable}}\right)}_{scarcity\ \ ratio}\right)^2 \cdot \left(\frac{1}{20\%}\right)^2 \tag{12}$$

Tab. 91 > Calculation of weighting factors from the ratios of water withdrawal to renewable water supply for the different water scarcity categories

Category		Weighting		
	Water scarcity ratio $\frac{water\ withdrawal}{water\ supply_{renewable}}$	Ratio used for calculation	Calculation of scarcity for critical flow = 20% of the water supply	Weighting factor (-)
low	<0.1	0.05	$(0.05)^2 / (0.2)^2$	0.0625
moderate	0.1 to <0.2	0.15	$(0.15)^2 / (0.2)^2$	0.563
medium	0.2 to <0.4	0.3	$(0.30)^2 / (0.2)^2$	2.25
high	0.4 to <0.6	0.5	$(0.50)^2 / (0.2)^2$	6.25
very high	0.6 to <1.0	0.8	$(0.80)^2 / (0.2)^2$	16.0
extreme	≥1	1.5	$(1.50)^2 / (0.2)^2$	56.3

13.6.4 Eco-factor for Swiss freshwater

Tab. 92 > Eco-factor for the consumption of Swiss freshwater in UBP/m³ freshwater

	Edition 2013	Q	Notes	Edition 2006
Normalization (km³/a)	2.61	A		2.57
Current flow (km³/a)	2.61	A	(FAO 2011b)	2.57
Critical flow (km³/a)	10.7	b	20% of the renewable water supply according to FAO (2011b)	10.7
Weighting (-)	0.0597		Ratio of water withdrawal to supply: 0.049	0.0577
Eco-factor (UBP/m³)	**23**			**22**

Q = data quality; for explanation, see Part 2, Chapter 6

This eco-factor should be applied in product and corporate life cycle assessments for consumptive freshwater use in Switzerland. No water scarcity prevails in Switzerland. Nevertheless, water shortages can arise in the summer months in certain locations. The eco-factor stated here does not capture such temporally and spatially limited situations. Where such situations need to be assessed, users of the method can derive eco-factors themselves in accordance with the methodology set out in Sections 3.4 and 3.5.

13.6.5 Eco-factors for freshwater according to scarcity categories

Tab. 93 > Eco-factors for consumptive freshwater use in regions with different levels of water scarcity in UBP/m³ freshwater

	Water scarcity ratio $\frac{\textit{water withdrawal}}{\textit{water supply}_{\textit{renewable}}}$	Normalization (km³/a)	Weighting (-)	Eco-factor 2013 (UBP/m³)	Eco-factor 2006 (UBP/m³)
Low	<0.1	2.61	0.0625	**24**	24
Moderate	0.1 to <0.2	2.61	0.563	**220**	220
Medium	0.2 to <0.4	2.61	2.25	**880**	880
High	0.4 to <0.6	2.61	6.25	**2 400**	2 400
Very high	0.6 to <1.0	2.61	16	**6 200**	6 200
Extreme	≥1	2.61	56.3	**22 000**	22 000

The weighting factors come from Tab. 91

Numerous countries have “low” to “medium” water scarcity, corresponding to eco-factors spanning a factor of around 40. In contrast, there is almost a factor of 1000 between the eco-factors in the “low” and “extreme” categories. This reflects the severe over-exploitation in arid regions such as Saudi Arabia, where more freshwater (especially groundwater) is utilized than is available from precipitation and inflows.

13.6.6 Eco-factors for consumptive freshwater use of unknown or undifferentiated origin (average of OECD and BRIC countries)

The eco-factor for consumptive freshwater use of unknown or undifferentiated origin is derived from the water scarcity in OECD and BRIC countries. The average eco-factor for OECD and BRIC countries is calculated in the same way as weighted mean for water withdrawal of the eco-factors for individual countries and comes to 610 UBP/m³ (see A8). The eco-factor for consumptive water use in OECD and BRIC countries is considerably higher than the 2006 eco-factor for OECD countries. This is attributable to the different calculation method (weighted instead of arithmetic method) and the new system boundary. For that reason, countries with high water demand and high water scarcity contribute a high eco-factor to the average eco-factor. In addition, the BRIC countries of Brazil, Russia, India and China are also taken into account due to their economic importance.

Tab. 94 > Eco-factor for freshwater of unknown or undifferentiated origin in UBP/m³ freshwater – derived from water scarcity in OECD and BRIC countries

	Edition 2013	Q	Notes	Edition 2006 (OECD only)
Normalization (km³/a)	2.61	A	Water withdrawal in Switzerland (i.e. current flow in Switzerland	2.57
Current flow (km³/a)	2467	A	(FAO 2011b)	1020
Critical flow (km³/a)	1955	b	Derived from the current flow and the weighting factor	2040
Weighting (-)	1.59		Withdrawal-weighted country average of the national weighting factors	0.250
Eco-factor (UBP/m³)	**610**			97

Q = data quality; for explanation, see Part 2, Chapter 6

This average value should be applied in product and corporate life cycle assessments when consumptive water use is of unknown or undifferentiated origin. The eco-factor is positioned between the categories for moderate and medium water scarcity (tab. 93). Water scarcity is a particular problem in arid regions, where it can be further exacerbated by intensive agriculture. Water scarcities that are limited in space or time cannot be taken into account by this eco-factor.

Wherever possible, classification into one of the six water scarcity categories (Part 3, Section 13.6.5) or differentiation by continent is preferable over use of this average eco-factor. A8 lists eco-factors for the individual OECD and non-OECD countries.

13.6.7 Regional eco-factors for freshwater

Based on the country-specific eco-factors, average eco-factors are weighted for various regions of the world and calculated using the quantity of water withdrawn in them. A separate eco-factor is calculated for OAPEC members (Organization of Arab Petroleum Exporting Countries) because these countries are affected by particularly high levels of water scarcity. tab. 95 shows that a lower level of water scarcity prevails in the Americas and Australia compared to Europe, while Asia is affected by a comparatively higher level of water scarcity. Australia's example shows, however, that a country average does not necessarily reflect the local situation adequately. In Australia, there is low water stress in coastal areas, while its inland water supply is small.

Tab. 95 > Average eco-factors for freshwater use in regions of the world in UBP/m³ freshwater

	Water withdrawal (10^9 m³/a)	Normalization (km³/a)	Eco-factor 2013 (UBP/m³)
Africa without OAPEC*	139	2.61	**490**
Asia without OAPEC*	2455	2.61	**1200**
OAPEC*	191	2.61	**370000**
Europe	291	2.61	**420**
Australia	28	2.61	**17**
North and Central America	629	2.61	**220**
South America	166	2.61	**5.0**
OECD	1028	2.61	**320**
BRIC (Brazil, Russia, India and China)	1439	2.61	**820**
OECD & BRIC	2467	2.61	**610**

*OAPEC = Organization of Arab Petroleum Exporting Countries (Saudi Arabia, Algeria. Bahrain, Egypt, United Arab Emirates, Iraq, Kuwait, Libya, Qatar and Syria)

13.6.8 Guidelines for application of (regionally specific) eco-factors

Consumptive use

In contrast to earlier versions, *consumptive* water use, instead of water *withdrawal*, is now assessed with the eco-factors for freshwater. There are three different types of consumptive water use. First, water can be embodied in products. Second, used water can evaporate/vaporize (due to plants or industrial processes). Third, water can be diverted from one water catchment and brought to another. In all three types of water use, the water in the catchment concerned is no longer available for other uses. Applications in which water is used and then returned to the same catchment from which it was withdrawn are excluded from the assessment using the freshwater eco-factor. Any contamination of the withdrawn, used and returned water is taken into account in the assessment of water pollutants (see Part 3, Chapter 10).

The eco-factor for consumptive freshwater use should be applied, but not limited to, the following cases:

- Evaporation in the case of drinking water use
- Irrigation in agriculture (proportion of water contained in the harvested plants plus evapotranspiration, excluding the proportion of rain water)
- Vaporization in industrial processes

If the life cycle inventory comprises no regional or scarcity-based differentiation, the average eco-factor should be used in accordance with Part 3, Section 13.6.6. The eco-factor of the highest scarcity category should be used for the withdrawal (not only the consumptive use) of fossil (non-renewable) water.

Eco-factors were calculated for all OECD and non-OECD countries. A7 lists them. A geographical representation of regionalized water scarcities and the corresponding data (water stress index) were published by Frischknecht & Jungbluth (2009).[26] This data can be used to calculate regionally-specific eco-factors for all water catchments around the world. The procedure is analogous to the procedure for calculating the Swiss eco-factor. Data sources, potential assumptions and the calculation of any eco-factors derived by users should always be stated in a reproducible manner.

Tab. 96 classes selected countries in the six scarcity categories. The list should serve as a reference for estimating the water scarcity category of countries or regions by analogy and without detailed data. These eco-factors do not, however, capture any regional scarcities within these countries. They also do not capture seasonal variations, as annual values are taken into account.

Tab. 96 > Classification of selected countries in the water scarcity categories

	Water scarcity ratio $\frac{\text{water withdrawal}}{\text{water supply}_{\text{renewable}}}$	Typical countries
Low	<0.1	Austria, Iceland, Ireland, Russia, Zambia, Switzerland, Venezuela
Moderate	0.1 to <0.2	Argentina, Estonia, Greece, France, Mexico, Poland, Czech Republic, Turkey, USA
Medium	0.2 to <0.4	Albania, Germany, Italy, Indonesia, Japan, Spain, Tanzania
High	0.4 to <0.6	Algeria, Bulgaria, Morocco, Sudan, Tunisia
Very high	0.6 to <1.0	China, Cuba, Moldova, Philippines, Tadzhikistan, Thailand
Extreme	≥1	Israel, Yemen, Qatar, Kuwait, Oman, Pakistan, Saudi Arabia, Syria, Cyprus

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[26] Download from a corresponding Google^{TM} Earth Layer to show the regionalized water scarcities, compatible with the ecological scarcity method at http://treeze.ch/projects/methodology-development/life-cycle-impact-assessment/ecological-scarcity-method-2006/

13.6.9 Guidelines for the application of life cycle inventory data

Water balance inventory data

This section explains how consumptive water use can be quantified from inventory data (unit processes) (see also Flury et al. 2012). The life cycle inventory data should include the entire water balance (including rain water). To do so, new elementary flows with country codes must be introduced so that a regional assessment is possible. Water input is now no longer differentiated by source, but rather subsumed under an elementary flow. Embodied water is also considered a water input.

Tab. 97 provides an overview of elementary flows required for an industrial and agricultural process as an example. The water input (1 + 2) should match the water output (sum of 3 to 7). If rain water is also covered, it must be taken into account in the output as well.

The following is the minimum information required for a complete inventory and a flexible assessment of processes:

> Water withdrawal, country-specific (1)
> Evaporation: emission from water into the air, country-specific (3)
> Water, contained in the product, country-specific (2, 7)

Tab. 97 > Elementary flows for a complete inventory of water used in processes

No.	Elementary flow	Industrial process	Agricultural process
Input			
1	Water, unspecified natural origin, country XY	Water for production process (e.g. cleaning devices, containers, etc.)	Water for irrigation
-	Water, rain	Not taken into account	Taken into account for complete inventory
2	Water, embodied, in product, country XY	Water embodied in raw materials	Water embodied in seeds
Output			
3	Water, country XY (emitted in the air)	Emission: water vaporized during the production process	Emission: evaporated water from farmed fields
4	Water, river/lake	Discharged directly from the industry into surface waters	Discharged from fields into surface waters
5	Water, sea	Discharged directly from industry into the sea	Discharged from the fields into the sea
6	Water, soil	Direct infiltration in the soil	Infiltration in the soil from fields
7	Water, embodied, in product, country XY	Water embodied in the product	Water embodied in the product
Total			
	Water withdrawal	1	
	Consumptive water use	3+7–2	

13.6.10 Guidelines for using the ecoinvent v.2.2 database

Correction factors for the ecoinvent v2.2 database

The life cycle inventory in the ecoinvent v2.2 database includes only data on water withdrawal and not on consumptive water use. Yet, the above-mentioned method is not feasible for the ecoinvent v2.2 database with reasonable effort. The following simplified procedure is therefore recommended for an assessment of consumptive water use: correction factors are introduced in the assessment method. They quantify the average proportion of consumptive water use (e.g. through evaporation) in water withdrawal for each individual elementary flow.

Tab. 98 > Standard values for the proportion of consumptive water use, to be applied to existing elementary flows in the ecoinvent v2.2 database

Elementary flow in the ecoinvent v.2.2 database	Proportion of consumptive water use	Source
Water, cooling, in unspecified natural origin	5 %	(Muñoz et al. 2010, Rosiek et al. 2010, Jefferies et al. 2011, Gleick 1994, Shaffer 2008, Stiegel & al. 2008, Scown & al. 2011)
Water, lake	10 %	(Shaffer 2008, Statistics Canada 2010)
Water, river	10 %	
Water, well, in ground	10 %	
Water, unspecified natural origin	10 %	
Water, salt, ocean	0	
Water, salt, sole	0	
Water, turbine use, in unspecified natural origin	0	

14 > Wastes

14.1 Introduction

In this chapter, eco-factors are derived for various types of wastes. Wastes in above-ground landfills are assessed on the basis of the carbon content in the stored wastes. Certain hazardous wastes (Part 3, Section 14.3) and radioactive wastes (Part 3, Section 14.4) are stored underground.

14.2 Carbon (C) in material consigned to landfills

14.2.1 Environmental relevance

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

14.2.2 Normalization

No characterization is performed. The normalization flow is identical to the current flow, as the current flow represents the C flow in landfills for all of Switzerland.

14.2.3 Weighting

Current flow

The current flow comprises the quantity of carbon that is stored through the waste in landfills for inert materials and stabilized residues, bioreactive landfills and slag compartments. tab. 99 lists the quantities of waste stored in landfills in 2011 according to the waste statistics of the Swiss Ordinance on the Charge for the Remediation of Contaminated Sites (VASA 2012). According to the Technical Ordinance on Waste (TVA 2011), bioreactive materials must comply with a limit value of 5% carbon content and all other wastes stored in landfills must meet the limit value of 2% carbon content. Based on current control measurements, it can now be assumed that the classes of stored material meet the requirements of the Technical Ordinance on Waste (TVA 2011).[27]

Tested samples show that the organic carbon content in municipal waste incineration slag is well below 3% (BUFU 2010b). The current flow is calculated based on the conservative assumption that the carbon content in wastes stored in landfills complies with the limit value, even though it should be assumed that the current flow is somewhat lower. This results in a current flow of 183 000 t C/a.

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[27] Personal communication, Waste and Raw Materials Division, FOEN 2012

As the stored wastes meet the requirements of the Technical Ordinance on Waste (TVA 2011), the critical flow corresponds to the current flow of 183 000 t C/a.

Critical flow

Tab. 99 > Quantities of waste consigned to landfills in Switzerland in 2011 and their maximum carbon content (Total Organic Carbon, TOC)

	2 011 statistics (t)	TOC limit value (TVA 2011) (%)	TOC (t)
Inert materials	6 887 808	2.0 %	137 756
Stabilised residues	127 622	2.0 %	2 552
Bioreactive substances	583 644	5.0 %	29 182
Slag compartments*	686 573	2.0 %	13 731
Total	**8 285 600**		**183 222**

* 2010 value (exported slag); Source: "Ablagerung_Uebersicht_Norbert.xlsx" data file[28]

14.2.4 Eco-factors for carbon in wastes consigned to landfills

Tab. 100 > Eco-factor for carbon in bioreactive landfill wastes in UBP/g C. The table also lists eco-factors for average slags and other bioactive landfill wastes

	Edition 2013	Q	Notes	Edition 2006
Normalization (t C/a)	183 222	B	(TVA 2011), (VASA 2012)	97 410
Current flow (t C/a)	183 222	B	(TVA 2011), (VASA 2012)	97 410
Critical flow (t C/a)	183 222	b	(TVA 2011), (VASA 2012)	79 420
Weighting (-)	1.00			1.50
Eco-factor (UBP/g C)	**5.5**			**15**
Eco-factor (UBP/g slags)	**0.11**		C content: 2%; TVA (2011)	**0.61**
Eco-factor (UBP/g other bioactive landfill wastes)	**0.27**		C content: 5%; TVA (2011)	**2.3**

Q = data quality; for explanation, see Part 2, Chapter 6

The eco-factor is two-thirds lower than the situation in 2006 because the carbon content of inert materials is now also taken into account and the critical flow is now just as high as the current flow.

14.2.5 Guidelines for using the ecoinvent v2.2 database

The ecoinvent database does not permit this eco-factor to be applied directly, as the database does not state the C content of wastes consigned to landfills as an elementary flow. Long-term TOC emissions are used instead as a proxy. In the ecoinvent data base, these emissions come only from bioreactive landfills and landfills for stabilised residues. The transfer coefficient of bioreactive landfills for carbon in waste to carbon as long-term TOC is 0.25, while the transfer coefficient for stabilized residues is 0.65 (Doka 2009). Thus, it is possible to calculate the eco-factor that should be applied in the ecoinvent database. This amounts to 8.4 UBP/g of long-term TOC for stabilised residue landfills and 21.8 UBP/g of long-term TOC for bioreactive waste landfills. As there is no differentiation between long-term TOC emissions from bioreactive waste

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[28] File transmitted by Nobert Egli, Federal Office for the Environment, on July 9, 2012

and stabilised residues landfills in the ecoinvent v2.2 database, a separate “TOC, Total Organic Carbon, from sanitary landfills” elementary flow should now be introduced for the long-term TOC emissions from bioreactive waste landfills.

The data streams in the ecoinvent v2.2 database pertaining to disposal in inert material landfills include disposal processes for clean, carbon-free materials. For that reason, there is no eco-factor for carbon in material consigned to landfills. Real construction site wastes that are consigned to inert material landfills usually contain organic contaminants. The eco-factor in tab. 100 (5.5 UBP/g C) should be applied when life cycle inventories take account of the disposal of materials with (allowed) carbon content in inert material landfills.

14.2.6 Guidelines for using modelling of wastes with organic carbon consigned to landfills

Wastes that contain organic carbon and are consigned to landfills should be assessed in the life cycle inventory with the model for sanitary landfills, or landfills with stabilised residues, where possible. This ensures that the anticipated chemical reactions, landfill gas and leachate formation are appropriately taken into account in the life cycle assessment.

14.3 Hazardous wastes in underground disposal sites

14.3.1 Background

The greater part of the hazardous wastes arising in Switzerland (around 1.1 million t per year) is treated within the country. Around one-third can be incinerated, while the rest is, wherever possible, recycled, consigned to physical-chemical treatment or otherwise stored in a landfill for stabilised residues. Soil removed when cleaning up contaminated sites is the principal source of hazardous waste, accounting for around one-third of the quantity (BAFU 2011b).

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

14.3.2 Normalization

A characterization is not performed, and both the current and the critical flow comprise the entire quantity of hazardous wastes consigned to underground disposal sites. For that reason, the normalization flow is identical to the current flow.

14.3.3 Weighting

Current flow

Swiss waste statistics give the quantity of wastes stored in underground disposal sites. This amounts to 37 200 t/a for 2010 and is exported in its entirety (BAFU 2011b). There are no underground disposal sites in Switzerland.

Critical flow

The Swiss Environmental Protection Act (USG 2010, Art. 30 (3)) stipulates the principle that wastes "*must be disposed of…, insofar as this possible and reasonable, within Switzerland*". It is assumed that the exported quantity cannot be consigned purposefully to final storage in Switzerland, which is why the critical flow is equated with the current flow.[29]

14.3.4 Eco-factors for the consignment of hazardous wastes to disposal sites

Tab. 101 > Eco-factor for consigning hazardous wastes to underground disposal sites in UBP/g and UBP/cm³ waste

	Edition 2013	Q	Notes	Edition 2006
Normalization (t waste/a)	37 223	A		36 900
Current flow (t waste/a)	37 223	A	(BAFU 2011b)	36 900
Critical flow (t waste/a)	37 223	c		36 900
Weighting (-)	1.00			1.00
Eco-factor (UBP/g waste.)	**27**			27
Eco-factor (UBP/cm³ waste)	43		Density 1600 kg/m³ in accordance with Doka (2003b, Part III, p. 41)	43

Q = data quality; for explanation, see Part 2, Chapter 6

This eco-factor relates exclusively to hazardous wastes stored in underground disposal sites. The final storage of wastes – including hazardous wastes – on normal above-ground landfills is assessed using the eco-factors for land use, emissions to air, water and groundwater, and the C content of the waste.

14.4 Radioactive wastes

14.4.1 Preliminary note

The generation of electricity in nuclear power plants produces radioactive wastes that must eventually be consigned to final storage. No final repository has yet to be constructed in Switzerland. The Wellenberg site in the canton of Nidwalden was selected for low-level and medium-level wastes. In 2002, the construction of an exploratory shaft was rejected in a referendum. New sites for low-level and medium-level, high-level and long-lived radioactive wastes are now in the process of being evaluated. The evaluation of radioactive wastes in Brand et al. (1998) and Frischknecht et al. (2008) reflected the situation of the proof of disposal provided and the efforts to find a site. However, there is still no concrete plan with a legal construction permit. Eco-factors

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[29] According to a personal communication by H.-P. Fahrni, Federal Office for the Environment, of 28 February 2005, this determination is relevant for the 2006 eco-factors. Therefore, it was retained.

are now determined on the basis of legal provisions and scientific calculations by Nagra. For that purpose, the risk potential of radioactive wastes is quantified using the radiotoxicity index (NAGRA 2008).

14.4.2 Background

The Swiss Nuclear Energy Act (KEG, Art. 30 (2)) states the following as concerns radioactive wastes: “*The radioactive wastes arising in Switzerland must be disposed of within the country as a matter of principle*”. In addition, the Act stipulates a moratorium on reprocessing spent fuel elements from July 2006 to 2016.[30]

Classification of wastes

In principle, two final repositories are planned – one for spent fuel elements, high-level wastes (HLW) and alpha-toxic wastes (ATW), and a second for low-level and medium-level wastes (LMLW). These final repositories may be built at separate sites or together at the same site.

The planned capacities required for the repositories are based on the estimated quantities of radioactive wastes including their encasements. NAGRA[31] now also bases its calculations of required volumes on plant service lives of 50 years (reference scenario).

Volume of high-level wastes

Based on this scenario, some 6600 m^3 of spent (and conditioned) fuel elements (SF), some 730 m^3 of high-level wastes (HLW) from reprocessing, and 2280 m^3 of long-lived, medium-level (alpha-toxic) wastes (ATW) arise. Overall, the deep repository thus needs to accept around 9600 m^3 of long-lived, high-level and medium-level wastes (volume including encasements, NAGRA 2011a).

Volume of low-level and medium-level wastes

The total quantity of low-level and medium-level (LMLW) wastes to be disposed of in deep geological repositories based on the 50-year service life of nuclear power plants is estimated at 89 400 m^2 (volume including encasements, NAGRA 2011a). Of this, 28 300 m^3 are wastes from nuclear power plant decommissioning, 26 000 m^3 from nuclear power plant operation (operating and reactor wastes), 32 200 m^3 from research and medicine (of which 23 000 m^3 from the decommissioning of the research facilities) and 3000 from the interim repository and the encasement facilities.

Overall, the total quantity of wastes to be stored in repository encasements is 99 000 m^3 (NAGRA 2011a).

Hazardousness of radioactive waste

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

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

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

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

The former are relatively short-lived, and already present a minor hazard after a shorter period. It is assumed that they require a shut-in time of around 500 years (KFW 2002; PSI 1996). The latter need to be stored safely for at least 100 000 years (EKRA 2000; PSI 1996).

Radiotoxicity index

The radiotoxicity of the individual isotopes contained in radioactive wastes and the various types of waste is quantified using the radiotoxicity index (RTI) of radioactive wastes. It is defined as

$$RTI = \Sigma_i A_i * DF_i/DL$$

with:

A_i = *activity of the nuclide i in Bq,*

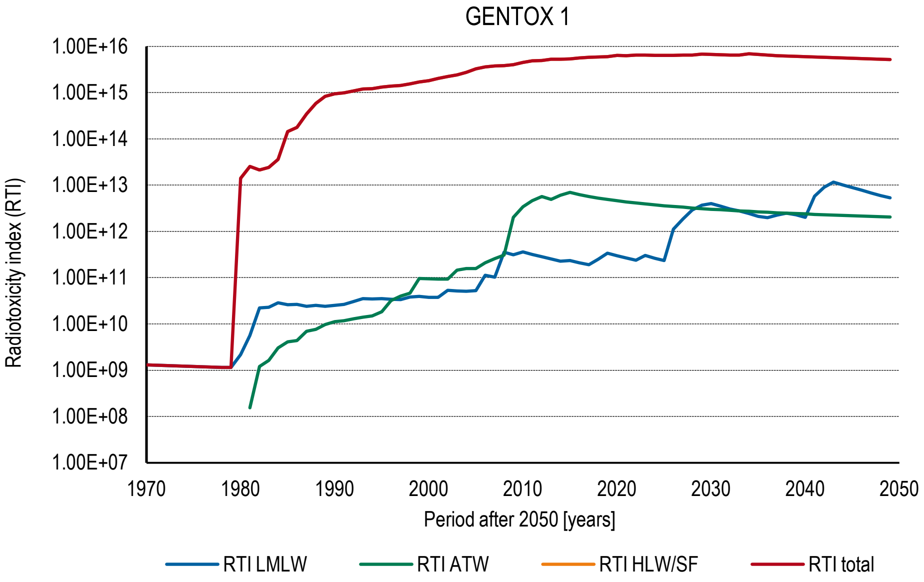
DF_i = *dose factor for the ingestion of the nuclide i in Sv/Bq, dose limit value for the release from a deep geological repository*

DL = *0.1 mSv/a (NAGRA 2008).*

Nagra quantifies the annual radiotoxicity course of the radioactive wastes that arise and are stored. The course in fig. 7 and fig. 8 shows that the radiotoxicity in the year 2029 is projected to peak and then steadily fall.

Fig. 7 > Development of the radiotoxicity index (RTI) of radioactive wastes in Switzerland up to the year 2050. Data from NAGRA (2008)

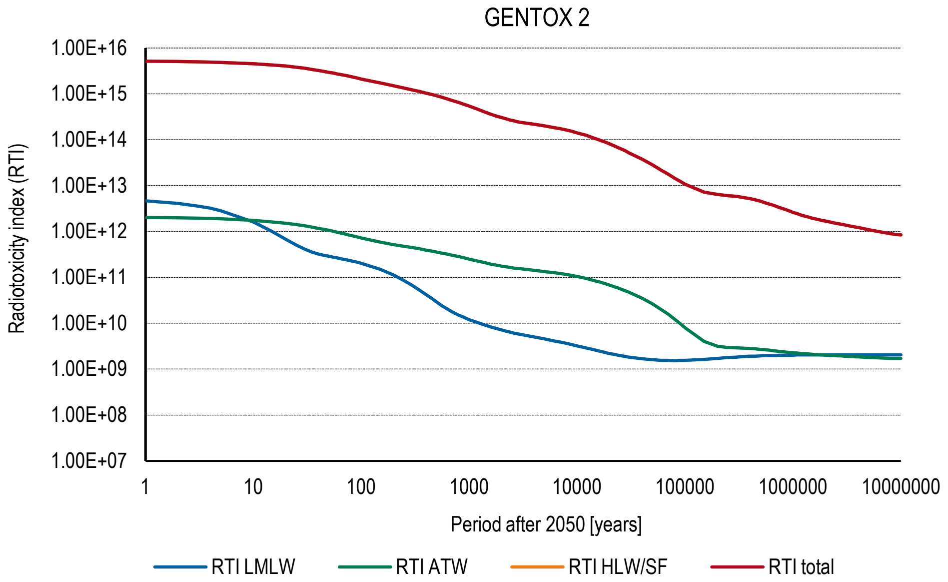
LMLW: low-level and medium-level wastes; ATW: alpha-toxic wastes; HLW: high-level wastes; SF: spent fuel elements



RTI total is dominated by RTI HLW/SF. RTI total (red line) covers RTI HLW/SF (orange line) completely.

Fig. 8 > Development of the radiotoxicity index (RTI) of radioactive wastes in Switzerland after the year 2050. Data from NAGRA (2008)

LMLW: low-level and medium-level wastes; ATW: alpha-toxic wastes; HLW: high-level wastes; SF: spent fuel elements



RTI total is dominated by RTI HLW/SF. RTI total (red line) covers RTI HLW/SF (orange line) completely.

Radiotoxicity of radioactive wastes in Switzerland

In 2029, the RTI of all radioactive wastes that will have to be consigned to a final repository in Switzerland is $6.8*10^{15}$ RTI (see also tab. 102). This corresponds to the highest RTI of the total radioactive waste arising in Switzerland.[32]

Tab. 102 > Radioactive waste volume, RTI in 2029 (absolute and per m³ of waste) and at the time of closing the final repository for radioactive wastes (year 2115) and characterization factors

	Waste volume (m^3)	RTI (-)	RTI per m^3 (m^{-3})	RTI at closing (-)	Characterization factor (cm^3 HLW-eq/cm^3)
Low-level and medium-level wastes (LMLW)	89 410	$3.7 * 10^{12}$	$4.1 * 10^{7}$	$2.5 * 10^{11}$	0.000045
Alpha-toxic wastes (ATW)	2 280	$3.1 * 10^{12}$	$1.4 * 10^{9}$	$9.2 * 10^{11}$	0.0015
High-level wastes (HLW & SF)	7 325	$6.8 * 10^{15}$	$9.3 * 10^{11}$	$2.6 * 10^{15}$	1.0
High-level and alpha-toxic wastes (HLW, SF & ATW)	9 605	$6.8 * 10^{15}$	$9.3 * 10^{11}$	$2.6 * 10^{15}$	0.76
Total	**99 015**	**$6.8 * 10^{15}$**		**$2.6 * 10^{15}$**	

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[32] As the maximum RTI does not occur for all radioactive wastes at the same point in time, the maximum total waste inventory shown in Fig. 7 does not correspond to the sum of the individual maximum RTI of wastes that arise at different points in time.

14.4.3 Characterization

The characterization is based on the radiotoxicity potential. The different waste categories are characterized using their radiotoxicity index in the year 2029. High-level wastes are the reference substance. Based on the RTI values per m³ of waste (see tab. 102), the characterization factor is 1 cm³ LMLW $4.5*10^{-5}$ cm³ HLW-eq., 1 cm³ ATW 0.0015 cm³ HLW-eq. and 1 cm³ ATW&HLW 0.76 cm³ HLW-eq.

14.4.4 Normalization

The normalization flow is defined as the characterized volume of radioactive wastes that arise in a year. The total characterized waste volume of 50 years of operation by Swiss nuclear power plants and of medicine and research comes to 7332 m³ HLW-eq. With a service life of 50 years of operation, a normalization flow of around 147 m³ HLW-eq./a results.

14.4.5 Weighting

Current flow

The maximum RTI of Swiss radioactive wastes (see Part 3, Section 14.4.2) divided by the 50-years service life of nuclear power plants ($1.36*10^{14}$ RTI) is used as the current flow.

Legislative basis

When the repository and all storage chambers are closed, the observation phase begins, i.e. a longer period, during which a deep geological repository is monitored before being closed and the radioactive wastes can be retrieved (cf. Nuclear Energy Act (KEG 2009, Art. 3)). These stipulations by legislators reflect the internationally recognised principle of passive long-term safety, i.e. the safe enclosure of radioactive substances without the necessity of human intervention, and the social concern of longer monitoring and easier retrievability prior to closure. Even after the repository is closed, monitoring continues and the wastes can be retrieved, albeit at great expense. The length of the monitoring phase is not specified and may be 50, 100 or more years. It is assumed here that the Federal Council will order the closure after 50 years in accordance with the projected costs, as defined in the Decommissioning and Disposal Funds Ordinance (SEFV 2008). The Federal Council orders the closure once it is convinced that the permanent protection of humans and the environment is ensured (KEG 2009, Art. 39 (2)). Ensuring the permanent protection of humans and environment is the basis for determining the critical flow.

Closure period

According to NAGRA planning (NAGRA 2011b), the final repository for low-level and medium-level radioactive wastes should be definitively closed in the period from 2100 to 2101 and the final repository for long-lived and/or high-level radio wastes should be closed in the period from 2115 to 2116.

Critical flow

At the time of the closure in 2115, the RTI of the total radioactive wastes will be $2.6*10^{16}$ RTI (see tab. 102 and fig. 8). Divided by 50 nuclear power plant service years, this results in $5.2*10^{13}$ RTI/a. This value corresponds to the critical flow.

Tab. 103 > Eco-factor for high-level radioactive wastes

	Edition 2013	Q	Notes	Edition 2006
Normalization (m³ HLW-eq./a)	146.6	A	Calculated from information in NAGRA (2008)	
Current flow (RTI/a)	1.36 * 1014	A	Calculated from information in NAGRA (2008)	
Critical flow (RTI/a)	5.22 * 1013	a	Calculated from information in NAGRA (2008)	
Weighting (-)	6.76			
Eco-factor (UBP/cm³ HLW-eq.)	46 000			see Tab. 104

Q = data quality; for explanation, see Part 2, Chapter 6

14.4.6 Eco-factor for other radioactive wastes

These eco-factors can be derived using the characterization factors for other types of radioactive wastes. tab. 104 shows the eco-factors for the “low-level and medium-level wastes” and “high-level and alpha-toxic wastes” categories used in the ecoinvent database.

Tab. 104 > Eco-factors for short-lived low-level and medium-level wastes (LMLW) as well as for long-lived and/or high-level wastes (SF/ATW/HLW) in UBP/cm³ waste

	Edition 2013 (UBP/cm³)	Q	Characterization factor (cm³ HLW-eq./cm³)	Edition 2006
Low-level and medium-level wastes (LMLW)	**2.1**	A	0.000045	3 300
High-level and alpha-toxic wastes (HLW, SF & ATW)	**35 000**	A	0.76	18 000
High-level wastes (HLW & SF)	**46 000**	A	1.0	
Alpha-toxic wastes (ATW)	**69**	A	0.0015	

Q = data quality; for explanation, see Part 2, Chapter 6; Densities of the conditioned and encased wastes: LMLW: 5 t/m³; HLW, SF & ATW: 6.85 t/m³

The eco-factor is applied to the final repository volume of radioactive wastes, including their encasing. Considerable adjustments were made due to the transition to a scientific justification for the eco-factors of radioactive wastes and particularly to the use of the radiotoxicity index. The eco-factor for the long-lived and/or high-level wastes is more than 90% higher than the eco-factor in 2006, while the new eco-factor for short-lived low-level and medium-level wastes is more than 99.9% lower than the eco-factor in 2006.

Overall, this shows that the new, methodologically better supported concept has similar weightings as the previous one, but the importance of the various waste categories is now more greatly differentiated.

15 > Non-substance emissions

15.1 Noise

15.1.1 Introduction

Noise is an undesirable sound that can harm persons physically, psychologically and socially. Chronic and excess noise is a health hazard, undermines quality of life and the attractiveness of affected areas and generates huge costs to society (BAFU 2009c).

The goal of the Environmental Protection Act (USG 2010) of 7 October 1983 is to protect the population from harmful and irritating noise. Early preventive measures can also be taken in order to limit effects that could become harmful or irritating. The aim of reducing noise emissions is to ensure that fewer people are highly annoyed by noise. That is why the eco-factor for people highly annoyed by noise is included. Improvements to the noise situation should be aimed at road, railway and air transportation. A separate eco-factor is determined for each of the three means of transportation.

15.1.2 Normalization

No characterization is performed. The normalization flow corresponds to the number of persons highly annoyed by road, railway and aircraft noise. The normalization flow amounts to around 800 000 persons (see tab. 105).

15.1.3 Weighting

Current flow

A specific eco-factor is calculated for each source of noise. The current flow corresponds to the number of persons highly annoyed by road, railway and aircraft noise.

Information on the number of persons affected by road and railway noise per dB class comes from the SonBase noise database. Relevant information on aircraft noise was determined by interpolating flight operations approved by Federal Office of Civil Aviation (FOCA) for the large airports located in Zurich and Geneva, Switzerland.

The noise level (L_{den}) is calculated to determine the proportion of highly annoyed persons. L_{den} is a European measurement that is calculated from L_{day} (6:00 a.m. to 6 p.m.), $L_{evening}$ (6 p.m. to 10 p.m.) a nd L_{night} (10 p.m. to 6 a.m.). As noise in the evening and at night is perceived as worse, $L_{evening}$ and L_{night} are given an additional 5 dB(A) and 10 dB (A). The proportion of highly annoyed persons is determined using the exposure/impact relationship in accordance with EEA (2010). The current flow is calculated from the number of people per dB (A) class multiplied by the proportion of highly annoyed persons in the same dB (A) class.

The FOEN has determined and provided the number of highly annoyed persons for all means of transportation (BAFU 2012f) (see tab. 105).

Tab. 105 > Number of highly annoyed persons by road, railway and aircraft noise (HAP), current flow, sources, see text

	Road noise	Rail noise	Aircraft noise	Total
Number of highly annoyed persons (rounded to 2 decimal places)	720 000	61 000	27 000	800 000

Critical flow

The long-term goal of noise abatement is to prevent anyone from being disturbed by noise. In the medium term, i.e. until around 2035, a reduction in noise pollution of 5 dB (A) each for road, rail and air traffic is the goal (BAFU 2012f). The number of highly annoyed persons by a 5 dB(A) lower noise level is determined in the same way as the current flow. By decreasing the noise level by 5 dB(A), the number of highly annoyed persons is reduced by roughly half.

Tab. 106 > Number of highly annoyed persons by road, railway and aircraft noise (HAP), critical flow, sources, see text

	Road noise	Railway noise	Aircraft noise
Number of highly annoyed persons (rounded to 2 decimal places)	440 000	33 000	15 000

15.1.4 Eco-factor for highly annoyed persons by traffic noise

The eco-factor for noise is used for the first time in this version. It refers to “highly annoyed persons by noise (HAP)” and is stated separately for road, railway and aircraft noise. The “highly annoyed persons” parameter is used because the goal of noise abatement is to protect people. However, easily quantifiable life cycle inventory parameters are necessary for use in life cycle assessments and for the use of noise eco-factors in life cycle assessment databases such as ecoinvent. Noise kilometres are suggested for this. The derivation of eco-factors per noise kilometre is described in Part 3, Section 15.1.5.

Eco-factor for road noise

Tab. 107 > Eco-factor for road noise, in UBP per highly annoyed person (HAP)

	Edition 2013	Q	Notes	Edition 2006
Normalization (HAP/a)	803 882	B	Takes account of road, railway and aircraft noise	
Current flow (HAP/a)	715 754	A	(BAFU 2012f)	
Critical flow (HAP/a)	436 058	b	(BAFU 2012f)	
Weighting (-)	2.69			
Eco-factor (UBP/HAP)	**3 400 000**			

Q = data quality; for explanation, see Part 2, Chapter 6

Eco-factor for railway noise

Tab. 108 > Ecofactor for railway noise, in UBP per highly annoyed person (HAP)

	Edition 2013	Q	Notes	Edition 2006
Normalization (HAP/a)	803 882	B	Takes account of road, railway and aircraft noise	
Current flow (HAP/a)	60 934	A	(BAFU 2012f)	
Critical flow (HAP/a)	32 754	b	(BAFU 2012f)	
Weighting (-)	3.46			
Eco-factor (UBP/HAP)	**4 300 000**		Railway noise	

Q = data quality; for explanation, see Part 2, Chapter 6

Eco-factor for aircraft noise

Tab. 109 > Ecofactor for aircraft noise, in UBP per highly annoyed person (HAP)

	Edition 2013	Q	Notes	Edition 2006
Normalization (HAP/a)	803 882	B	Takes account of road, railway and aircraft noise	
Current flow (HAP/a)	27 194	A	(BAFU 2012f)	
Critical flow (HAP/a)	15 042	b	(BAFU 2012f)	
Weighting (-)	3.27			
Eco-factor (UBP/HAP)	**4 100 000**		Aircraft noise	

Q = data quality; for explanation, see Part 2, Chapter 6

15.1.5 Eco-factor for traffic noise in current life cycle assessment databases

Six new elementary flows have been introduced at the inventory level so that the eco-factor for noise can be applied in current life cycle assessment databases (see tab. 110). The units of these elementary flows are vehicle kilometre of noise, person kilometre of noise and tonne kilometre of noise. For instance, operating an (average) passenger car over 1 km of distance causes 1 km of “noise, road, passenger car”, while one person kilometre of train travel causes 1 pkm of “noise, rail, passenger train” and so forth.

Tab. 110 > Elementary flows for implementation of the noise eco-factor at the inventory level

		Elementary flow name
Road noise caused by passenger cars*	km	Noise, road, passenger car
Road noise caused by trucks	km	Noise, road, lorry
Railway noise caused by passenger transportation	pkm	Noise, rail, passenger train
Railway noise caused by cargo transportation	tkm	Noise, rail, freight train
Aircraft noise caused by passenger transportation	pkm	Noise, aircraft, passenger
Aircraft noise caused by freight transportation	tkm	Noise, aircraft, freight

km: vehicle kilometre, pkm: person kilometre, tkm: tonne kilometre; * For the assessment of noise by motorcycles, see Tab. 113

Eco-factor based on kilometres

The eco-factor per vehicle kilometre of noise, person kilometre of noise and tonne kilometre of noise is determined using the number of highly annoyed persons by road, railway and aircraft noise. All three means of transportation carry both people and goods. The impacts of noise emissions from road traffic, for instance, must therefore be broken down into person transportation (passenger cars) and freight transportation (lorry).

It is assumed from this that the noise emissions are largely independent of the payload. Therefore, in the case of road and railway traffic, the kilometres travelled (BFS 2009; 2011c) and the average noise emission level of passenger cars and trucks, as well as passenger and freight trains, are used to differentiate person from freight transportation.

Tab. 112 shows the noise levels of the various means of transportation. The noise level of a truck is approximately 10 dB(A) higher than the noise level of a passenger car. In railway transportation, freight trains are approximately 10 dB(A) louder than passenger trains. A noise level of 10 dB corresponds to ten times more energy released through sound. For this reason, when allocating the number of highly annoyed persons, the distance travelled (in km) to transport the freight by road or railway is multiplied by a factor of 10.

The eco-factor for freight and passenger transportation per distance covered is calculated (see tab. 111) by applying the eco-factor per highly annoyed person in tab. 107 to tab. 109.

The number of highly annoyed persons is based on the vehicle kilometres travelled to transport freight by road (independently of the truck size and load capacity).

Tab. 111 > Calcuation of the noise eco-factor of various means of transportation in UBP/km, UBP/pkm and UBP/tkm

The number of highly annoyed persons by the noise from road, railway and air traffic and the allocated distance travelled to transport freight and people.

	Unit	Road traffic		Railway traffic		Air traffic	
		People	Freight	People	Freight	People	Freight
Number of highly annoyed persons	HAP	720 000		61 000		27 000	
Distance travelled	vkm	$5.59*10^{10}$	$5.87*10^{9}$	$1.83*10^{8}$	$3.00*10^{7}$	$6.57*10^{9}$	$1.45*10^{9}$
Number of highly annoyed persons	HAP/vkm	$6.25*10^{-6}$	$6.25*10^{-5}$	$1.26*10^{-4}$	$1.26*10^{-3}$	$3.39*10^{-6}$	$3.39*10^{-6}$
Number of highly annoyed persons	HAP/km	$6.25*10^{-6}$	$6.25*10^{-5}$				
Number of highly annoyed persons	HAP/pkm			$1.20*10^{-6}$		$3.39*10^{-7}$	
Number of highly annoyed persons	HAP/tkm				$3.42*10^{-6}$		$3.39*10^{-6}$
Eco-factors road traffic	UBP/km	**21**	**210**				
Eco-factors passenger kilometre	UBP/pkm			**5.2**		**1.4**	
Eco-factors tonne kilometre	UBP/tkm				**15**		**14**

HAP: highly annoyed persons, vkm: vehicle kilometre, pkm: passenger kilometre, tkm: tonne kilometre
To allocate the number of highly annoyed persons to passenger and freight transportation by road and railway, the distance traveled to transport freight is multiplied by a factor of 10, as the noise level of trucks and freight trains is around 10 dB higher than the noise level of passenger cars and trains.

Eco-factor for quiet vehicles

Furthermore, the option of a differentiated assessment of quiet or particularly loud vehicles should be provided. tab. 112 shows the average noise emissions of different means of transportation. We assume that the average eco-factors derived for road traffic noise apply to average passenger cars and trucks. If the dB values of the means of transportation to be inventoried are known, the noise kilometres can be multiplied by the appropriate factor in accordance with tab. 113. The formula published in Doka (2003a) is used here.

Tab. 112 > Average noise emissions of the means of transportation

Means of transportation		Noise level	Notes
Road, passenger cars	dB(A)	72	Lmax, according to RWTÜV Fahrzeug GmbH (2005), free flowing traffic at 50 km/h
Road, trucks, 150–250 kW	dB(A)	81	
Railway, ICN, 140 kmh	dB(A)	55.8	Leq (16h) according to SonRail (BAFU 2012f), single pass, distance: 1 meter with moderate rail roughness and concrete sleepers
Railway, freight train	dB(A)	65.9	
Airplane, A320, take-off	dB(A)	47.9	Leq (16h) according to SANCDB (BAFU 2012f), distance: 300 metres
Airplane, B747, take-off	dB(A)	59.5	

For instance, if the vehicle to be assessed is 3 dB quieter (noise level -3 dB) than the average vehicle, the vehicle kilometre of noise to be used in the life cycle inventory should be reduced by half (factor 0.5, see tab. 113). Thus, driving 1 km with a 3dB quieter car causes 0.5 km of “noise, road, passenger cars”.

Eco-factor for motorcycles

The vehicle kilometre of noise to be used for the noise emissions of motorcycles can be determined in the same way, by establishing the difference between the noise level of the average passenger car and the noise level of a motor cycle. This makes it possible to read the correction factor in tab. 113 and calculate the vehicle kilometre of motorcycle noise.

Tab. 113 > Factor by which noise kilometres must be multiplied for an appropriate level difference from the average (see tab. 112)

The formula for determining the factor is: Factor = $10^{(\text{Level change}/10)}$*, in accordance with Doka(2003a), based on the road traffic noise model StL 97.*

Level change (dB)	Factor
-5	0.32
-4	0.40
-3	0.50
-2	0.63
-1	0.79
0	1.00
1	1.26
2	1.58
3	2.00
4	2.51
5	3.16
6	3.98
7	5.01
8	6.31
9	7.94
10	10.00

16 > Selected methodological issues

16.1 Inventory method for FSC forest

FSC forest is a special form of forestry. This type of land use is not covered by the extended CORINE nomenclature. It is therefore recommended that the land use be broken down into defined types of land use. In the case of FSC forest, it should be divided into areas of managed forest and areas of unmanaged forest (see also tab. 84). FSC forest is ultimately inventoried according to the proportions of each type of land use.

16.2 Inventory method for CO_2 emission certificates

International and national standards on greenhouse gas inventories and CO_2 footprints of products and companies clearly have something to say about the role of certificates (Carbon Trust & DEFRA 2011; WBCSD & WRI 2011a; b): CO_2 emission certificates are a reduction measure and may not be offset against generated emissions in product and company inventories.

17 > Unassessed environmental impacts

17.1 VOC emissions to groundwater

In addition to other substances, VOC concentrations in groundwater have been observed as part of NAQUA activities (BAFU 2009b) for around 10 years. Careless handling and improper disposal of fuels and solvents, accidents and permeable storage facilities are the main causes of discharges into groundwater. As highly volatile compounds, VOCs can also enter the atmosphere through evaporation and then end up in underground or above-ground bodies of water through precipitation (BAFU 2009b). The Waters Protection Act (GSchV 2011) sets out numerical requirements for various VOC substances and substance groups in groundwater that is used as drinking water. In the years 2004, 2005, 2006, the numerical requirement was exceeded at least once per year at 6% to 8% of the tested monitoring wells. Moreover, traces of VOCs below this threshold were detected in around one-third of the monitoring wells (BAFU 2009b).

As there is no information about the quantities of VOCs emitted to groundwater, an eco-factor cannot be calculated. For instance, weighting factors for several substances were established from the measured concentrations (median) and the statutory requirements (see tab. 114). The weighting factor for all substances is well below 1. The pollution situation is thus (on average) not of primary importance from an environmental point of view.

Tab. 114 > Determination of the weighting factors of several VOCs in groundwater

Substance	Group	Concentration (median) (µg/l)	Target value* (µg/l)	Weighting factor (-)
1,1,1-Trichlorethane NT	VHH	0.11	1	0.012
Benzene	MAH	0.51	1	0.260
Chloroform NT	VHH	0.17	1	0.029
Ethylbenzene	MAH	0.10	1	0.01
m/p-Xylol NS	MAH	0.25	1	0.063
MTBE	Ether	0.13	2	0.017
Tetrachlorethene NT	VHH	0.36	1	0.13
Tetrachlormethane NT	VHH	0.07	1	0.0049
Toluene	MAH	0.35	1	0.12
Trichlorethylene NT	VHH	0.25	1	0.063

* Target values for MAHs and VHHs come from the Waters Protection Act (GSchV). There are currently no statutory requirements for MTBEs in Switzerland. Groundwater protection guidelines provide an indicator value of 2 µg/l an for MTBE in groundwater. If this value is exceeded, the cause of the pollution and potential rehabilitation measures are assessed.

17.2 Salinization

When food and other consumer goods (for instance, lithium batteries) are imported into Switzerland, foreign soil salinization is present throughout the value creation chains. As salinization is not an environmental problem issue in Switzerland, there is no legislation governing it. International agreements must be used instead.

Salinization can have two causes: ion deposition and water abstraction. The latter overlaps to some extent with the “water use” indicator. For an assessment, ion deposition is basically considered a pollutant emission via salinization.

Existing methodological approaches (Feitz & Lundie 2002; Leske & Buckley 2003; Leske & Buckley 2004a; Leske & Buckley 2004b) are not detailed or broad enough to be applied. Furthermore, we know of no quantitative national or international targets.

17.3 Erosion and desiccation

In the context of life cycle assessments, erosion and desiccation are referred to as important environmental impacts that are not represented. However, there is still insufficient knowledge of these two indicators at this time. The development of meaningful indicators and their connection to life cycle inventories would require a great deal of effort, as maintained by Hauschild et al. (2008).

17.4 Overfishing

Stocks of species such as tuna, European plaice or halibut are threatened by overfishing. Indeed, efforts are being made, particularly by environmental groups, to protect threatened species (see, for instance, the “MSC-WWF Ratgeber Fische und Meeresfrüchte” sustainable seafood guide). Various international agreements are in effect that may potentially make it possible to derive eco-factors.

17.5 Plastic waste in the sea

Plastic waste is brought by rivers and ships and accumulates in the world’s seas. The “North Pacific Trash Vortex” is for instance said to be larger than the “Great Pacific Garbage Patch”. Solar radiation, tides and waves cause plastic waste to disintegrate into ever smaller pieces. In pulverized form, plastic containing poisonous and carcinogenic substances can enter the food chain. But the larger pieces of plastic can also harm marine life. When pieces of plastic are eaten by animals, they remain in their stomach and cause the animals to starve.

From the Swiss point of view, this phenomenon can be attributed to the illegal disposal of plastic waste. Plastic wastes cannot be easily assigned to one specific product or product group. Furthermore, to our knowledge, there are no (national or international) agreements with the goal of reducing plastic waste in the sea.

For these reasons, it is not possible at this time to determine eco-factors for the (illegal) disposal of plastic waste in bodies of water (that ultimately flow into the sea).

17.6 Noise from machines and stationary sources

Eco-factors have not yet been prepared for noise from construction machines, leaf and hay blowers, lawnmowers, construction sites, wind power stations, and commercial and industrial installations. The impacts of these sources of noise are limited to local areas. Accordingly, the (required) abatement measures are defined locally. As a result, it is difficult to determine Swiss eco-factors for noise from these sources.

17.7 Underwater noise

Increasing underwater noise from ships and exploration for natural resources under the seafloor are forcing marine mammals out of their habitats and even physically harming them. There are several related international initiatives (International Ocean Noise Coalition, European Coalition for Silent Oceans). Due to a lack of international agreements or laws, an eco-factor cannot be derived at this time.

> Annex

A1 Conversion factors for emissions

Tab. 115 > Conversion factors for emissions of nitrogen and phosphorous compounds and for COD/DOC

	Mass, rounded (g/mol)	
NO_x as NO_2	46	1 g NO_2 corresponds to 0.3 g NO_x-N
NH_3	17	1 g NH_3 corresponds to 0.82 g NH_3-N
NH_4^+	18	1 g NH_4^+ corresponds to 0.78 g NH_4^+-N
NO_3^-	62	1 g NO_3^- corresponds to 0.23 g NO_3^--N
N_2O	44	1 g N_2O corresponds to 0.64 g N_2O-N
PO_4^{3-}	95	1 g PO_4^{3-} corresponds to 0.33 g PO_4^{3-}-P
P_2O_5	142	1 g P_2O_5 corresponds to 0.44 g P_2O_5-P
COD	-	1 g COD corresponds to 0.3 g DOC (rough approximation)

A2 Eco-factors for greenhouse gases and ozone-depleting substances

When substances have both a GWP and an ODP, the factor resulting in the higher eco-factor is used. The grey shading of values in the table indicates whether the GWP or the ODP was used for the calculation. The GWP values are in accordance with IPCC (2007), the ODP values are in accordance with UNEP (2007).

Tab. 116 > Eco-factors for greenhouse gases and ozone-depleting substances

	Formula	CAS no.	GWP (CO_2-eq.)	ODP (R11-eq.)	Eco-factor 2013 (UBP/g)	Eco-factor 2006 (UBP/g)	Basis 2006
Carbon dioxide	CO_2	124-38-9	**1**	-	**0.46**	0.31	GWP
Carbon monoxide	CO	630-08-0	**1.57**	-	**0.72**	0.49	GWP
Methane	CH_4	74-82-8	**25**	-	**12**	7.1	GWP
Nitrous oxide	N_2O	10 024-97-2	**298**	-	**140**	92	GWP
Chlorofluorocarbons (CFCs)							
CFC-11	CCl_3F	75-69-4	4 750	**1**	**8 500**	11 000	ODP
CFC-12	CCl_2F_2	75-71-8	10 900	**1**	**8 500**	11 000	ODP
CFC-13	$CClF_3$	75-72-9	14 400	**1**	**8 500**	11 000	ODP
CFC-111	C_2Cl_5F	354-56-3	-	**1**	**8 500**	11 000	ODP
CFC-112	$C_2Cl_4F_2$	76-12-0	-	**1**	**8 500**	11 000	ODP
CFC-113	CCl_2FCClF_2	76-13-1	6 130	**0.8**	**6 800**	11 000	ODP
CFC-114	$CClF_2CClF_2$	76-14-2	10 000	**1**	**8 500**	11 000	ODP
CFC-115	CF_3CClF_2	76-15-3	7 370	**0.6**	**5 100**	11 000	ODP
CFC-211	C_3Cl_7F	422-78-6	-	**1**	**8 500**	11 000	ODP
CFC-212	$C_3Cl_6F_2$	3182-26-1	-	**1**	**8 500**	11 000	ODP
CFC-213	$C_3Cl_5F_3$	2354-06-5	-	**1**	**8 500**	11 000	ODP
CFC-214	$C_3Cl_4F_4$	29 255-31-0	-	**1**	**8 500**	11 000	ODP
CFC-215	$C_3Cl_3F_5$	4259-43-2	-	**1**	**8 500**	11 000	ODP
CFC-216	$C_3Cl_2F_6$	661-97-2	-	**1**	**8 500**	11 000	ODP
CFC-217	C_3ClF_7	422-86-6	-	**1**	**8 500**	11 000	ODP
Hydrofluorocarbons (HFCs)							
HFC-23	CHF_3	75-46-7	**14 800**	-	**6 800**	3 700	GWP
HFC-32	CH_2F_2	75-10-5	**675**	-	**310**	170	GWP
HFC-41	CH_3F	593-53-3	**92**	-	**42**	30	GWP
HFC-125	CHF_2CF_3	354-33-6	**3 500**	-	**1 600**	1 100	GWP
HFC-134	CHF_2CHF_2	359-35-3	**1 100**	-	**510**	340	GWP
HFC-134a	CH_2FCF_3	811-97-2	**1 430**	-	**660**	400	GWP
HFC-143	CHF_2CH_2F	430-66-0	**353**	-	**160**	100	GWP
HFC-143a	CF_3CH_3	420-46-2	**4 470**	-	**2 100**	1 300	GWP
HFC-152	CH_2FCH_2F	624-72-6	**53**	-	**24**	13	GWP
HFC-152a	CH_3CHF_2	75-37-6	**124**	-	**57**	37	GWP
HFC-161	CH_3CH_2F	353-36-6	**12**	-	**5.5**	3.7	GWP
HFC-227ea	CF_3CHFCF_3	431-89-0	**3 220**	-	**1 500**	1 100	GWP

	Formula	CAS no.	GWP (CO$_2$-eq.)	ODP (R11-eq.)	Eco-factor 2013 (UBP/g)	Eco-factor 2006 (UBP/g)	Basis 2006
HFC-236cb	$CH_2FCF_2CF_3$	677-56-5	**1 340**	-	**620**	400	GWP
HFC-236ea	CHF_2CHFCF_3	431-63-0	**1 370**	-	**630**	370	GWP
HFC-236fa	$CF_3CH_2CF_3$	690-39-1	**9 810**	-	**4 500**	2 900	GWP
HFC-245ca	$CH_2FCF_2CHF_2$	679-86-7	**693**	-	**320**	200	GWP
HFC-245fa	$CHF_2CH_2CF_3$	460-73-1	**1 030**	-	**470**	290	GWP
HFC-365mfc	$CF_3CH_2CF_2CH_3$	406-58-6	**794**	-	**370**	280	GWP
HFC-43–10mee	$CF_3CHFCHFCF_2CF_3$	138 495-42-8	**1 640**	-	**750**	470	GWP
Partially halogenated chlorofluorocarbons (HCFCs)							
HCFC-21	$CHCl_2F$	75-43-4	151	**0.04**	**340**	440	ODP
HCFC-22	$CHClF_2$	75-45-6	**1 810**	0.055	**830**	610	ODP
HCFC-31	CH_2FCl	593-70-4	-	**0.02**	**170**	220	ODP
HCFC-121	$CHCl_2CCl_2F$	354-14-3	-	**0.04**	**340**	440	ODP
HCFC-122	$CHCl_2CClF_2$	354-21-2	-	**0.08**	**680**	880	ODP
HCFC-123	$CHCl_2CF_3$	306-83-2	77	**0.02**	**170**	220	ODP
HCFC-124	$CHFClCF_3$	2837-89-0	**609**	0.022	**280**	240	ODP
HCFC-131	CH_2ClCCl_2F	359-28-4	-	**0.05**	**430**	550	ODP
HCFC-133a	CH_2ClCF_3	75-88-7	-	**0.06**	**510**	660	ODP
HCFC-141	$CH_2ClCHClF$	430-57-9	-	**0.07**	**600**	770	ODP
HCFC-141b	CH_3CFCl_2	1717-00-6	725	**0.11**	**940**	1 200	ODP
HCFC-142b	CH_3CF_2Cl	75-68-3	**2 310**	0.065	**1 100**	740	GWP,
HCFC-225ca	$CF_3CF_2CHCl_2$	422-56-0	122	**0.025**	**210**	280	ODP
HCFC-225cb	$CClF_2CF_2CHClF$	507-55-1	595	**0.033**	**280**	360	ODP
HCFC-253	$C_3H_4F_3Cl$	460-35-5	-	**0.03**	**260**	330	ODP
HCFC-261	$CH_3CClFCH_2Cl$	420-97-3	-	**0.02**	**170**	220	ODP
HCFC-271	C_3H_6FCl	430-55-7	-	**0.03**	**260**	330	ODP
Perfluorocarbons (PFCs)							
Methane, perfluoro- (HFC-14)	CF_4	75-73-0	**7 390**	-	**3 400**	1 800	GWP
Ethane, perfluoro- (HFC-116)	C_2F_6	76-16-4	**12 200**	-	**5 600**	3 700	GWP
Propane, octafluoro- (HFC-218)	C_3F_8	76-19-7	**8 830**	-	**4 100**	2 700	GWP
Propane, hexafluorcyclo-	c-C_3F_6	931-91-9	**17 340**	-	**8 000**	5 200	GWP
Butane, decafluoro-	C_4F_{10}	355-25-9	**8 860**	-	**4 100**	2 700	GWP
Butane, octafluorcyclo-	c-C_4F_8	115-25-3	**10 300**	-	**4 700**	3 100	GWP
Pentane, dodecafluoro-	C_5F_{12}	678-26-2	**9 160**	-	**4 200**	2 800	GWP
Hexane, tetradecafluor-	C_6F_{14}	355-42-0	**9 300**	-	**4 300**	2 800	GWP
PFC-9–1-18	C10F18		**7 500**	-	**3 500**	-	-
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$		**10 300**	-	**4 700**	-	-

	Formula	CAS no.	GWP (CO_2-eq.)	ODP (R11-eq.)	Eco-factor 2013 (UBP/g)	Eco-factor 2006 (UBP/g)	Basis 2006
Brominated hydrocarbons							
Methane, bromo-	CH_3Br	74-83-9	5	**0.6**	**5 100**	6 600	ODP
Methane, dibromo-	CH_2Br_2	74-95-3	**2**	-	**0.71**	0.31	GWP
Methane, bromchloro-	CH_2BrCl	74-97-5	-	**0.12**	**1 000**	1 300	ODP
Methane, bromfluoro-	CH_2FBr	373-52-4	-	**0.73**	**6 200**	8 000	ODP
Methane, bromdifluoro-	$CHBrF_2$	1511-62-2	404	**0.74**	**6 300**	8 100	ODP
Methane, dibromfluoro-	$CHFBr_2$	1868-53-7	-	**1**	**8 500**	11 000	ODP
Halon 1211 (Methane, bromochlordifluoro-)	$CBrClF_2$	353-59-3	1 890	**3**	**26 000**	33 000	ODP
Halon 1301 (Methane, bromtrifluoro-)	$CBrF_3$	75-63-8	7 140	**10**	**85 000**	110 000	ODP
Halon 2402 (Ethane, 1,2-dibromo-1,1,2,2-tetrafluoro-)	$C_2Br_2F_4$	124-73-2	1 640	**6**	**51 000**	66 000	ODP
Chlorinated hydrocarbons							
Methane, tetrachloro-, (R-10)	CCl_4	56-23-5	1 400	**1.1**	**9 400**	12 000	ODP
Chloroform, (R-20)	$CHCl_3$	67-66-3	**31**	-	- *	- *	
Methane, monochloro-, (R-40)	CH_3Cl	74-87-3	**13**	-	- *	- *	
Methane, dichloro-, (R-30)	CH_2Cl_2	75-09-2	**9**	-	- *	- *	
Ethane, 1,1,1-trichloro-, (R-140)	CH_3CCl_3	71-55-6	146	**0.1**	**850**	1 100	ODP
Other halogenated hydrocarbon compounds							
Methane, trifluoriodo-	CF_3I	2314-97-8	**0**	-	**0.18**	0.31	GWP
Ethanol, 2,2,2-trifluoro-	CF_3CH_2OH	75-89-8	**57**	-	**26**	18	GWP
1-propanol, 2,2,3,3,3-pentafluoro-	$CF_3CF_2CH_2OH$	422-05-9	**42**	-	**19**	12	GWP
2-propanol, 1,1,1,3,3,3-hexafluoro-	$(CF_3)_2CHOH$	920-66-1	**195**	-	**90**	59	GWP
Nitrogen trifluoride	NF_3	7783-54-2	**17 200**	-	**7 900**	3 300	GWP
Sulphur, pentafluoro(trifluoromethyl)-	SF_5CF_3	373-80-8	**17 700**	-	**8 100**	5 400	GWP
Sulphur hexafluoride	SF_6	2551-62-4	**22 800**	-	**10 000**	6 900	GWP
Ethers and halogenated ether compounds							
Ether, dimethyl-	CH_3OCH_3	115-10-6	**1**	-	**- ***	- *	
Ether, methyl perfluoroisopropyl-	$(CF_3)_2CFOCH_3$	22 052-84-2	**343**	-	**160**	100	GWP
HCFE-235da2	$CF_3CHClOCHF_2$	26 675-46-7	**350**	-	**160**	110	GWP
HFE-125	CF_3OCHF_2	3822-68-2	**14 900**	-	**6 900**	4 600	GWP
HFE-134	CHF_2OCHF_2	1691-17-4	**6 320**	-	**2 900**	1 900	GWP
HFE-227ea	$CF_3CHFOCF_3$	2356-61-8	**1 540**	-	**710**	470	GWP

* Assessed with the eco-factor for ozone creation potential (POCP), as that value is higher

A3 PAHs (polycyclic aromatic hydrocarbons)

The following table contains a list of the most common PAHs. The list is not conclusive. The eco-factor to be used can be found in Section 10.11.

Tab. 117 > PAHs (polycyclic aromatic hydrocarbons)

PAH-no.	Name	CAS no.	Molecular weight	Synonyms
8	Acenaphthene	83-32-9	154	1,2-Dihydroacenaphthylene; 1,8-Ethylenenaphthalene
7	Acenaphthylene	208-96-8	152	Acenaphthalene
15	Anthracene	120-12-7	178	Anthracin
38	Benz(a)anthracene	56-55-3	228	Benz(a)anthracene; 1,2-Benzanthracene; 1,2-Benzanthrene; Benzo[b]phenanthrene; 2,3-Benzophenanthrene; Tetraphene; Naphthanthracene
74	Benzo(a)pyrene	50-32-8	252	Benzo[def]chrysene; 3,4-Benzopyrene; 6,7-Benzopyrene; 1,2-Benzpyrene; 4,5-Benzpyrene
69	Benzo(b)fluoranthene	205-99-2	252	3,4-Benz[e]acephenanthrylene; Benzo[b]fluoranthene; Benzo[e]fluoranthene; 2,3-Benzofluoranthene; 3,4-Benzofluoranthene;
120	Benzo(ghi)perylene	191-24-2	276	1,12-Benzoperylene
71	Benzo(k)fluoranthene	207-08-9	252	11,12-Benzofluoranthene; 8,9-Benzofluoranthene; 2,3:1',8'-Binaphthylene; Dibenzo[b,jk]fluorene
39	Chrysene	218-01-9	228	Benzo[a]phenanthrene; 1,2-Benzophenanthrene
130	Dibenz(a,h)anthracene	53-70-3	278	1,2:5,6-Benz[a]anthracene; 1,2:5,6-Benzanthracene; 1,2,5,6-Dibenzoanthracene
18	Fluoranthene	206-44-0	202	Benzo[jk]fluorene; Idryl; 1,2-(1,8-Naphthalenediyl)benzene; Benz[a]acenaphthylene; 1,2-Benzoacenaphthylene
11	Fluorene	86-73-7	166	o-Biphenylenemethane; Diphenylenemethane; 9H-Fluorene; 2,2'-Methylenebiphenyl; 2,3-Benzidene; o-Biphenylmethane
113	Indeno(1,2,3-cd)pyrene	193-39-5	276	1,10-(1,2-Phenylene)pyrene; 1,10-(o-Phenylene)pyrene; o-Phenylenepyrene; 2,3-(o-Phenylene)pyrene; 2,3-Phenylenepyrene
4	Naphthalene	91-20-3	128	Naphthalin
14	Phenanthrene	85-01-8	178	Phenanthrin
21	Pyrene	129-00-0	202	Benzo[def]phenanthrene; Pyren

A4 Eco-factors for persistent organice pollutants (POPs)

This is a list of all POPs considered to be emissions to surface waters. The substances, characterization and eco-factors were determined by Ruiz et al. (2012). The CAS number is standard.

Tab. 118 > Persistent organic pollutants (POPs), emitted to surface waters

Name	CAS no.	BCF (l/kg)	Characterization factor (kg 2,4,6-Tribromophenol-eq./kg)	Eco-factor 2013 (UBP/g)
1 1 2 2-Tetrachloroethane	79-34-5	14	0.06	**3200**
1 1'-Bianthracene -9 9' 10 10'-tetrone 4 4'-diamino-	4051-63-2	3 890	15.85	**900 000**
1 2 4-Benzenetricarboxylic acid tris(2-ethylhexyl) ester	3319-31-1	19	0.08	**4400**
1 2-Benzenedicarboxylic acid 3 4 5 6-tetrabromo- 2-(2-hydroxyethoxy)ethyl 2-hydroxypropyl ester	20 566-35-2	87	0.35	**20 000**
1 2-Benzenedicarboxylic acid di-c6-10-alkyl esters	68 515-51-5	617	2.51	**140 000**
1 2-Benzenedicarboxylic acid dioctadecyl ester	14 117-96-5	3	0.01	**730**
1 3 5-Triazine 2 4-dimethoxy-6-(1-pyrenyl)-	3271-22-5	2 570	10.47	**590 000**
1 3 5-Triazine-2 4 6(1H 3H 5H)-trione 1 3 5-tris[[3 5-bis(1 1-dimethylethyl)-4-hydroxyphenyl]methyl]-	27 676-62-6	3	0.01	**730**
1 3 5-Triazine-2 4 6(1H 3H 5H)-trione 1 3 5-tris[[4-(1 1-dimethylethyl)-3-hydroxy-2 6-dimethylphenyl]methyl]-	40 601-76-1	3	0.01	**730**
1 3-Eicosanedione 1-phenyl-	58 446-52-9	170	0.69	**39 000**
1 3-Isobenzofurandione 4 5 6 7-tetrachloro-	117-08-8	537	2.19	**120 000**
1 3-Propanediol 2 2 -[oxybis(methylene)]bis[2-(hydroxymethyl)-	126-58-9	3	0.01	**730**
1 3-Propanediol 2-ethyl-2-(hydroxymethyl)-	77-99-6	3	0.01	**730**
1 3-Propanedione 1 3-diphenyl-	120-46-7	5	0.02	**1 300**
1 4:7 10-Dimethanodibenzo a e cyclooctene 1 2 3 4 7 8 9 10 13 13 14 14-dodecachloro-1 4 4a 5 6 6a 7 10 10a 11 12 12a-	13 560-89-9	107	0.44	**25 000**
10:2 FTOH (10:2 fluorotelomer alcohol)	865-86-1	2 234	9.10	**510 000**
12H-Phthaloperin-12-one	6925-69-5	24	0.10	**5 500**
13-Docosenamide (Z)-	112-84-5	661	2.69	**150 000**
14H-Benz 4 5 isoquino 2 1-a perimidin-14-one	6829-22-7	145	0.59	**33 000**
1H-Indene-1 3(2H)-dione 2-(3-hydroxy-2-quinolinyl)-	7576-65-0	240	0.98	**55 000**
1H-Isoindol-1-one 3 3'-(1 4-phenylenediimino)bis 4 5 6 7-tetrachloro-	5590-18-1	3 802	15.49	**880 000**
1H-Isoindol-3-amine 1-imino-	3468-11-9	3	0.01	**730**
1H-Isoindole-1 3(2H)-dione 2- (trichloromethyl)thio -	133-07-3	35	0.14	**8 200**
1H-Isoindole-1 3(2H)-dione 2 2 -(1 2-ethanediyl)bis[4 5 6 7-tetrabromo-	32 588-76-4	562	2.29	**130 000**
1H-Isoindole-1 3(2H)-dione 3a 4 7 7a-tetrahydro-2-[(trichloromethyl)thio]-	133-06-2	32	0.13	**7 500**
1H-Isoindole-1 3(2H)-dione 4 5 6 7-tetrachloro-2-[2-(4 5 6 7-tetrachloro-2 3-dihydro-1 3-dioxo-1H-inden-2-yl)-8-quinol	30 125-47-4	95	0.39	**22 000**
1-Propanol 2-chloro- phosphate (3:1)	6145-73-9	6	0.02	**1 300**
2 4 6(1H 3H 5H)-Pyrimidinetrione 5 5'-(1H-isoindole-1 3(2H)-diylidene)bis-	36 888-99-0	3	0.01	**730**
2 4 6(1H 3H 5H)-Pyrimidinetrione 5-[(2 3-dihydro-6-methyl-2-oxo-1H-benzimidazol-5-yl)azo]-	72 102-84-2	10	0.04	**2 300**
1 1 2 2-Tetrachloroethane	79-34-5	14	0.06	**3 200**
1 1'-Bianthracene -9 9' 10 10'-tetrone 4 4'-diamino-	4051-63-2	3 890	15.85	**900 000**

Name	CAS no.	BCF (l/kg)	Characterization factor (kg 2,4,6-Tribromophenol-eq./kg)	Eco-factor 2013 (UBP/g)
1 2 4-Benzenetricarboxylic acid tris(2-ethylhexyl) ester	3319-31-1	19	0.08	**4 400**
1 2-Benzenedicarboxylic acid 3 4 5 6-tetrabromo- 2-(2-hydroxyethoxy)ethyl 2-hydroxypropyl ester	20566-35-2	87	0.35	**20 000**
1 2-Benzenedicarboxylic acid di-c6-10-alkyl esters	68515-51-5	617	2.51	**140 000**
1 2-Benzenedicarboxylic acid dioctadecyl ester	14117-96-5	3	0.01	**730**
1 3 5-Triazine 2 4-dimethoxy-6-(1-pyrenyl)-	3271-22-5	2 570	10.47	**590 000**
1 3 5-Triazine-2 4 6(1H 3H 5H)-trione 1 3 5-tris[[3 5-bis(1 1-dimethylethyl)-4-hydroxyphenyl]methyl]-	27676-62-6	3	0.01	**730**
1 3 5-Triazine-2 4 6(1H 3H 5H)-trione 1 3 5-tris[[4-(1 1-dimethylethyl)-3-hydroxy-2 6-dimethylphenyl]methyl]-	40601-76-1	3	0.01	**730**
1 3-Eicosanedione 1-phenyl-	58446-52-9	170	0.69	**39 000**
1 3-Isobenzofurandione 4 5 6 7-tetrachloro-	117-08-8	537	2.19	**120 000**
1 3-Propanediol 2 2 -[oxybis(methylene)]bis[2-(hydroxymethyl)-	126-58-9	3	0.01	**730**
1 3-Propanediol 2-ethyl-2-(hydroxymethyl)-	77-99-6	3	0.01	**730**
1 3-Propanedione 1 3-diphenyl-	120-46-7	5	0.02	**1 300**
1 4:7 10-Dimethanodibenzo a e cyclooctene 1 2 3 4 7 8 9 10 13 13 14 14-dodecachloro-1 4 4a 5 6 6a 7 10 10a 11 12 12a-	13560-89-9	107	0.44	**25 000**
10:2 FTOH (10:2 fluorotelomer alcohol)	865-86-1	2 234	9.10	**510 000**
12H-Phthaloperin-12-one	6925-69-5	24	0.10	**5 500**
13-Docosenamide (Z)-	112-84-5	661	2.69	**150 000**
14H-Benz 4 5 isoquino 2 1-a perimidin-14-one	6829-22-7	145	0.59	**33 000**
1H-Indene-1 3(2H)-dione 2-(3-hydroxy-2-quinolinyl)-	7576-65-0	240	0.98	**55 000**
1H-Isoindol-1-one 3 3'-(1 4-phenylenediimino)bis 4 5 6 7-tetrachloro-	5590-18-1	3 802	15.49	**880 000**
1H-Isoindol-3-amine 1-imino-	3468-11-9	3	0.01	**730**
1H-Isoindole-1 3(2H)-dione 2- (trichloromethyl)thio -	133-07-3	35	0.14	**8 200**
1H-Isoindole-1 3(2H)-dione 2 2 -(1 2-ethanediyl)bis[4 5 6 7-tetrabromo-	32588-76-4	562	2.29	**130 000**
1H-Isoindole-1 3(2H)-dione 3a 4 7 7a-tetrahydro-2-[(trichloromethyl)thio]-	133-06-2	32	0.13	**7 500**
1H-Isoindole-1 3(2H)-dione 4 5 6 7-tetrachloro-2-[2-(4 5 6 7-tetrachloro-2 3-dihydro-1 3-dioxo-1H-inden-2-yl)-8-quinol	30125-47-4	95	0.39	**22 000**
1-Propanol 2-chloro- phosphate (3:1)	6145-73-9	6	0.02	**1 300**
2 4 6(1H 3H 5H)-Pyrimidinetrione 5 5'-(1H-isoindole-1 3(2H)-diylidene)bis-	36888-99-0	3	0.01	**730**
2 4 6(1H 3H 5H)-Pyrimidinetrione 5-[(2 3-dihydro-6-methyl-2-oxo-1H-benzimidazol-5-yl)azo]-	72102-84-2	10	0.04	**2 300**
2 4 6-Tribromophenol	118-79-6	245	1.00	**57 000**
2 4 8 10-Tetraoxa-3 9-diphosphaspiro 5.5 undecane 3 9-bis 2 4-bis(1 1-dimethylethyl)phenoxy -	26741-53-7	162	0.66	**37 000**
2 4'-Dichlorobiphenyl	34883-43-7	6 902	28.12	**1 600 000**
2 5-Pyrrolidinedione 3-dodecyl-1-(2 2 6 6-tetramethyl-4-piperidinyl)-	79720-19-7	562	2.29	**130 000**
2H-1-Benzopyran-6-ol 3 4-dihydro-2 5 7 8-tetramethyl-2-(4 8 12-trimethyltridecyl)-	10191-41-0	39	0.16	**9 000**
2H-Pyran-2 4(3H)-dione 3-acetyl-6-methyl-	520-45-6	3	0.01	**730**
2-Naphthalenecarboxamide 4- (2 5-dichlorophenyl)azo -N-(2 3-dihydro-2-oxo-1H-benzimidazol-5-yl)-3-hydroxy-	6992-11-6	10	0.04	**2 300**
2-Naphthalenecarboxamide 4-[[5-[[[4-(aminocarbonyl)phenyl]amino]carbonyl]-2-methoxyphenyl]azo]-N-(5-chloro-2 4-dimetho	59487-23-9	10	0.04	**2 300**
2-Naphthalenecarboxamide N-(2 3-dihydro-2-oxo-1H-benzimidazol-5-yl)-3-hydroxy-4- 2-methoxy-5- (phenylamino)carbonyl	12225-06-8	10	0.04	**2 300**

Name	CAS no.	BCF (l/kg)	Characterization factor (kg 2,4,6-Tribromophenol-eq./kg)	Eco-factor 2013 (UBP/g)
2-Naphthalenecarboxamide N N'-(2-chloro-1 4-phenylene)bis[4-[(2 5-dichlorophenyl)azo]-3-hydroxy-	5280-78-4	10	0.04	**2 300**
2-Naphthalenecarboxamide N N'-(2-chloro-1 4-phenylene)bis[4-[(4-chloro-2-nitrophenyl)azo]-3-hydroxy-	35869-64-8	10	0.04	**2 300**
2-Naphthalenecarboxamide N N'-1 4-phenylenebis[4-[(2 5-dichlorophenyl)azo]-3-hydroxy-	3905-19-9	10	0.04	**2 300**
2-n-Octyl-4-isothiazolin-3-one	26530-20-1	19	0.08	**4 400**
2-Thiophenecarboxylic acid 4-cyano-5-[[5-cyano-2 6-bis[(3-methoxypropyl)amino]-4-methyl-3-pyridinyl]azo]-3-methyl- me	72968-71-9	10	0.04	**2 300**
3 3'-((2 5-Dimethyl-p-phenylene)bis(imino(1-acetyl-2-oxoethylene)azo))bis(4-chloro-N-(5-chloro-o-tolyl)benzamide)	5280-80-8	10	0.04	**2 300**
3H-Dibenz f ij isoquinoline-2 7-dione 3-methyl-6- (4-methylphenyl)amino -	81-39-0	112	0.46	**26 000**
3H-Pyrazol-3-one 4- (1 5-dihydro-3-methyl-5-oxo-1-phenyl-4H-pyrazol-4-ylidene)methyl -2 4-dihydro-5-methyl-2-phenyl-	4702-90-3	389	1.58	**90 000**
3H-Pyrazol-3-one 4 4'-[(3 3'-dichloro[1 1'-biphenyl]-4 4'-diyl)bis(azo)]bis[2 4-dihydro-5-methyl-2-(4-methylphenyl)-	15793-73-4	10	0.04	**2 300**
4 5-Dichloro-2-octyl-3(2H)-isothiazolone	64359-81-5	110	0.45	**25 000**
4 7-Methano-1H-isoindole-1 3(2H)-dione 2 2 -(1 2-ethanediyl)bis[5 6-dibromohexahydro-	52907-07-0	9	0.04	**2 100**
4 7-Methanoisobenzofuran-1 3-dione 4 5 6 7 8 8-hexachloro-3a 4 7 7a-tetrahydro-	115-27-5	355	1.45	**82 000**
5 9 14 18-Anthrazinetetrone 6 15-dihydro-	81-77-6	1 514	6.17	**350 000**
7-Oxa-3 20-diazadispiro[5.1.11.2]heneicosan-21-one 2 2 4 4-tetramethyl-	64338-16-5	7 586	30.90	**1 700 000**
8:2 FTOH (8:2 fluorotelomer alcohol)	678-39-7	12 190	49.65	**2 800 000**
9 10-Anthracenedione 1-(methylamino)-	82-38-2	62	0.25	**14 000**
9 10-Anthracenedione 1 1'- (6-phenyl-1 3 5-triazine-2 4-diyl)diimino bis-	4118-16-5	26	0.11	**6 100**
9 10-Anthracenedione 1 4-bis (4-methylphenyl)amino -	128-80-3	513	2.09	**120 000**
9 10-Anthracenedione 1-hydroxy-4- (4-methylphenyl)amino -	81-48-1	1 585	6.46	**360 000**
9-Octadecenamide (Z)-	301-02-0	372	1.51	**86 000**
Acetamide 2-cyano-2-[2 3-dihydro-3-(tetrahydro-2 4 6-trioxo-5(2H)-pyrimidinylidene)-1H-isoindol-1-ylidene]-N-methyl-	76199-85-4	3	0.01	**730**
Adipate bis(2-ethylhexyl)-	103-23-1	955	3.89	**220 000**
Anthra 2 1 9-def:6 5 10-d'e'f' diisoquinoline-1 3 8 10(2H 9H)-tetrone 2 9-dimethyl-	5521-31-3	263	1.07	**61 000**
Anthracene	120-12-7	2 765	11.26	**640 000**
Antioxidant MD-1024	32687-78-8	3 236	13.18	**750 000**
Azamethine Yellow 2GLT	5045-40-9	2 042	8.32	**470 000**
Benzamide 3 3'-[(2-chloro-5-methyl-1 4-phenylene)bis[imino(1-acetyl-2-oxo-2 1-ethanediyl)azo]]bis[4-chloro-N-[2-(4-chl	79953-85-8	10	0.04	**2 300**
Benzamide N-[4-(aminocarbonyl)phenyl]-4-[[1-[[(2 3-dihydro-2-oxo-1H-benzimidazol-5-yl)amino]carbonyl]-2-oxopropyl]azo]	74441-05-7	10	0.04	**2 300**
Benzenamine 4-(1-methyl-1-phenylethyl)-N- 4-(1-methyl-1-phenylethyl)phenyl -	10081-67-1	2 399	9.77	**550 000**
Benzenamine N-phenyl- reaction products with 2 4 4-trimethylpentene	68411-46-1	12 589	51.28	**2 900 000**
Benzene (as BTEX)	71-43-2	9	0.04	**2 000**
Benzene 1 1 -[1 2-ethanediylbis(oxy)]bis[2 4 6-tribromo-	37853-59-1	1 175	4.79	**270 000**
Benzene 1 1 -oxybis- octabromo deriv.	32536-52-0	1 950	7.94	**450 000**
Benzene 1 1'-(1-methylethylidene)bis 3 5-dibromo-4-(2 3-dibromopropoxy)-	21850-44-2	81	0.33	**19 000**
Benzene 1 2 4 5-tetrabromo-3 6-bis(pentabromophenoxy)-	58965-66-5	3	0.01	**730**

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Benzene ethyl-	100-41-4	53	0.22	**12 000**
Benzene pentabromomethyl-	87-83-2	19 055	77.62	**4 400 000**
Benzenepropanamide N N -1 6-hexanediylbis[3 5-bis(1 1-dimethylethyl)-4-hydroxy-	23128-74-7	107	0.44	**25 000**
Benzenepropanoic acid 3-(1 1-dimethylethyl)- -[3-(1 1-dimethylethyl)-4-hydroxyphenyl]-4-hydroxy- -methyl- 1 2-ethaned	32509-66-3	4	0.02	**1 000**
Benzenepropanoic acid 3-(1 1-dimethylethyl)-4-hydroxy-5-methyl- 1 2-ethanediylbis(oxy-2 1-ethanediyl) ester	36443-68-2	513	2.09	**120 000**
Benzenepropanoic acid 3 5-bis(1 1-dimethylethyl)-4-hydroxy- 1 6-hexanediyl ester	35074-77-2	10	0.04	**2 200**
Benzenepropanoic acid 3 5-bis(1 1-dimethylethyl)-4-hydroxy- thiodi-2 1-ethanediyl ester	41484-35-9	46	0.19	**11 000**
Benzo(a)pyrene	50-32-8	8 241	33.57	**1 900 000**
Benzo(b)fluoranthene	205-99-2	5 189	21.14	**1 200 000**
Benzo(k)fluoranthene	207-08-9	10 116	41.20	**2 300 000**
Benzoic acid 2-[[3-[[(2 3-dihydro-2-oxo-1H-benzimidazol-5-yl)amino]carbonyl]-2-hydroxy-1-naphthalenyl]azo]- butyl est	31778-10-6	10	0.04	**2 300**
Benzoxazole 2- 4- 2- 4-(2-benzoxazolyl)phenyl ethenyl phenyl -5-methyl-	5242-49-9	4 074	16.59	**940 000**
Benzoxazole 2 2 -(1 4-naphthalenediyl)bis-	5089-22-5	5 248	21.38	**1 200 000**
Benzoxazole 2 2 -(2 5-thiophenediyl)bis[5-(1 1-dimethylethyl)-	7128-64-5	2 138	8.71	**490 000**
Benzoxazole 2 2'-(1 2-ethenediyldi-4 1-phenylene)bis-	1533-45-5	7 586	30.90	**1 700 000**
Bisbenzimidazo 2 1-b:2' 1'-i benzo lmn 3 8 phenanthroline-8 17-dione	4424-06-0	490	2.00	**110 000**
Bisphenol A	80-05-7	72	0.30	**17 000**
Butanamide 2 2'- (3 3'-dichloro 1 1'-biphenyl -4 4'-diyl)bis(azo) bis N-(2 4-dimethylphenyl)-3-oxo-	5102-83-0	10	0.04	**2 300**
Butanamide 2 2'-[1 2-ethanediylbis(oxy-2 1-phenyleneazo)]bis[N-(2 3-dihydro-2-oxo-1H-benzimidazol-5-yl)-3-oxo-	77804-81-0	10	0.04	**2 300**
BZ NO 153	35065-27-1/38380-05-1	77 446	315.46	**18 000 000**
C i solvent yellow 14	842-07-9	10	0.04	**2 300**
Cresyl diphenyl phosphate	26444-49-5	66	0.27	**15 000**
Cyclododecane hexabromo-	25637-99-4	5 754	23.44	**1 300 000**
Cyclohexane 1 2 3 4 5-pentabromo-6-chloro-	87-84-3	603	2.45	**140 000**
Decabromodiphenyl oxide	1163-19-5	42	0.17	**9 600**
Decanedioic acid bis(1 2 2 6 6-pentamethyl-4-piperidinyl) ester	41556-26-7	724	2.95	**170 000**
Decanedioic acid bis(2 2 6 6-tetramethyl-4-piperidinyl) ester	52829-07-9	380	1.55	**88 000**
Decanedioic acid bis(2-ethylhexyl) ester	122-62-3	105	0.43	**24 000**
D-Glucitol	50-70-4	3	0.01	**730**
Dichloromethane	75-09-2	2	0.01	**420**
Diisononyl phthalate	28553-12-0	229	0.93	**53 000**
Dimethylphenol phosphate (3:1)	25155-23-1	661	2.69	**150 000**
Dioxin 2 3 7 8 Tetrachlorodibenzo-p-	1746-01-6	13 804	56.23	**3 200 000**
Diundecyl phthalate	3648-20-2	21	0.09	**4 900**
Diuron	330-54-1	23	0.09	**5 300**
EtFOSA (N-ethyl perfluorooctane sulfonamide)	4151-50-2	13 366	54.44	**3 100 000**
Ethane 1 2-dichloro-	107-06-2	2	0.01	**460**

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Ethanediamide N-(2-ethoxyphenyl)-N -(2-ethylphenyl)-	23949-66-8	126	0.51	**29 000**
Ethanol 2 2 -[(1-methylethylidene)bis[(2 6-dibromo-4 1-phenylene)oxy]]bis-	4162-45-2	7 762	31.62	**1 800 000**
Ethanol 2-butoxy- phosphate (3:1)	78-51-3	21	0.09	**4 800**
Ethene tetrachloro-	127-18-4	83	0.34	**19 000**
Ethylene oxide	75-21-8	3	0.01	**730**
HBCD (Hexabromocyclododecane)	3194-55-6	32 584	132.72	**7 500 000**
HCFC-141b (1 1-dichlorofluoroethane)	1717-00-6	13	0.05	**3 000**
HCFC-142b (1-chloro-1 1-difluoroethane)	75-68-3	8	0.03	**1 800**
Hexanedioic acid diisononyl ester	33703-08-1	269	1.10	**62 000**
Indeno(1 2 3-cd)pyrene	193-39-5	32 137	130.90	**7 400 000**
MeFOSA (N-methyl perfluorooctane sulfonamide)	31506-32-8	6 339	25.82	**1 500 000**
Melamine	108-78-1	3	0.01	**730**
Methanone 2-hydroxy-4-(octyloxy)phenyl phenyl-	1843-05-6	200	0.81	**46 000**
Methanone (2 4-dihydroxyphenyl)phenyl-	131-56-6	11	0.04	**2 500**
Methanone (2-hydroxy-4-methoxyphenyl)phenyl-	131-57-7	38	0.15	**8 800**
Naphthalene	91-20-3	69	0.28	**16 000**
Nonanedioic acid bis(2-ethylhexyl) ester	103-24-2	182	0.74	**42 000**
Octadecanamide	124-26-5	513	2.09	**120 000**
Octadecanoic acid 1 2 3-propanetriyl ester	555-43-1	3	0.01	**730**
Octadecanoic acid butyl ester	123-95-5	158	0.65	**36 000**
Octadecanoic acid diester with 1 2 3-propanetriol	1323-83-7	3	0.01	**730**
Octadecanoic acid ester with 2 2-bis(hydroxymethyl)-1 3-propanediol	8045-34-9	3 020	12.30	**700 000**
Octadecanoic acid octadecyl ester	2778-96-3	3	0.01	**730**
Octadecyl 3 5-bis(tert-butyl)-4-hydroxybenzenep*	2082-79-3	6	0.02	**1 300**
Oxirane 2 2 -[(1-methylethylidene)bis(4 1-phenyleneoxymethylene)]bis-	1675-54-3	158	0.65	**36 000**
PBDE-100 (2 2' 4 4' 6-pentabromodiphenyl ether)	189084-64-8	6 324	25.76	**1 500 000**
PBDE-28 (2 4 4'-tribromodiphenyl ether)	41318-75-6	6 714	27.35	**1 500 000**
PBDE-47 (2 2' 4 4'- tetrabromodiphenyl ether)	5436-43-1	32 584	132.72	**7 500 000**
PBDE-99 (2 2' 4 4' 5-pentabromodiphenyl ether)	60348-60-9	15 136	61.65	**3 500 000**
PCB 105 (2 3 3' 4 4'-Pentachlorobiphenyl)	32598-14-4	14 0605	572.73	**32 000 000**
PCB 110 (2 3 3' 4' 6-Pentachlorobiphenyl)	38380-03-9	51 168	208.42	**12 000 000**
PCB 118 (2 3' 4 4' 5-Pentachlorobiphenyl)	31508-00-6	18 4502	751.53	**42 000 000**
PCB 123 (2 3' 4 4' 5'-Pentachlorobiphenyl)	65510-44-3	19 6 789	801.58	**45 000 000**
PCB 138 (2 2' 3 4 4' 5'-Hexachlorobiphenyl)	35065-28-2	67 143	273.49	**15 000 000**
PCB 149 (2 2' 3 4' 5' 6-Hexachlorobiphenyl)	38380-04-0	111 173	452.84	**26 000 000**
PCB 158 (2 3 3' 4 4' 6-Hexachlorobiphenyl)	74472-42-7	37 584	153.09	**8 700 000**
PCB 160 (2 3 3' 4' 5 6-Hexachlorobiphenyl)	41411-62-5	143 219	583.38	**33 000 000**
PCB 180 (2 2' 3 4 4' 5 5'-Heptachlorobiphenyl)	35065-29-3	4 920	20.04	**1 100 000**
PCB 194 (2 2' 3 3' 4 4' 5 5'-Octachlorobiphenyl)	35694-08-7	1 343	5.47	**310 000**
PCB 199 (2 2' 3 3' 4 5 5' 6'-Octachlorobiphenyl)	52663-75-9	644	2.62	**150 000**
PCB 28 + 31 (2 4 4'-Trichlorobiphenyl + 2 4' 5-Trichlorobiphenyl)	7012-37-5/16606-02-3	18 793	76.55	**4 300 000**
PCB 5 (2 3-dichlorobiphenyl)	16605-91-7	6 095	24.83	**1 400 000**

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PCB 52 (2 2' 5 5'-Tetrachlorobiphenyl)	35693-99-3	40 644	165.56	**9 400 000**
PCB 70 (2 3' 4' 5-Tetrachlorobiphenyl)	32598-11-1	52 119	212.30	**12 000 000**
PCB 90 + 101 (2 2' 3 4' 5-Pentachlorobiphenyl + 2 2' 4 5 5'-Pentachlorobiphenyl)	68194-07-0/37680-73-2	167 880	683.83	**39 000 000**
Pcb-18	37680-65-2	15 631	63.67	**3 600 000**
Pentabromodiphenyl ether	32534-81-9	15 136	61.65	**3 500 000**
Pentaerythritol	115-77-5	3	0.01	**730**
Pentaerythritol tetrakis(3-(3 5-di-tert-butyl-4-hydroxyphenyl)propionate)	6683-19-8	2	0.01	**500**
PFBA (perfluorobutanoic acid)	375-22-4	3	0.01	**730**
PFBS (perfluorobutane sulfonate)	375-73-5	3	0.01	**730**
PFDA (perfluorodecanoic acid)	335-76-2	56	0.23	**13 000**
PFHpA (perfluoroheptanoic acid)	375-85-9	6	0.02	**1 300**
PFHxA (perfluorohexanoic acid)	307-24-4	3	0.01	**730**
PFHxS (perfluorohexane sulfonate)	355-46-4	3	0.01	**730**
PFNA (perfluorononanoic acid)	375-95-1	10	0.04	**2 300**
PFOA (Perfluorooctanoic acid)	335-67-1	3	0.01	**730**
PFOS (Perfluorooctanesulfonic acid)	1763-23-1	3	0.01	**730**
PFPA (pentafluoropropionic anhydride)	356-42-3	10	0.04	**2 200**
Phenol 2-(2H-benzotriazol-2-yl)-4-(1 1 3 3-tetramethylbutyl)-	3147-75-9	5 888	23.99	**1 400 000**
Phenol 2-(2H-benzotriazol-2-yl)-4-(1 1-dimethylethyl)-6-(1-methylpropyl)-	36437-37-3	6 761	27.54	**1 600 000**
Phenol 2-(2H-benzotriazol-2-yl)-4 6-bis(1 1-dimethylethyl)-	3846-71-7	3 802	15.49	**880 000**
Phenol 2-(2H-benzotriazol-2-yl)-4 6-bis(1 1-dimethylpropyl)-	25973-55-1	6 026	24.54	**1 400 000**
Phenol 2-(2H-benzotriazol-2-yl)-4 6-bis(1-methyl-1-phenylethyl)-	70321-86-7	3 715	15.13	**860 000**
Phenol 2-(2H-benzotriazol-2-yl)-4-methyl-	2440-22-4	324	1.32	**75 000**
Phenol 2-(5-chloro-2H-benzotriazol-2-yl)-4 6-bis(1 1-dimethylethyl)-	3864-99-1	10 233	41.68	**2 400 000**
Phenol 2-(5-chloro-2H-benzotriazol-2-yl)-6-(1 1-dimethylethyl)-4-methyl-	729335	1 288	5.25	**300 000**
Phenol 2 2 -methylenebis[6-(1 1-dimethylethyl)-4-methyl-	119-47-1	3 715	15.13	**860 000**
Phenol 2 2'-thiobis 6-(1 1-dimethylethyl)-4-methyl-	90-66-4	1 950	7.94	**450 000**
Phenol 2 4-bis(1 1-dimethylethyl)- phosphite (3:1)	31570-04-4	3	0.01	**730**
Phenol 2 4-dibromo-	615-58-7	62	0.25	**14 000**
Phenol 2 6-bis(1 1-dimethylethyl)-4-ethyl-	4130-42-1	1 230	5.01	**280 000**
Phenol 2 6-bis(1 1-dimethylethyl)-4-methyl-	128-37-0	646	2.63	**150 000**
Phenol 4- 4 6-bis(octylthio)-1 3 5-triazin-2-yl amino -2 6-bis(1 1-dimethylethyl)-	991-84-4	3	0.01	**730**
Phenol 4 4 -(1-methylethylidene)bis[2 6-dibromo-	79-94-7	10 471	42.65	**2 400 000**
Phenol 4 4 4 -(1-methyl-1-propanyl-3-ylidene)tris[2-(1 1-dimethylethyl)-5-methyl-	1843-03-4	13	0.05	**3 000**
Phenol 4 4 -butylidenebis[2-(1 1-dimethylethyl)-5-methyl-	85-60-9	759	3.09	**170 000**
Phenol 4 4 -thiobis[2-(1 1-dimethylethyl)-5-methyl-	96-69-5	1 950	7.94	**450 000**
Phenol 4 4' 4"-[(2 4 6-trimethyl-1 3 5-benzenetriyl)tris(methylene)]	1709-70-2	3	0.01	**730**
Phenol nonyl- phosphite (3:1)	26523-78-4	3	0.01	**730**
Phosphate tris(2-chloroethyl)-	115-96-8	1	0.00	**140**
Phosphonic acid [[3 5-bis(1 1-dimethylethyl)-4-hydroxyphenyl]methyl]- diethyl ester	976-56-7	132	0.54	**30 000**
Phosphonous acid [1 1 -biphenyl]-4 4 -diylbis- tetrakis[2 4-bis(1 1-dimethylethyl)phenyl] ester	38613-77-3	3	0.01	**730**

Name	CAS no.	BCF (l/kg)	Characterization factor (kg 2,4,6-Tribromophenol-eq./kg)	Eco-factor 2013 (UBP/g)
Phosphoric acid triethyl ester	78-40-0	3	0.01	**730**
Phosphoric acid tris(2-ethylhexyl) ester	78-42-2	30	0.12	**7 000**
Phosphorous acid diisodecyl phenyl ester	25550-98-5	245	1.00	**57 000**
Phosphorous acid isodecyl diphenyl ester	26544-23-0	603	2.45	**140 000**
Phosphorous acid triphenyl ester	101-02-0	10 965	44.66	**2 500 000**
Phthalate butyl-benzyl-	85-68-7	617	2.51	**140 000**
Phthalate dibutyl-	84-74-2	437	1.78	**100 000**
Phthalate diisodecyl-	26761-40-0	76	0.31	**17 000**
Phthalate diisooctyl-	27554-26-3	708	2.88	**160 000**
Phthalate dioctyl-	117-81-7	1 698	6.92	**390 000**
Pigment Red 149	4948-15-6	8 913	36.30	**2 100 000**
Pigment yellow 83	5567-15-7	10	0.04	**2 300**
Propanedioic acid [[3 5-bis(1 1-dimethylethyl)-4-hydroxyphenyl]methyl]butyl- bis(1 2 2 6 6-pentamethyl-4-piperidinyl)	63843-89-0	263	1.07	**61 000**
Propanoic acid 3 3 -thiobis- didodecyl ester	123-28-4	15	0.06	**3 500**
Propanoic acid 3 3'-thiobis- dioctadecyl ester	693-36-7	3	0.01	**730**
Quino 2 3-b acridine-7 14-dione 2 9-dichloro-5 12-dihydro-	3089-17-6	891	3.63	**210 000**
Quino[2 3-b]acridine-7 14-dione 5 12-dihydro-	1047-16-1	1	0.00	**230**
Quino[2 3-b]acridine-7 14-dione 5 12-dihydro-2 9-dimethyl-	980-26-7	5	0.02	**1 200**
Quinoline 1 2-dihydro-2 2 4-trimethyl-	147-47-7	71	0.29	**16 000**
Sorbitan monododecanoate	1338-39-2	56	0.23	**13 000**
Soybean oil epoxidized	8013-07-8	3	0.01	**730**
Sulfur hexafluoride	2551-62-4	4	0.02	**900**
Tetraphenyl m-phenylene bis(phosphate)	57583-54-7	1 259	5.13	**290 000**
Toluene	108-88-3	25	0.10	**5 800**
Tributylphosphate	126-73-8	30	0.12	**7 000**
Trichlorobenzenes	12002-48-1	262	1.07	**60 000**
Trichloroethene	79-01-6	15	0.06	**3 400**
Trichloromethane	67-66-3	7	0.03	**1 500**
Tricresyl phosphate	1330-78-5	162	0.66	**37 000**
Triphenylphosphate	115-86-6	74	0.30	**17 000**
Tris(1 3-dichloroisopropyl) phosphate	13674-87-8	18	0.07	**4 100**
Xylene	1330-20-7	58	0.24	**13 000**

A5 Plant protection products

There are different ways of spelling the plant protection products. The spellings in the Swiss Plant Protection Products Ordinance (PSMV 2010) are used here. For substances that are not listed in the Plant Protection Products Ordinance, the ecoinvent spelling has been adopted. The CAS number is standard.

Tab. 119 > Plant protection products

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Herbicides					
2,4-D	000094-75-7	941	2.6	**390**	a)
Acetochlor	034256-82-1	3 230	0.76	**110**	b)
Aclonifen	074070-46-5	2 600	0.94	**140**	a)
Alachlor	015972-60-8	2 770	0.88	**130**	a)
Ametryn	000834-12-8	1 790	1.4	**210**	b)
Amidosulfuron	120923-37-7	37.3	65	**9 800**	a)
Asulam	003337-71-1	2 160	1.1	**170**	a)
Atrazine	001912-24-9	1 000	2.4	**360**	a)
Beflubutamid	113614-08-7	102	24	**3 600**	a)
Benazolin	003813-05-6	305	8	**1 200**	a)
Bensulfuron methyl ester	083055-99-6	117	21	**3 200**	b)
Bentazon	025057-89-0	1 160	2.1	**320**	a)
Bifenox	042576-02-3	1 100	2.2	**330**	a)
Bromoxynil	001689-84-5	370	6.6	**990**	a)
Carbetamide	016118-49-3	2 040	1.2	**180**	a)
Carfentrazone-ethyl	128639-02-1	39.4	62	**9 300**	a)
Chloridazon	001698-60-8	2 060	1.2	**180**	a)
Chlorimuron-ethyl	090982-32-4	117	21	**3 200**	b)
Chlorotoluron	015545-48-9	2 000	1.2	**180**	a)
Chlorsulfuron	064902-72-3	11.2	220	**33 000**	d)
Chlorthal	002136-79-0	9 380	0.26	**39**	a)
Cinidon-ethyl	142891-20-1	57.5	43	**6 500**	a)
Clethodim	099129-21-2	181	13	**2 000**	a)
Clodinafop-propargyl	105512-06-9	69	35	**5 300**	a)
Clomazone	081777-89-1	91.5	27	**4 100**	a)
Clopyralid	001702-17-6	113	22	**3 300**	a)
Cloquintocet-mexyl	099607-70-2	18	140	**21 000**	a)
Cloransulam-methyl	147150-35-4	448	5.5	**830**	b)
Cyanamid	000420-04-2	14 2000	0.017	**2.6**	a)
Cyanazine	021725-46-2	475	5.1	**770**	a)
Cycloxydim	101205-02-1	350	7	**1 100**	a)
Dazomet (DMTT)	000533-74-4	34 3000	0.0071	**1.1**	a)
Desmedipham	013684-56-5	98.7	25	**3 800**	a)
Dicamba	001918-00-9	243	10	**1 500**	a)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Dichlobenil	001194-65-6	300	8.1	**1 200**	e)
Dichlorprop-P	015165-67-0	630	3.9	**590**	e)
Diclofop	040843-25-2	492	5	**750**	c)
Diclofop-methyl	051338-27-3	360	6.8	**1 000**	b)
Diflufenican	083164-33-4	87.1	28	**4 200**	a)
Diflufenzopyr-sodium	109293-98-3	66.7	37	**5 600**	e)
Dimefuron	034205-21-5	955	2.6	**390**	a)
Dimethachlor	050563-36-5	656	3.7	**560**	a)
Dimethenamid	087674-68-8	1 260	1.9	**290**	a)
Dimethenamid-P	163515-14-8	950	2.6	**390**	a)
Dinoseb	000088-85-7	5 160	0.47	**71**	e)
Diquat	000231-36-7	1 460	1.7	**260**	a)
Diquat-dibromid	000085-00-7	1 270	1.9	**290**	e)
Diuron	000330-54-1	2 120	1.2	**180**	a)
Dinitrokreosol (DNOC)	000534-52-1	18 300	0.13	**20**	e)
Eisen-II-Sulfat	013463-43-9	77.8	31	**4 700**	a)
Endothall	000145-73-3	2240	1.1	**170**	f)
EPTC	000759-94-4	3 220	0.76	**110**	d)
Ethalfluralin	055283-68-6	1 270	1.9	**290**	d)
Ethofumesate	026225-79-6	483	5.1	**770**	a)
Fenoxaprop	095617-09-7	61.6	40	**6 000**	d)
Fenoxaprop ethyl ester	066441-23-4	84.9	29	**4 400**	f)
Fenoxaprop-P-ethyl	071283-80-2	58.8	42	**6 300**	a)
Flamprop-M-isopropyl	063782-90-1	600	4.1	**620**	e)
Flazasulfuron	104040-78-0	46	53	**8 000**	a)
Florasulam	145701-23-1	4.49	540	**81 000**	a)
Fluazifop-P-butyl	079241-46-6	278	8.8	**1 300**	a)
Flucarbazone sodium salt	181274-17-9	3.15	780	**120 000**	b)
Flufenacet	142459-58-3	325	7.5	**1 100**	a)
Flumetsulam	098967-40-9	38	64	**9 600**	f)
Flumioxazin	103361-09-7	135	18	**2 700**	a)
Fluometuron	002164-17-2	3 360	0.73	**110**	e)
Fluoroglycofen-ethyl	077501-90-7	30	81	**12 000**	e)
Flupyrsulfuron-methyl-sodium	144740-54-5	10	240	**36 000**	a)
Flurenolcarbonsäure	000467-69-6	197	12	**1 800**	a)
Flurochloridon	061213-25-0	750	3.3	**500**	a)
Fluroxypyr	069377-81-7	233	10	**1 500**	a)
Flurtamone	096525-23-4	250	9.8	**1 500**	c)
Fomesafen	072178-02-0	72.9	34	**5 100**	b)
Foramsulfuron	173159-57-4	39.4	62	**9 300**	a)
Glufosinate	051276-47-2	923	2.6	**390**	a)
Glyphosat	001071-83-6	2 440	1	**150**	a)
Halosulfuron-methyl	100784-20-1	39.2	62	**9 300**	d)
Haloxyfop-(R)-Methylester	087237-48-7	97.2	25	**3 800**	a)
Imazamox	114311-32-9	40	61	**9 200**	a)
Imazapyr	081334-34-1	0.23	11 000	**1 700 000**	f)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Imazethapyr	081335-77-5	89	27	**4 100**	e)
Iodosulfuron	144550-36-7	4.72	520	**78 000**	a)
Ioxynil	001689-83-4	284	8.6	**1 300**	a)
Isoproturon	034123-59-6	1 250	2	**300**	a)
Isoxadifen-ethyl	163520-33-0	31.3	78	**12 000**	a)
Isoxaflutole	141112-29-0	58.5	42	**6 300**	a)
Lactofen	077501-63-4	448	5.5	**830**	b)
Lenacil	002164-08-1	2 160	1.1	**170**	a)
Linuron	000330-55-2	854	2.9	**440**	a)
MCPA	000094-74-6	1 260	1.9	**290**	a)
MCPB	000094-81-5	1 730	1.4	**210**	a)
Mecoprop	000093-65-2	770	3.2	**480**	e)
Mecoprop-P	016484-77-8	830	2.9	**440**	a)
Mefenpyr-Diethyl	135590-91-9	36.8	66	**9 900**	a)
Mesosulfuron-methyl	208465-21-8	7.13	340	**51 000**	a)
Mesotrione	104206-82-8	100	24	**3 600**	a)
Metamitron	041394-05-2	3 380	0.72	**110**	a)
Metam	000137-42-8	358 000	0.0068	**1**	b)
Metazachlor	067129-08-2	1 000	2.4	**360**	a)
Methabenzthiazuron	018691-97-9	2 730	0.9	**140**	e)
Metolachlor	051218-45-2	1 670	1.5	**230**	a)
Metosulam	139528-85-1	22.5	110	**17 000**	a)
Metribuzin	021087-64-9	531	4.6	**690**	a)
Metsulfuron-methyl	074223-64-6	5.8	420	**63 000**	a)
Monolinuron	001746-81-2	1 070	2.3	**350**	e)
MSMA	002163-80-6	1 030	2.4	**360**	d)
Napropamide	015299-99-7	1 320	1.9	**290**	a)
Nicosulfuron	111991-09-4	40	61	**9 200**	a)
Norflurazon	027314-13-2	1 350	1.8	**270**	d)
Orbencarb	034622-58-7	3 580	0.68	**100**	a)
Oryzalin	019044-88-3	3 360	0.73	**110**	a)
Oxadiargyl	039807-15-3	150	16	**2 400**	a)
Oxadixyl	077732-09-3	219	11	**1 700**	e)
Oxydemeton-methyl	000301-12-2	545	4.5	**680**	e)
Oxyfluorfen	042874-03-3	583	4.2	**630**	a)
Paraquat	004685-14-7	723	3.4	**510**	e)
Pelargonsäure	000112-05-0	31 000	0.079	**12**	a)
Pendimethalin	040487-42-1	1 560	1.6	**240**	a)
Pethoxamid	106700-29-2	1 110	2.2	**330**	a)
Phenmedipham	013684-63-4	864	2.8	**420**	a)
Picloram	001918-02-1	23.5	100	**15 000**	a)
Pinoxaden	243973-20-8	33.8	72	**11 000**	a)
Prometryn	007287-19-6	1 720	1.4	**210**	d)
Pronamide	023950-58-5	200	12	**1 800**	f)
Propachlor	001918-16-7	4 500	0.54	**81**	a)
Propanil	000709-98-8	5 400	0.45	**68**	d)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Propaquizafop	111479-05-1	163	15	**2 300**	a)
Propoxycarbazone-sodium	181274-15-7	42	58	**8 700**	a)
Propyzamide	023950-58-5	971	2.5	**380**	a)
Prosulfocarb	052888-80-9	3 540	0.69	**100**	a)
Prosulfuron	094125-34-5	13.5	180	**27 000**	e)
Pyraflufen-ethyl	129630-19-9	26.8	91	**14 000**	a)
Pyridate	055512-33-9	737	3.3	**500**	a)
Pyrithiobac Natrium Salz	123343-16-8	44.8	55	**8 300**	d)
Quinclorac	084087-01-4	626	3.9	**590**	f)
Quinmerac	090717-03-6	250	9.8	**1 500**	c)
Quinoclamine	002797-51-5	3 750	0.65	**98**	a)
Quizalofop ethyl ester	076578-14-8	150	16	**2 400**	f)
Quizalofop-P-ethyl	100646-51-3	73.4	33	**5 000**	a)
Rimsulfuron	122931-48-0	8.93	270	**41 000**	a)
Sethoxydim	074051-80-2	293	8.3	**1 200**	d)
Simazine	000122-34-9	994	2.5	**380**	e)
S-Metolachlor	087392-12-9	1390	1.8	**270**	a)
Starane	081406-37-3	208	12	**1 800**	f)
Sulcotrione	099105-77-8	525	4.7	**710**	a)
Sulfentrazone	122836-35-5	8.07	300	**45 000**	d)
Sulfosate	081591-81-3	3 200	0.76	**110**	e)
Sulfosulfuron	141776-32-1	14.8	170	**26 000**	a)
Sulfuric acid	007664-93-9	2'080'000	0.0012	**0.18**	f)
Tebupirimphos	096182-53-5	409	6	**900**	f)
Tebutam	035256-85-0	3 300	0.74	**110**	e)
Tembotrione	335104-84-2	62.5	39	**5 900**	a)
Tepraloxydim	149979-41-9	75	33	**5 000**	a)
Terbacil	005902-51-2	1 800	1.4	**210**	a)
Terbufos	013071-79-9	206	12	**1 800**	a)
Terbuthylazine	005915-41-3	732	3.3	**500**	a)
Thifensulfuron-methyl	079277-27-3	17.6	140	**21 000**	a)
Thiobencarb	028249-77-6	4 360	0.56	**84**	d)
Tralkoxydim	087820-88-0	269	9.1	**1 400**	d)
Tri-allate	002303-17-5	2 250	1.1	**170**	c)
Triasulfuron	082097-50-5	7.5	330	**50 000**	a)
Tribenuron	106040-48-6	30	81	**12 000**	a)
Tribenuron-methyl	101200-48-0	10.7	230	**35 000**	a)
Tribufos	000078-48-8	1 330	1.8	**270**	f)
Triclopyr	055335-06-3	1 020	2.4	**360**	c)
Trifluralin	001582-09-8	1 250	2	**300**	a)
Triflusulfuron-methyl	126535-15-7	12.5	200	**30'000**	a)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Insecticides					
Abamectin	071751-41-2	21.6	110	**17 000**	a)
Acephate	030560-19-1	1 570	1.6	**240**	d)
Acetamiprid	135410-20-7	34.2	72	**11 000**	a)
Aldrin	000309-00-2	2 310	1.1	**170**	f)
alpha-Cypermethrin	067375-30-8	10.4	230	**35 000**	a)
Amitraz	033089-61-1	101	24	**3 600**	d)
Apfelwicklergranulose-Virus	-	254	9.6	**1 400**	a)
Azadirachtin A*	011141-17-6	27.6	89	**13 000**	a)
Azadirachtin A+B	011141-17-6	48.9	50	**7 500**	a)
Azinphos-methyl	000086-50-0	382	6.4	**960**	f)
Bacillus thuringiensis var. israeliensis	-	46 300	0.053	**8**	a)
Bacillus thuringiensis var. kurstaki	-	171	14	**2 100**	a)
Bifenthrin	082657-04-3	18.1	130	**20 000**	a)
Buprofezin	069327-76-0	250	9.8	**1 500**	a)
Carbaryl	000063-25-2	1 400	1.7	**260**	d)
Carbofuran	001563-66-2	2 380	1	**150**	a)f)
Carbosulfan	055285-14-8	12 500	0.2	**30**	a)
Chlorfenvinphos	000470-90-6	5 000	0.49	**74**	a)
Chlorpyrifos	002921-88-2	600	4.1	**620**	a)
Chlorpyrifos-methyl	005598-13-0	403	6.1	**920**	a)
Clothianidin	210880-92-5	38.2	64	**9 600**	a)
Cyfluthrin	068359-37-5	44.5	55	**8 300**	e)
Cypermethrin	052315-07-8	51.9	47	**7 100**	a)
Deltamethrin	052918-63-5	12.5	200	**30 000**	a)
Diafenthiuron	080060-09-9	450	5.4	**810**	f)
Diazinon	000333-41-5	260	9.4	**1 400**	a)
Dicofol	000115-32-2	1 050	2.3	**350**	d)
Dicrotophos	000141-66-2	930	2.6	**390**	f)
Diflubenzuron	035367-38-5	121	20	**3 000**	a)
Dimethoate	000060-51-5	361	6.8	**1 000**	a)
Endosulfan	000115-29-7	794	3.1	**470**	a)
Esfenvalerate	066230-04-4	15.6	160	**24 000**	e)
Ethoprop	013194-48-4	6 720	0.36	**54**	d)
Etofenprox	080844-07-1	86.3	28	**4 200**	a)
Fatty acids (potassium salts)	-	9 350	0.26	**39**	a)
Fatty acids (sodium oleate)	000143-19-1	7 840	0.31	**47**	a)
Fenoxycarb	072490-01-8	224	11	**1 700**	a)
Fenpropathrin	039515-41-8	367	6.7	**1 000**	d)
Fipronil	120068-37-3	90	27	**4 100**	a)
Flonicamid	158062-67-0	69.8	35	**5 300**	a)
Imidacloprid	138261-41-3	117	21	**3 200**	a)
Indoxacarb	173584-44-6	39.7	62	**9 300**	a)
Kaolin	001332-58-7	3 040	0.8	**120**	a)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Lambda-Cyhalothrin	091465-08-6	10.5	230	**35 000**	a)
Lufenuron	103055-07-8	62.5	39	**5 900**	a)
Malathion	000121-75-5	923	2.6	**390**	a)
Methamidophos	010265-92-6	3 360	0.73	**110**	c)
Methomyl	016752-77-5	386	6.3	**950**	a)
Methoxyfenozide	161050-58-4	123	20	**3 000**	a)
Milbemectin	-	15.1	160	**24 000**	a)
Mineralöl / Petroleum oils	-	5 310	0.46	**69**	a)
Monocrotophos	006923-22-4	320	7.6	**1100**	f)
Naled	000300-76-5	1 130	2.2	**330**	d)
Natriumfluorsilikat	016893-85-9	1 880	1.3	**200**	a)
Novaluron	116714-46-6	50.4	48	**7 200**	a)
Oils biogenic	-	2 790	0.87	**130**	a)
Oxamyl	023135-22-0	4 750	0.51	**77**	c)
Parathion	000056-38-2	1 000	2.4	**360**	e)
Permethrin	052645-53-1	2 000	1.2	**180**	e)
Phorate	000298-02-2	1 680	1.5	**230**	d)
Phosalone	002310-17-0	552	4.4	**660**	a)
Phosmet	000732-11-6	2 610	0.94	**140**	d)
Pirimicarb	023103-98-2	83.1	29	**4 400**	a)
Profenofos	041198-08-7	600	4.1	**620**	f)
Propargite	002312-35-8	2 180	1.1	**170**	d)
Pymetrozine	123312-89-0	185	13	**2 000**	a)
Pyrethrine	000121-29-9	77.2	32	**4 800**	a)
Pyriproxyfen	095737-68-1	75.6	32	**4 800**	d)
Quassia extract	-	1 140	2.2	**330**	a)
Rotenon	000083-79-4	81.3	30	**4 500**	a)
Spinosad	168316-95-8	74.8	33	**5 000**	a)
Tau-fluvalinate	102851-06-9	51.2	48	**7 200**	e)
Tebufenozide	112410-23-8	118	21	**3 200**	a)
Teflubenzuron	083121-18-0	60.1	41	**6 200**	a)
Tefluthrin	079538-32-2	15.6	160	**24 000**	c)
Terbufos	013071-79-9	206	12	**1 800**	a)
Thiacloprid	111988-49-9	67.2	36	**5 400**	a)
Thiamethoxam	153719-23-4	60.4	40	**6 000**	a)
Tralomethrin	066841-25-6	0.268	9 100	**1 400 000**	d)
Triazamat	112143-82-5	61.6	40	**6 000**	a)
Trichlorfon	000052-68-6	333	7.3	**1 100**	f)
zeta-Cypermethrin	052315-07-8	10.7	230	**35 000**	a)
Fungicides					
Azoxystrobin	131860-33-8	184	13	**2 000**	a)
Bacillus subtilis	-	7.74	320	**48 000**	a)
Benalaxyl-M	071626-11-4	100	24	**3 600**	a)
Benomyl	017804-35-2	800	3.1	**470**	e)
Benthiavalicarb	413615-35-7	34	72	**11 000**	a)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Bitertanol	055179-31-2	313	7.8	**1 200**	f)
Boscalid	188425-85-6	356	6.9	**1 000**	a)
Bromuconazole	116255-48-2	243	10	**1 500**	f)
Bupirimate	041483-43-6	239	10	**1 500**	a)
Captan	000133-06-2	511	4.8	**720**	a)
Carbendazim	010605-21-7	428	5.7	**860**	a)
Carboxin	005234-68-4	450	5.4	**810**	a)
Chlorothalonil (TCPN)	001897-45-6	1 250	2	**300**	a)
Cyazofamid	120116-88-3	87.8	28	**4 200**	a)
Cyflufenamid	180409-60-3	14.5	170	**26 000**	a)
Cymoxanil	057966-95-7	131	19	**2 900**	a)
Cyproconazole	094361-06-5	77.7	31	**4 700**	a)
Cyprodinil	121552-61-2	626	3.9	**590**	a)
Diethofencarb	087130-20-9	489	5	**750**	a)
Difenoconazole	119446-68-3	123	20	**3 000**	a)
Dimethomorph	110488-70-5	161	15	**2 300**	a)
Dithianon	003347-22-6	500	4.9	**740**	a)
Dodine	002439-10-3	793	3.1	**470**	a)
Epoxiconazole	106325-08-0	107	23	**3 500**	a)
Etridiazole	002593-15-9	202	12	**1 800**	b)
Famoxadone	131807-57-3	211	12	**1 800**	a)
Fenamidone	161326-34-7	514	4.7	**710**	a)
Fenbuconazole	114369-43-6	6.7	360	**54 000**	a)
Fenhexamid	126833-17-8	883	2.8	**420**	a)
Fenpropidin	067306-00-7	328	7.4	**1 100**	a)
Fenpropimorph	067306-03-0	359	6.8	**1 000**	a)
Fentin acetate	000900-95-8	17.4	140	**21 000**	e)
Fentin hydroxide	000076-87-9	23.4	100	**15 000**	e)
Fluazinam	079622-59-6	457	5.3	**800**	a)
Fludioxonil	131341-86-1	37.8	65	**9 800**	a)
Fluoxastrobin	361377-29-9	102	24	**3 600**	a)
Fluquinconazole	136426-54-5	109	22	**3 300**	a)
Flusilazole	085509-19-9	197	12	**1 800**	a)
Flutolanil	066332-96-5	185	13	**2 000**	d)
Folpet	000133-07-3	2 560	0.95	**140**	a)
Fosetyl	039148-24-8	2 400	1	**150**	a)
Fuberidazole	003878-19-1	9.03	270	**41 000**	c)
Hexaconazole	079983-71-4	61.2	40	**6 000**	a)
Imazalil	035554-44-0	50.6	48	**7 200**	a)
Iprodione	036734-19-7	538	4.5	**680**	a)
Iprovalicarb	140923-17-7	151	16	**2 400**	a)
Kaliumbicarbonat	000298-14-6	5 820	0.42	**63**	a)
Kresoxim-methyl	143390-89-0	146	17	**2 600**	a)
Kupfer	007440-50-8	866	2.8	**420**	a)
Lecithin	008002-43-5	917	2.7	**410**	a)
Lindane	000058-89-9	1 500	1.6	**240**	e)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Mancozeb	008018-01-7	2 240	1.1	**170**	a)
Mandipropamid	374726-62-2	1 360	1.8	**270**	a)
Maneb	012427-38-2	1 040	2.3	**350**	a)
Mepanipyrim	110235-47-7	435	5.6	**840**	a)
Metalaxil	057837-19-1	800	3.1	**470**	e)
Metalaxyl-M	070630-17-0	45.7	53	**8 000**	a)
Metconazole	125116-23-6	88.8	28	**4 200**	a)
Metiram	009006-42-2	1 550	1.6	**240**	a)
Metrafenone	220899-03-6	147	17	**2 600**	a)
Myclobutanil	088671-89-0	82.3	30	**4 500**	a)
Penconazole	066246-88-6	40.8	60	**9 000**	a)
Picoxystrobin	117428-22-5	250	9.8	**1 500**	a)
Prochloraz	067747-09-5	366	6.7	**1 000**	a)
Procymidone	032809-16-8	750	3.3	**500**	c)
Propamocarb hydrochloride	025606-41-1	769	3.2	**480**	a)
Propiconazole	060207-90-1	132	19	**2 900**	a)
Propineb	012071-83-9	2 560	0.95	**140**	a)
Proquinazid	189278-12-4	52.7	46	**6 900**	a)
Prothioconazol	178928-70-6	156	16	**2 400**	a)
Pyraclostrobin	175013-18-0	216	11	**1 700**	a)
Pyrimethanil	053112-28-0	171	14	**2 100**	a)
Quinoxyfen	124495-18-7	126	19	**2 900**	a)
Sulphur	007704-34-9	28 200	0.087	**13**	a)
Silthiofam	175217-20-6	34.8	70	**11 000**	c)
Spiroxamin	118134-30-8	461	5.3	**800**	a)
Tebuconazol	080443-41-0	246	9.9	**1 500**	a)
Thiophanate-methyl	023564-05-8	546	4.5	**680**	a)
Thiram (TMTD)	000137-26-8	1 560	1.6	**240**	a)
Triadimenol	055219-65-3	40	61	**9 200**	a)
Triazoxid	072459-58-6	1.96	1 200	**180 000**	a)
Tridemorph	081412-43-3	55.8	44	**6 600**	a)
Trifloxystrobin	141517-21-7	246	9.9	**1 500**	a)
Triflumizole	068694-11-1	1 850	1.3	**200**	a)
Vinclozolin	050471-44-8	375	6.5	**980**	a)
Ziram	000137-30-4	324	7.5	**1 100**	a) c)
Zoxamide	156052-68-5	154	16	**2 400**	a)
Molluscicides					
Iron-III-phosphate	010045-86-0	269	9.1	**1 400**	a)
Metaldehyde	009002-91-9	450	5.4	**810**	a)
Seed dressings					
Fenpiclonil	074738-17-3	48.5	50	**7 500**	e)
Hymexazol	010004-44-1	23.4	100	**15 000**	a)
Mepronil	055814-41-0	563	4.3	**650**	a)
Pencycuron	066063-05-6	375	6.5	**980**	a)

	CAS no.	Standard dose (g/ha)	Characterization factor (g glyphosate-eq./g)	Eco-factor 2013 (UBP/g)	
Methiocarb*	002032-65-7	175	14	**2 100**	a)
Plant growth regulators					
1-Naphthylacetic acid	000086-87-3	43.4	56	**8 400**	c)
2-(1-Naphthyl)acetamide	000086-86-2	900	2.7	**410**	a)
6-Benzyladenin	001214-39-7	27 800	0.088	**13**	c)
Chlormequat	007003-89-6	949	2.6	**390**	a)
Chlormequat (Chlorcholinchlorid) (CCC)	000999-81-5	961	2.5	**380**	a)
Chlorpropham (CIPC)	000101-21-3	219	11	**1 700**	a)
Cyclanilide	113136-77-9	78.4	31	**4 700**	d)
Ethephon	016672-87-0	380	6.4	**960**	a)
Gibberellin A3	000077-06-5	115	21	**3 200**	a)
Maleinhydrazid	000123-33-1	2 010	1.2	**180**	a)
Mepiquat-chloride	024307-26-4	300	8.1	**1 200**	a)
Prohexadione-Calcium	127277-53-6	78.1	31	**4 700**	a)
Thidiazuron	051707-55-2	67.2	36	**5 400**	d)
Trinexapac-ethyl	095266-40-3	125	20	**3 000**	e)
Acaricides					
Bromopropylate	018181-80-1	550	4.4	**660**	a)
Clofentezine	074115-24-5	320	7.6	**1 100**	a)
Etoxazole	153233-91-1	54.5	45	**6 800**	a)
Fenazaquin	120928-09-8	180	14	**2 100**	a)
Fenpyroximate	111812-58-9	81.4	30	**4 500**	a)
Hexythiazox	078587-05-0	90	27	**4 100**	a)
Spirodiclofen	148477-71-8	119	21	**3 200**	a)
Tebufenpyrad	119168-77-3	69.1	35	**5 300**	a)
Others					
1-Decanol	000112-30-1	10 800	0.23	**35**	f)
Acibenzolar-S-methyl	135158-54-2	28.2	87	**13 000**	a)
Aethylenglycolmonobuthylaether	000111-76-2	139	18	**2 700**	a)
Aldicarb	000116-06-3	2 000	1.2	**180**	a)
Anthraquinone	000084-65-1	410	0.59	**89**	f)
Bacillus thuringiensis var. aizawai	-	1 400	1.7	**260**	c)
Choline chloride	000067-48-1	458	5.3	**800**	e)
E2Z13-18 Ac	086252-74-6	23.4	100	**15 000**	a)
E3Z13-18 Ac	053120-26-6	0.89	2 700	**410 000**	a)
Laminarin	009008-22-4	37.3	65	**9 800**	a)
Streptomycin (as streptomycin sulfate)	003810-74-0	250 000	0.0098	**1.5**	c)

Derivation of the standard doses:
a) Swiss plant protection product index (BLW 2012);
b) Product data sheets from the CMDS database (CMDS 2012);
c) European database (Directorate General for Health & Consumers 2008);
d) North American database (Kegley 2011);
e) Ecological Scarcity Method 2006 (Frischknecht et al. 2008);
f) Other sources

A6 Eco-factors for land use

BDP (Biodiversity Damage Potential) values were taken over from de Baan et al. (2012) and derived on that basis (see notes at the end of the table). The characterization factors are based on the “Settlement area” land-use reference (with a BDP of 0.44).

Tab. 120 > Biodiversity Damage Potentials, characterization and eco-factors for land use in biome 5 (one of the biomes in which Switzerland is located)

CORINE+	Land use	BDP		Charact. factor (m²a SA-eq./m²a)	Eco-factor 2013 (UBP/m²a)	Eco-factor 2006 (UBP/m²a)
Settlement areas						
111	Urban fabric, continuous >80% sealed	0.44	a)	1.00	**300**	260
112	Urban fabric, distcontinous <80% sealed	0.26	b)	0.59	**180**	220
113	Urban fallow	0.00	c)	0.00	**0**	-33
114	Rural settlement	0.26	d)	0.59	**180**	190
121	Industrial or commercial units	0.44	a)	1.00	**300**	220
121a	Industrial area, built up part, >80% sealed	0.44	e)	1.00	**300**	260
121b	Industrial area, part with vegetation <80% sealed	0.26	d)	0.59	**180**	210
122	Road and rail networks and associated land	0.44	e)	1.00	**300**	220
122a	Road networks	0.44	e)	1.00	**300**	220
122b	Road embankments and associated land (min. 100m width)	0.26	b)	0.59	**180**	180
122c	Rail networks	0.44	e)	1.00	**300**	220
122d	Rail embankments and associated land (min. 100m width)	0.26	b)	0.59	**180**	180
122e	Rail fallow	0.04	f)	0.10	**30**	-4
124	Airports	0.26	d)	0.59	**180**	-
125	Industrial fallow	0.00	c)	0.00	**0**	-35
131	Mineral extraction sites	0.44	g)	1.00	**300**	220
132	Dump sites	0.44	a)	1.00	**300**	220
133	Construction sites	0.44	g)	1.00	**300**	220
134	Mining fallow	0.00	c)	0.00	**0**	-33
14	Artificial, non-agricultural areas with vegetation	0.26	h)	0.59	**180**	220
141	Green urban areas	0.26	b)	0.59	**180**	180
142	Sport and leisure facilities	0.26	b)	0.59	**180**	260
Agricultural areas						
21	Arable land	0.60	a)	1.40	**420**	100
211	Arable land, non-irrigated	0.60	a)	1.40	**420**	100
211a	Arable land, non-irrigated, conventional	0.60	i)	1.40	**420**	110
211b	Arable land, non-irrigated, IP	0.60	i)	1.40	**420**	130
211c	Arable land, non-irrigated, organic	0.21	j)	0.49	**150**	59
211d	Arable land, non-irrigated, fibre/energy crops	0.60	i)	1.40	**420**	110
211e	Arable land, non-irrigated, fallow	0.21	j)	0.49	**150**	-40
211f	Arable land, non-irrigated, artificial meadow	0.42	a)	0.95	**290**	97
22	Permanent crops	0.42	a)	0.95	**290**	29
221	Permanent crops, vineyard	0.42	a)	0.95	**290**	29
221a	Permanent crops, vineyard, intensive	0.42	a)	0.95	**290**	29
221b	Permanent crops, vineyard, non-intensive	0.15	b)	0.34	**100**	29

CORINE+	Land use	BDP		Charact. factor (m²a SA-eq./m²a)	Eco-factor 2013 (UBP/m²a)	Eco-factor 2006 (UBP/m²a)
222	Permanent crops, fruit trees and berry plantations	0.42	a)	0.95	**290**	13
222a	Permanent crops, orchards, conventional	0.42	a)	0.95	**290**	97
222b	Permanent crops, orchards, organic	0.15	b)	0.34	**100**	-12
231	Pastures and meadows	0.33	a)	0.75	**230**	57
231a	Pastures and meadows, intensive	0.33	a)	0.75	**230**	84
231b	Pastures and meadows, less intensive	0.12	k)	0.27	**81**	0
231c	Pastures and meadows, organic	0.12	k)	0.27	**81**	-48
243a	Heterogeneous agricultural lands	0.39	q)	0.89	**270**	110
245	Agricultural fallow with hedgerows	0.12	k)	0.27	**81**	-48
244	Agroforestry lands	0.20	a)	0.45	**140**	-
Forests and shrub						
311	Forest, broad-leafed	0.04	l)	0.10	**30**	15
311a	Forest, broad-leafed, plantations	0.18	m)	0.41	**120**	100
311b	Forest, broad-leafed, semi-natural	0.00	l)	0.00	**0**	-8.1
312	Forest, coniferous	0.04	l)	0.10	**30**	15
312a	Forest, coniferous, plantations	0.18	a)	0.41	**120**	100
312b	Forest, coniferous, semi-natural	0.00	l)	0.00	**0**	-8.1
313	Forest, mixed	0.04	l)	0.10	**30**	-8.1
313a	Forest, mixed broad-leafed/coniferous	0.04	l)	0.10	**30**	-8.1
313b	Forest, mixed coniferous/broad-leafed	0.04	l)	0.10	**30**	-8.1
313c	Forest, mixed, plantations	0.18	m)	0.41	**120**	100
314	Forest, forest edge	0.00	l)	0.00	**0**	-44
321	Schrub and/or herbaceous vegetation, grassland, semi-natural	0.00	a)	0.00	**0**	-35
322	Schrub and/or herbaceous vegetation, moors and heathland	0.00	a)	0.00	**0**	12
323	Schrub and/or herbaceous vegetation, sclerophyllous vegetation	0.18	n)	0.41	**120**	-12
324	Schrub and/or herbaceous vegetation, transitional woodland/shrub	0.18	a)	0.41	**120**	-12
325	Schrub and/or herbaceous vegetation, hedgerows	0.15	o)	0.34	**100**	-40
Other uses						
-	Unknown use	0.17	p)	0.38	**110**	160

SA: Settlement area

a) Derived using the classification given in de Baan et al. (2012); "high intensity", supplementary information Table 1 and Table 6

b) Derived using the classification given in de Baan et al. (2012); "low intensity", supplementary information Table 1 and Table 6; ratio of EDPs for "low intensity" to "high intensity" in accordance with Köllner et al. (2007b)

c) Equated with factor for CORINE 321

d) Equated with factor for CORINE 112

e) Equated with factor for CORINE 121

f) Equated with factor for CORINE 313

g) Equated with factor for CORINE 132

h) Equated with factor for CORINE 141 and CORINE 142

i) Equated with factor for CORINE 211

j) Derived using the ratio of EDPs for "agricultural low intensity" to "agricultural high intensity" in accordance with Köllner et al (2007b), whereby CORINE 211 is classified as "high intensity"

k) Derived using the ratio of EDPs "agricultural low intensity" to "agricultural high intensity" in accordance with Köllner et al (2007b), whereby CORINE 231 is classified as "high intensity"

l) Derived in accordance with the description in Section 13.3.4

m) Equated with factor for CORINE 312a

n) Equated with factor for CORINE 324

o) Equated with factor for CORINE 222b

p) Derived using the weighted average of the land use

q) Derived using the mean from CORINE 21, 22, 231 and 211e

Tab. 121 > Eco-factors in 2013 for land use in biomes 1–7

CORINE+	Land use	Biome 1 UBP/m^{2}a	Biome 2 UBP/m^{2}a	Biome 3 UBP/m^{2}a	Biome 4 UBP/m^{2}a	Biome 5 UBP/m^{2}a	Biome 6 UBP/m^{2}a	Biome 7 UBP/m^{2}a
		Tropical and subtropical moist broadleaf forests	Tropical and subtropical dry broadleaf forests	Tropical and subtropical coniferous forests	Temperate broadleaf and mixed forests	Temperate coniferous forests	Boreal forests/ taiga	Tropical and subtropical grasslands, savannas and shrublands
Settlment areas								
111	Urban fabric, continuous >80% sealed	600	290	480	330	300	300	110
112	Urban fabric, discontinuous <80% sealed	360	170	280	190	180	180	63
113	Urban fallow	0	0	0	0	0	0	0
114	Rural settlement	360	170	280	190	180	180	63
121	Industrial or commercial units	600	290	480	330	300	300	110
121a	Industria area, built up part >80% sealed	600	290	480	330	300	300	110
121b	Industrial area, part with vegetation <80% sealed	360	170	280	190	180	180	63
122	Road and rail networks and associated land	600	290	480	330	300	300	110
122a	Road networks	600	290	480	330	300	300	110
122b	Road embankments and associated land (min. 100m width)	360	170	280	190	180	180	63
122c	Rail networks	600	290	480	330	300	300	110
122d	Rail embarkments and associated land (min. 100m width)	360	170	280	190	180	180	63
122e	Rail fallow	60	29	48	33	30	30	11
124	Airports	360	170	280	190	180	180	63
125	Industrial fallow	0	0	0	0	0	0	0
131	Mineral extraction sites	600	290	480	330	300	300	110
132	Dump sites	600	290	480	330	300	300	110
133	Construction sites	600	290	480	330	300	300	110
134	Mining fallow	0	0	0	0	0	0	0
14	Artificial, non-agricultural areas with vegetation	360	170	280	190	180	180	63
141	Green urban areas	360	170	280	190	180	180	63
142	Sport and leisure facilities	360	170	280	190	180	180	63
Agricultural areas								
211	Arable land, non-irrigated	810	390	660	420	420	420	140
211b	Arable land, non-irrigated, conventionel	810	390	660	420	420	420	140
211a	Arable land, non-irrigated, IP	810	390	660	420	420	420	140
211c	Arable land, non-irrigated, organic	290	140	230	150	150	150	51
211d	Arable land, non-irrigated, fibre/energy crops	810	390	660	420	420	420	140
211e	Arable land, non-irrigated, fallow	290	140	230	150	150	150	51
211f	Arable land, non-irrigated, artificial meadow	570	280	450	300	290	290	99
22	Permanent crops	570	280	450	300	290	290	99
221	Permanent crops, vineyard	570	280	450	300	290	290	99
221a	Permanent crops, vineyard, intensive	570	280	450	300	290	290	99
221b	Permanent crops, vineyard, non-intensive	200	99	170	110	100	100	36
222	Permanent crops, fruit trees and berry plantations	570	280	450	300	290	290	99
222a	Permanent crops, orchards, conventional	570	280	450	300	290	290	99

CORINE+	Land use	Biome 1 UBP/m²a	Biome 2 UBP/m²a	Biome 3 UBP/m²a	Biome 4 UBP/m²a	Biome 5 UBP/m²a	Biome 6 UBP/m²a	Biome 7 UBP/m²a
		Tropical and subtropical moist broadleaf forests	Tropical and subtropical dry broadleaf forests	Tropical and subtropical coniferous forests	Temperate broadleaf and mixed forests	Temperate coniferous forests	Boreal forests/ taiga	Tropical and subtropical grasslands, savannas and shrublands
222b	Permanent crops, orchards, organic	200	99	170	110	100	100	36
231	Pastures and meadows	450	220	360	240	230	230	78
231a	Pastures and meadows, intensive	450	220	360	240	230	230	78
231b	Pastures and meadows, less intensive	160	78	130	84	81	81	28
231c	Pastures and meadows, organic	160	78	130	84	81	81	28
243a	Heterogeneous agricultural lands	530	260	430	280	270	270	92
245	Agricultural fallow with hedgerows	160	78	130	84	81	81	28
244	Agroforestry areas	270	130	220	140	140	140	48
Forest and shrubs								
311	Forest, broad-leafed	60	29	48	33	30	30	11
311a	Forest, broad-leafed, plantations	240	120	200	130	120	120	42
311b	Forest, broad-leafed, semi-natural	0	0	0	0	0	0	0
312	Forest, coniferous	60	29	48	33	30	30	11
312a	Forest, coniferous, plantations	240	120	200	130	120	120	42
312b	Forest, coniferous, semi-natural	0	0	0	0	0	0	0
313	Forest, mixed	60	29	48	33	30	30	11
313a	Forest, mixed broad-leafed/coniferous	60	29	48	33	30	30	11
313b	Forest, mixed coniferous/broad-leafed	60	29	48	33	30	30	11
313c	Forest, mixed, plantations	240	120	200	130	120	120	42
314	Forest, forest edge	0	0	0	0	0	0	0
321	Schrub and/or herbaceous vegetation, grassland, semi-natural	0	0	0	0	0	0	0
322	Schrub and/or herbaceous vegetation, moors and heathland	0	0	0	0	0	0	0
323	Schrub and/or herbaceous vegetation, sclerophyllous vegetation	240	120	200	130	120	120	42
324	Schrub and/or herbaceous vegetation, transitional woodland/shrub	240	120	200	130	120	120	42
325	Schrub and/or herbaceous vegetation, hedgerows	200	99	170	110	100	100	36
Other uses								
-	Uknown use	230	110	190	120	110	110	39

Tab. 122 > Eco-factors in 2013 for land use in biomes 8–14

CORINE+	Land use	Biome 8 UBP/m^{2}a	Biome 9 UBP/m^{2}a	Biome 10 UBP/m^{2}a	Biome 11 UBP/m^{2}a	Biome 12 UBP/m^{2}a	Biome 13 UBP/m^{2}a	Biome 14 UBP/m^{2}a
		Temperate grasslands, savannas and shrublands	Flooded grasslands and savannas	Montane grasslands and shrublands	Tundra	Mediterranean forests, woodlands and scrub	Deserts and xeric shrublands	Mangroves
Settlement areas								
111	Urban fabric, continuous >80% sealed	240	210	170	250	63	420	160
112	Urban fabric, discontinuous <80% sealed	140	120	96	150	36	250	93
113	Urban fallow	0	0	0	0	0	0	0
114	Rural settlement	140	120	96	150	36	250	93
121	Industrial or commercial units	240	210	170	250	63	420	160
121a	Industria area, built up part >80% sealed	240	210	170	250	63	420	160
121b	Industrial area, part with vegetation <80% sealed	140	120	96	150	36	250	93
122	Road and rail networks and associated land	240	210	170	250	63	420	160
122a	Road networks	240	210	170	250	63	420	160
122b	Road embankments and associated land (min. 100m width)	140	120	96	150	36	250	93
122c	Rail networks	240	210	170	250	63	420	160
122d	Rail embarkments and associated land (min. 100m width)	140	120	96	150	36	250	93
122e	Rail fallow	24	21	17	26	6.3	45	16
124	Airports	140	120	96	150	36	250	93
125	Industrial fallow	0	0	0	0	0	0	0
131	Mineral extraction sites	240	210	170	250	63	420	160
132	Dump sites	240	210	170	250	63	420	160
133	Construction sites	240	210	170	250	63	420	160
134	Mining fallow	0	0	0	0	0	0	0
14	Artificial, non-agricultural areas with vegetation	140	120	96	150	36	250	93
141	Green urban areas	140	120	96	150	36	250	93
142	Sport and leisure facilities	140	120	96	150	36	250	93
Agricultural areas								
211	Arable land, non-irrigated	330	290	230	330	87	600	220
211b	Arable land, non-irrigated, conventionel	330	290	230	330	87	600	220
211a	Arable land, non-irrigated, IP	330	290	230	330	87	600	220
211c	Arable land, non-irrigated, organic	110	100	81	120	30	210	78
211d	Arable land, non-irrigated, fibre/energy crops	330	290	230	330	87	600	220
211e	Arable land, non-irrigated, fallow	110	100	81	120	30	210	78
211f	Arable land, non-irrigated, artificial meadow	230	200	160	240	60	420	150
22	Permanent crops	230	200	160	240	60	420	150

CORINE+	Land use	Biome 8 UBP/m^{2}a	Biome 9 UBP/m^{2}a	Biome 10 UBP/m^{2}a	Biome 11 UBP/m^{2}a	Biome 12 UBP/m^{2}a	Biome 13 UBP/m^{2}a	Biome 14 UBP/m^{2}a
		Temperate grasslands, savannas and shrublands	Flooded grasslands and savannas	Montane grasslands and shrublands	Tundra	Mediterranean forests, woodlands and scrub	Deserts and xeric shrublands	Mangroves
221	Permanent crops, vineyard	230	200	160	240	60	420	150
221a	Permanent crops, vineyard, intensive	230	200	160	240	60	420	150
221b	Permanent crops, vineyard, non-intensive	81	72	57	84	21	150	54
222	Permanent crops, fruit trees and berry plantations	230	200	160	240	60	420	150
222a	Permanent crops, orchards, conventional	230	200	160	240	60	420	150
222b	Permanent crops, orchards, organic	81	72	57	84	21	150	54
231	Pastures and meadows	180	160	120	190	48	330	120
231a	Pastures and meadows, intensive	180	160	120	190	48	330	120
231b	Pastures and meadows, less intensive	63	57	45	66	17	110	42
231c	Pastures and meadows, organic	63	57	45	66	17	110	42
243a	Heterogeneous agricultural lands	210	190	150	220	56	390	140
245	Agricultural fallow with hedgerows	63	57	45	66	17	110	42
244	Agroforestry areas	110	96	75	110	29	200	72
Forest and shrub								
311	Forest, broad-leafed	24	21	17	26	6.3	45	16
311a	Forest, broad-leafed, plantations	96	87	66	100	26	180	63
311b	Forest, broad-leafed, semi-natural	0	0	0	0	0	0	0
312	Forest, coniferous	24	21	17	26	6.3	45	16
312a	Forest, coniferous, plantations	96	87	66	100	26	180	63
312b	Forest, coniferous, semi-natural	0	0	0	0	0	0	0
313	Forest, mixed	24	21	17	26	6.3	45	16
313a	Forest, mixed broad-leafed/coniferous	24	21	17	26	6.3	45	16
313b	Forest, mixed coniferous/broad-leafed	24	21	17	26	6.3	45	16
313c	Forest, mixed, plantations	96	87	66	100	26	180	63
314	Forest, forest edge	0	0	0	0	0	0	0
321	Schrub and/or herbaceous vegetation, grassland, semi-natural	0	0	0	0	0	0	0
322	Schrub and/or herbaceous vegetation, moors and heathland	0	0	0	0	0	0	0
323	Schrub and/or herbaceous vegetation, sclerophyllous vegetation	96	87	66	100	26	180	63
324	Schrub and/or herbaceous vegetation, transitional woodland/shrub	96	87	66	100	26	180	63
325	Schrub and/or herbaceous vegetation, hedgerows	81	72	57	84	21	150	54
Other uses								
-	Unknown use	90	81	63	96	24	170	60

A7 Eco-factors for primary mineral resources (minerals and metals

In the current version of the eco-factors, resource extraction, and not dissipative use, is assessed. In case studies on the use of important primary resources, it should be ensured that only dissipative use (see Section 13.4.7) is assessed.

Tab. 123 > Characterization and eco-factors for dissipative use of primary mineral resources (minerals and metals)

	Characterization (kg Sb-eq./kg)	Eco-factor 2013 (UBP/g)
Tantalum, 81.9% in tantalite, 1.6E-4% in crude ore, in ground	1.3	**1 500**
Nickel, 1.98% in silicates, 1.04% in crude ore, in ground	0.0064	**7.1**
Iron, 46% in ore, 25% in crude ore, in ground	0.0000076	**0.0084**
Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground	0.0010	**1.1**
Silver, 3.2ppm in sulfide, Ag 1.2ppm, Cu and Te, in crude ore, in ground	2.0	**2 300**
Gold, Au 4.9E-5%, in ore, in ground	23	**26 000**
Tin, 79% in cassiterite, 0.1% in crude ore, in ground	0.23	**260**
Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground	0.0010	**1.1**
TiO2, 54% in ilmenite, 2.6% in crude ore, in ground	0.00032	**0.35**
Gold, Au 2.1E-4%, Ag 2.1E-4%, in ore, in ground	23	**26 000**
Gold, Au 1.4E-4%, in ore, in ground	23	**26 000**
Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	4.3	**4 800**
Aluminium, 24% in bauxite, 11% in crude ore, in ground	0.000027	**0.03**
Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	0.0010	**1.1**
Gold, Au 1.3E-4%, Ag 4.6E-5%, in ore, in ground	23	**26 000**
Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground	0.0010	**1.1**
Silver, Ag 4.6E-5%, Au 1.3E-4%, in ore, in ground	2.0	**2 300**
Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In, in ground	2.0	**2 300**
Chromium, 25.5% in chromite, 11.6% in crude ore, in ground	0.0043	**4.8**
Silver, Ag 4.2E-3%, Au 1.1E-4%, in ore, in ground	2.0	**2 300**
Gold, Au 1.1E-4%, Ag 4.2E-3%, in ore, in ground	23	**26 000**
Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground	0.058	**65**
Gold, Au 7.1E-4%, in ore, in ground	23	**26 000**
Gold, Au 6.7E-4%, in ore, in ground	23	**26 000**
Zinc, 9.0% in sulfide, Zn 5.3%, Pb, Ag, Cd, In, in ground	0.0046	**5.1**
Pt, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	4.0	**4 500**
Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground	0.058	**65**
Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	0.00079	**0.87**
Silver, Ag 2.1E-4%, Au 2.1E-4%, in ore, in ground	2.0	**2 300**
Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground	0.058	**65**
Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	0.0064	**7.1**
Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground	0.058	**65**
Gold, Au 4.3E-4%, in ore, in ground	23	**26 000**
Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground	0.058	**65**
Silver, Ag 9.7E-4%, Au 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground	2.0	**2 300**
Lead, 5.0% in sulfide, Pb 3.0%, Zn, Ag, Cd, In, in ground	0.015	**17**

	Characterization (kg Sb-eq./kg)	Eco-factor 2013 (UBP/g)
Cobalt, in ground	0.040	**44**
Pt, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	4.0	**4 500**
Tellurium, 0.5ppm in sulfide, Te 0.2ppm, Cu and Ag, in crude ore, in ground	6.2	**6 900**
Pd, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	4.3	**4 800**
Gold, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore, in ground	23	**26 000**
Indium, 0.005% in sulfide, In 0.003%, Pb, Zn, Ag, Cd, in ground	114	**130 000**
Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	2.9	**3 200**
Zirconium, 50% in zircon, 0.39% in crude ore, in ground	0.0091	**10**
TiO2, 95% in rutile, 0.40% in crude ore, in ground	0.00032	**0.35**
Cadmium, 0.30% in sulfide, Cd 0.18%, Pb, Zn, Ag, In, in ground	1.2	**1 300**
Rh, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	2.9	**3 200**
Europium, 0.06% in bastnasite, 0.006% in crude ore, in ground	0.34	**380**
Gadolinium, 0.15% in bastnasite, 0.015% in crude ore, in ground	0.34	**380**
Cerium, 24% in bastnasite, 2.4% in crude ore, in ground	0.00017	**0.18**
Praseodymium, 0.42% in bastnasite, 0.042% in crude ore, in ground	0.0022	**2.5**
Lanthanum, 7.2% in bastnasite, 0.72% in crude ore, in ground	0.00016	**0.17**
Samarium, 0.3% in bastnasite, 0.03% in crude ore, in ground	0.035	**39**
Neodymium, 4% in bastnasite, 0.4% in crude ore, in ground	0.00086	**0.95**
Rhenium, in crude ore, in ground	184	**200 000**
Gallium, 0.014% in bauxite, in ground	25	**28 000**
Fluorine, 4.5% in apatite, 3% in crude ore, in ground	0.0024	**2.7**
Phosphorus, 18% in apatite, 12% in crude ore, in ground	0.000056	**0.062**
Sodium chloride, in ground	0.000000089	**0.000098**
Barite, 15% in crude ore, in ground	0.0029	**3.2**
Fluorine, 4.5% in apatite, 1% in crude ore, in ground	0.0024	**2.7**
Phosphorus, 18% in apatite, 4% in crude ore, in ground	0.000056	**0.062**
Magnesite, 60% in crude ore, in ground	0.000023	**0.026**
Sulfur, in ground	0.000065	**0.072**
Kieserite, 25% in crude ore, in ground	0.000023	**0.026**
Fluorspar, 92%, in ground	0.0024	**2.7**
Gypsum, in ground	0.0000057	**0.0063**
Sodium sulphate, various forms, in ground	0.000013	**0.015**
Talc, in ground	0.00058	**0.64**
Cinnabar, in ground	9.03	**10 000**
Diatomite, in ground	0.00034	**0.37**
Stibnite, in ground	0.72	**790**
Helium, 0.08% in natural gas, in ground	0.36	**390**
Colemanite, in ground	0.0061	**6.8**
Lithium, 0.15% in brine, in ground	0.0036	**4**
Ulexite, in ground	0.0061	**6.8**

A8 Country-specific eco-factors for freshwater consumption

The country-specific eco-factors for OECD and non-OECD countries listed in the following tables are only to be used for specific or sufficiently detailed life cycle inventories. Normally, the classification in scarcity categories as set out in Section 13.6.5 should be applied.

Tab. 124 > Eco-factors for freshwater consumption in the OECD countries

	Scarcity ratio	Normalization (km^3/a)	Current flow (km^3/a)	Critical flow (km^3/a)	Weighting (-)	Eco-factor 2013 (UBP/m^3)
Australia	0.046	2.614	22.6	98.4	0.0527	**20.1**
Austria	0.047	2.614	3.66	15.5	0.0554	**21.2**
Belgium	0.34	2.614	6.22	3.66	2.88	**1 100**
Canada	0.016	2.614	46	580	0.00627	**2.4**
Chile	0.012	2.614	11.3	184	0.00378	**1.45**
Czech Republic	0.13	2.614	1.7	2.63	0.417	**160**
Denmark	0.11	2.614	0.66	1.2	0.303	**116**
Estonia	0.14	2.614	1.8	2.56	0.491	**188**
Finland	0.015	2.614	1.63	22	0.00552	**2.11**
France	0.15	2.614	31.6	42.2	0.561	**215**
Germany	0.21	2.614	32.3	30.8	1.1	**421**
Greece	0.13	2.614	9.47	14.9	0.407	**156**
Hungary	0.054	2.614	5.59	20.8	0.0722	**27.6**
Iceland	0.00097	2.614	0.165	34	0.0000236	**0.01**
Iceland	0.015	2.614	0.79	10.4	0.00577	**2.21**
Israel	1.1	2.614	1.95	0.356	30.1	**11 500**
Italy	0.24	2.614	45.4	38.3	1.41	**539**
Japan	0.21	2.614	90	86	1.1	**419**
Korea	0.37	2.614	25.5	13.9	3.34	**1 280**
Luxemburg	0.019	2.614	0.0602	0.62	0.00943	**3.61**
Mexico	0.17	2.614	79.8	91.4	0.762	**291**
Netherlands	0.12	2.614	10.6	18.2	0.34	**130**
New Zeeland	0.015	2.614	4.75	65.4	0.00528	**2.02**
Norway	0.0077	2.614	2.94	76.4	0.00148	**0.57**
Poland	0.19	2.614	12	12.3	0.942	**361**
Portugal	0.11	2.614	8.46	15.5	0.299	**114**
Slovakia	0.014	2.614	0.688	10	0.00471	**1.8**
Slovenia	0.03	2.614	0.942	6.37	0.0218	**8.36**
Spain	0.29	2.614	32.5	22.3	2.12	**811**
Sweden	0.015	2.614	2.62	34.8	0.00565	**2.16**
Switzerland	0.049	2.614	2.61	10.7	0.0597	**22.8**
Turkey	0.17	2.614	40.1	46.3	0.749	**286**
UK (Great Britain and Northern Ireland)	0.088	2.614	13	29.4	0.195	**74.7**
USA	0.16	2.614	478	614	0.607	**232**
OECD (weighted mean)	-	-	-	-	-	**318**

Source: FAO 2011

Tab. 125 > Eco-factors for freshwater consumption in non-OECD countries

	Scarcity ratio	Normalization (km³/a)	Current flow (km³/a)	Criticial flow (km³/a)	Weighting (-)	Eco-factor 2013 (UBP/m³)
Afghanistan	1.8	2.614	23.1	13	3.163	**1 200**
Albania	0.22	2.614	1.8	8.34	0.049	**19**
Algeria	2.6	2.614	6.2	2.334	6.968	**2 700**
Angola	0.022	2.614	0.6	29.6	0.000	**0.18**
Argentina	0.2	2.614	32.6	162.8	0.040	**15**
Armenia	1.8	2.614	2.8	1.5538	3.310	**1 300**
Azerbaijan	1.8	2.614	12.2	6.936	3.099	**1 200**
Bahrain	15	2.614	0.4	0.0232	237.319	**91 000**
Bangladesh	0.15	2.614	35.9	245.4	0.021	**8.2**
Barbados	3.8	2.614	0.1	0.016	14.488	**5 500**
Belarus	0.37	2.614	4.3	11.6	0.140	**54**
Belize	0.04	2.614	0.2	3.71	0.002	**0.63**
Benin	0.025	2.614	0.1	5.278	0.001	**0.23**
Bhutan	0.022	2.614	0.3	15.6	0.000	**0.18**
Bolivia	0.016	2.614	2.0	124.5	0.000	**0.1**
Botswana	0.079	2.614	0.2	2.448	0.006	**2.4**
Brazil	0.035	2.614	58.1	1 646.6	0.001	**0.48**
Bulgaria	1.4	2.614	6.1	4.26	2.063	**790**
Burkina Faso	0.39	2.614	1.0	2.5	0.155	**59**
Burundi	0.11	2.614	0.3	2.508	0.013	**5**
Cambodia	0.023	2.614	2.2	95.22	0.001	**0.2**
Cameroon	0.017	2.614	1.0	57.1	0.000	**0.11**
Cape Verde	0.37	2.614	0.0	0.06	0.134	**51**
Chad	0.043	2.614	0.4	8.6	0.002	**0.7**
China	0.98	2.614	554.1	568	0.952	**360**
Columbia	0.03	2.614	12.7	426.4	0.001	**0.34**
Congo	0.00028	2.614	0.0460	166.4	0.000	**0.000029**
Costa Rica	0.12	2.614	2.7	22.48	0.014	**5.4**
Croatia	0.03	2.614	0.6	21.1	0.001	**0.34**
Cuba	0.99	2.614	7.6	7.624	0.982	**380**
Cyprus	1.2	2.614	0.2	0.156	1.391	**530**
Djibouti	0.32	2.614	0.0	0.0600	0.100	**38**
Dominican Republic	0.83	2.614	3.5	4.2	0.689	**260**
Egypt	4	2.614	68.3	17.16	15.842	**6 100**
El Salvador	0.27	2.614	1.4	5.046	0.074	**28**
Equador	0.18	2.614	15.3	86.4	0.031	**12**
Equatorial Guinea	0.0033	2.614	0.0	5.2	0.000	**0.0043**
Eritrea	0.46	2.614	0.6	1.26	0.213	**82**
Ethiopia	0.23	2.614	5.6	24.4	0.052	**20**
Fiji	0.014	2.614	0.1	5.71	0.000	**0.078**
Gambia	0.045	2.614	0.1	1.6	0.002	**0.76**
Georgia	0.12	2.614	1.6	13.296	0.015	**5.7**

	Scarcity ratio	Normalization (km³/a)	Current flow (km³/a)	Criticial flow (km³/a)	Weighting (-)	Eco-factor 2013 (UBP/m³)
Ghana	0.092	2.614	1.0	10.64	0.009	**3.3**
Guatemala	0.13	2.614	2.9	22.26	0.017	**6.6**
Guinea	0.036	2.614	1.6	45.2	0.001	**0.49**
Guinea-Bissau	0.028	2.614	0.2	6.2	0.001	**0.3**
Guyana	0.034	2.614	1.6	48.2	0.001	**0.44**
Haiti	0.43	2.614	1.2	2.806	0.183	**70**
Honduras	0.062	2.614	1.2	19.186	0.004	**1.5**
India	1.8	2.614	761.0	416.2	3.343	**1 300**
Indonesia	0.28	2.614	113.3	403.8	0.079	**30**
Iraq	3.4	2.614	66.0	19.322	11.668	**4 500**
Iran	3.4	2.614	93.3	27.5	11.511	**4 400**
Ivory Coast	0.087	2.614	1.4	16.228	0.008	**2.9**
Jamaica	0.31	2.614	0.6	1.8808	0.097	**37**
Jordan	2.9	2.614	0.9	0.3244	8.413	**3 200**
Kazakhstan	1.5	2.614	33.1	21.92	2.273	**870**
Kenya	0.45	2.614	2.7	6.14	0.198	**76**
Kyrgyzstan	1	2.614	10.1	9.79	1.060	**410**
Kuwait	230	2.614	0.9	0.004	52 120.890	**20 000 000**
Laos	0.064	2.614	4.3	66.7	0.004	**1.6**
Lesotho	0.048	2.614	0.1	1.046	0.002	**0.87**
Latvia	0.058	2.614	0.4	7.09	0.003	**1.3**
Lebanon	1.4	2.614	1.3	0.9676	1.833	**700**
Liberia	0.0038	2.614	0.2	46.4	0.000	**0.0057**
Libya	36	2.614	4.3	0.12	1 299.603	**500 000**
Lithuania	0.48	2.614	2.4	4.98	0.228	**87**
Madagascar	0.22	2.614	14.7	67.4	0.047	**18**
Malawi	0.28	2.614	1.0	3.456	0.079	**30**
Malaysia	0.11	2.614	13.2	116	0.013	**5**
Mali	0.33	2.614	6.5	20	0.107	**41**
Malta	5.3	2.614	0.1	0.0101	28.480	**11 000**
Mauritania	0.7	2.614	1.6	2.28	0.493	**190**
Mauritius	1.3	2.614	0.7	0.5502	1.736	**660**
Moldavia	0.82	2.614	1.9	2.33	0.676	**260**
Mongolia	0.073	2.614	0.5	6.96	0.005	**2.1**
Morocco	2.2	2.614	12.6	5.8	4.719	**1 800**
Mozambique	0.017	2.614	0.7	43.42	0.000	**0.11**
Myanmar	0.14	2.614	33.2	233.6	0.020	**7.7**
Namibia	0.033	2.614	0.3	9.092	0.001	**0.42**
Nepal	0.23	2.614	9.8	42.04	0.054	**21**
Nicaragua	0.033	2.614	1.3	39.32	0.001	**0.41**
Niger	0.35	2.614	2.4	6.73	0.123	**47**
Nigeria	0.18	2.614	10.3	57.24	0.032	**12**
Oman	4.7	2.614	1.3	0.28	22.258	**8 500**
Pakistan	3	2.614	183.5	60.82	9.103	**3 500**

	Scarcity ratio	Normalization (km³/a)	Current flow (km³/a)	Criticial flow (km³/a)	Weighting (-)	Eco-factor 2013 (UBP/m³)
Panama	0.015	2.614	0.5	29.6	0.000	**0.089**
Paraguay	0.0073	2.614	0.5	67.2	0.000	**0.02**
Peru	0.051	2.614	19.3	382.6	0.003	**0.98**
Philippines	0.85	2.614	81.6	95.8	0.725	**280**
Puerto Rico	0.7	2.614	1.0	1.42	0.491	**190**
Qatar	38	2.614	0.4	0.0116	1 465.042	**560 000**
Romania	0.16	2.614	6.9	42.38	0.026	**10**
Russia	0.073	2.614	66.2	901.6	0.005	**2.1**
Rwanda	0.079	2.614	0.2	1.9	0.006	**2.4**
Saudi Arabia	49	2.614	23.7	0.48	2 431.723	**930 000**
Senegal	0.29	2.614	2.2	7.76	0.082	**31**
Sierra Leone	0.015	2.614	0.5	32	0.000	**0.091**
Somalia	1.1	2.614	3.3	2.94	1.258	**480**
Sri Lanka	1.2	2.614	13.0	10.56	1.504	**580**
South Africa	1.3	2.614	12.5	10	1.563	**600**
Sudan	1.2	2.614	37.1	29.8	1.553	**590**
Suriname	0.027	2.614	0.7	24.4	0.001	**0.29**
Swaziland	1.2	2.614	1.0	0.902	1.335	**510**
Syria	1.5	2.614	16.8	11.156	2.257	**860**
Tajikistan	0.6	2.614	12.0	19.946	0.360	**140**
Tanzania	0.27	2.614	5.2	19.254	0.072	**28**
Thailand	0.65	2.614	57.3	87.72	0.427	**160**
The Comoros	0.042	2.614	0.0	0.24	0.002	**0.66**
Togo	0.057	2.614	0.2	2.94	0.003	**1.3**
Trinidad and Tobago	0.3	2.614	0.2	0.768	0.091	**35**
Tunisia	3.1	2.614	2.9	0.919	9.617	**3 700**
Turkmenistan	2	2.614	24.9	12.172	4.188	**1 600**
Uganda	0.025	2.614	0.3	13.2	0.001	**0.24**
Ukraine	1.4	2.614	38.5	27.92	1.900	**730**
United Arab Emirates	130	2.614	4.0	0.03	17 760.004	**6 800 000**
Uruguay	0.13	2.614	3.7	27.8	0.017	**6.6**
Uzbekistan	4.1	2.614	59.6	14.442	17.037	**6 500**
Venezuela	0.037	2.614	9.1	246.6	0.001	**0.52**
Vietnam	0.46	2.614	82.0	176.82	0.215	**82**
Yemen	8.5	2.614	3.6	0.42	72.048	**28 000**
Zambia	0.083	2.614	1.7	21.04	0.007	**2.6**
Zimbabwe	1.1	2.614	4.2	4	1.105	**420**

Quelle: FAO 2011

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> Abbreviations, figures and tables

Abbreviations

a
Annum, year

ADP
Abiotic Depletion Potential

AOX
Adsorbable organic halogen compounds (aggregate parameter expressing the quantity of halogenated substances in bodies of water and in sewage sludge)

AP
Acidification Potential

ATW
Alpha-toxic waste

BaP
Benzo(a)pyrene

BCF
Bioconcentration factor

BDP
Biodiversity Damage Potential

BRIC countries
Brazil, Russia, India and China

CFCs
Chlorofluorocarbons

COD
Chemical oxygen demand (measure of the quantity of oxygen needed to oxidate organic compounds in bodies of water)

CTU
Comparative toxic unit, i.e. toxic to humans

DOC
Dissolved organic carbon (measure of the content of organically bound carbon from dissolved organic compounds)

Ecological scarcity
is determined as a function of the limited carrying capacity of the environment in relation to anthropogenic impacts (critical flow) and of the effective extent of these impacts (current flow) upon the environment. The greater the ratio of the current flow to the critical flow, the greater the ecological scarcity.

UBP
Eco-point (unit for the ecological scarcity assessment method)

EDP
Ecosystem Damage Potential

eq.
equivalent

F
Current flow (emission load in an area during a year)

F_k
Critical flow (critical emission load in an area during a year)

F_n
Normalization flow (emission load of Switzerland, as characterized quantity, where required)

Feedstock
Energy resource not used to produce energy

GSchV
Waters Protection Ordinance

GWP_{100}
Global warming potential of a substance relative to CO_2; in this report, all data relate to a time horizon of 100 years and are based on the latest IPCC figures (IPCC 2007)

HAP
Highly annoyed person (by noise)

HCFCs
Partially halogenated CFCs

HLW
High-level waste

IAWR
Internationale Arbeitsgemeinschaft der Wasserwerke im Rheineinzugsgebiet (interntional association of waterworks in the Rhine catchment area)

Inventory
Analysis of material and energy flows, or outcome of such an analysis

ISO
International Organisation for Standardization (Geneva/CH)

km
kilometre

LMLW
Low-level and medium-level wastes

MAHs
Monocyclic aromatic hydrocarbons MJ
Megajoule (10^6 joules)

MJ_e
Megajoule electric (in the form of electric energy)

MJ_t
Megajoule thermal (in the form of thermal energy)

NMVOCs
Non-methane volatile organic compounds (excluding methane, excluding CFCs), see also VOCs

OAPEC countries
Organization of Arab Petroleum Exporting Countries

ODP
Ozone Depletion Potential (measure of the ozone-depleting effect of a substance relative to R11)

OECD
Organisation for Economic Co-Operation and Development

PAHs
Polycyclic aromatic hydrocarbon compounds

PFCs
Perfluorocarbons

PFOS
Perfluorooctane sulfonate

PJ
Petajoule (10^{15} joules)

pkm
person kilometre

POPs
Persistent organic pollutants

PPP
Plant protection product; includes herbicides, plant growth regulators and products and items that protect plants and their propagative material against diseases and pests

PM10
Particle with a diameter of less than 10 micrometres

PM2.5
Particle with a diameter of less than 2.5 micrometres

RTI
Radiotoxicity sindex

Sb
Antimony

SETAC
Society for Environmental Toxicology and Chemistry (Brussels/B)

SA
Settlement area

SF
(Spent) fuel elements

TEQ
Toxicity-equivalent

TJ
Terajoule (10^{12} joules)

tkm
tonne kilometre

TOC
Total organic carbon (carbon bound in organic molecules).

TVA
Technical Ordinance on Waste

VHHs
Volatile halogenated hydrocarbons

vkm
vehicle kilometre

VOCs
Volatile organic compounds; examples of VOCs are listed in the Swiss Air Pollution Control Ordinance of 16 December 1985 in Art. 72 (table of organic substances in gaseous, vapour or particle form)

Figures

Tables