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Ecological Scarcity Japan

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Summary “Ecological Scarcity Japan”

Recent discussions and debates of biomass utilization in Japan necessitate conducting life cycle assessment (LCA). However, there are no impact assessment methods suitable for the assessment of agricultural production and biomass utilization in Japan from a comprehensive perspective.

In 2004 eco-factors for Japan (JEPIX, Miyazaki et al. 2004) were calculated based on the former version of Swiss ecological scarcity 1998 (Brand et al. 1998). Unfortunately, the adapted version did not take into account, for example, ammonium and nitrate emissions, which are crucial in assessing agricultural production and biomass utilization. Recently a new version of ecological scarcity (Frischknecht et al. 2009) was published. The aims of this report are to complete and update the existing Japanese eco-factors according to the new version of the Swiss ecological scarcity method.

The following Table 1 lists the eco-factors according to the Japanese situation. The Annexe presents the factors for further substances determined by characterization. The “normalization flow” column states today’s emission situation. The “current flow” column presents the reference quantity, which in most cases is identical to the normalization 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.

Table 1: Overview of Japanese eco-factors

	Normalization flow		Current flow	Critical flow		Ecofactor	EP per
Emissions to air							
CO_2	1'374'300'000	t CO_2-eq	1'374'300'000	274'860'000	t CO_2-eq	0.018	g CO_2-eq
Ozone-depleting substances	3'746	t CFC-11-eq	3'746	2'624	t CFC-11-eq	540	g CFC-11-eq
NMVOC	869'771	t ethylene-eq	1'638'000	1'260'335	t NMVOC	1.9	g ethylene-eq
NO_x	1'920'000	t	1'920'000	1'659'113	t	0.7	g
Ammonia	522'525	t	522’525	1‘682’747	t	0.18	g
SO_2	780'000	t SO_2-eq	780’000	1‘282’312	t SO_2-eq	0.21	g SO_2-eq
PM	192'025	t	192'025	119'354	t	13	g
Benzene	12'744	t	12'744	18'924	t	36	g
Dioxins and Furans	304	g	304	329	g	2.80E+09	g
Lead	332'000	t heavy metal	232'500	53'315	t Pb	57	g
Cadmium	332'000	t heavy metal	5'300	3'164	t Cd	8.4	g
Mercury	332'000	t heavy metal	-	-	T Hg	3.3	g
Zinc	332'000	t heavy metal	92'000	47'556	T Zn	11	g
Emissions to surface waters							
BOD	1'350'000	t	1'350'000	1'854'550	t	0.39	g
Nitrogen (as N)	357'905	t	357'905	316'784	t	3.6	g N
Phosphorus (as P)	20'690	t	20'690	18'003	t	64	g P
Arsenic	1'026	t heavy metal	18	47	t As	140	g
Lead	1'026	t heavy metal	15	37	t Pb	170	g
Cadmium	1'026	t heavy metal	2.0	20	t Cd	15	g
Manganese	1'026	t heavy metal	833	103'304	t Mn	0.06	g
Antimony	1'026	t heavy metal	11	20	t Sb	290	g
Mercury	1'026	t heavy metal	0.505	0.504	t Hg	980	g
Molybdenum	1'026	t heavy metal	145	1'255	t Mo	13	g

Radioactive emissions	1'000	GBq C14-eq	0.00042	0.002	mg U/l	43	kBq C14-eq
AOX (as Cl$^-$)	56	t	56	472	t	310	g Cl
Endocrine disruptors	133	kg E2-eq	52	24	kg E2-eq	50000000	g E2-eq
Emissions to groundwater							
Nitrogen (as N)	272'373	t	272'373	270'000	t	0.84	g N
Emissions to soil							
Lead	199'588	t	12	2.7	t	95	g
Cadmium	4'806	t	3.4	2.0	t	580	g
Copper	167'522	t	77	34	t	31	g
Zinc	115'367	t	532	275	t	32	g
Potassium	392'489	t	17	12	t	5.1	g
Plant protection products	773'314	t PPP-eq	63'125	62'378	t	1.3	g PPP-eq
Resources							
Primary energy carriers - fossil	21'277	PJ-oil eq	21'277	14'799	PJ-oil eq	0.1	MJ oil-eq
Primary energy carriers - nuclear	21'277	PJ-oil eq	21'277	14'799	PJ-oil eq	0.030	MJ oil-eq
Primary energy carriers - renewable	21'277	PJ-oil eq	21'277	14'799	PJ-oil eq	0.034	MJ oil-eq
Land use, settlement area	40'495	km^2.a-eq	31'800	31'800	km^2.a	25	m^{2}a-eq
Freshwater Japan	88	km^3	88	86	km^3	12	m^3
Freshwater OECD	88	km^3	1'018	2'043	km^3	2.8	m^3
Gravel and sand	113'151'036	m^3	113'151'036	96'178'380	m^3	0.0080	g
Phosphorous	565'417	t	565'417	480'605	t	2.0	g
Wastes							
Landfilled waste	29'000'000	t	29'000'000	26'000'000	t	0.055	g
Hazardous wastes to underground repositories	158'641	t	158'641	134'845	t	9.0	g
High-level radioactive wastes	3'643	m^3	3'643	2'497	m^3	580	cm^3
Low/medium-level radioactive wastes	20'556	m^3	20'556	20'556	m^3	49	cm^3

*derived from characterization of SO_X

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.

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Abbreviations

AOX	Organic halogens subjected to absorption
BOD	Biological oxygen demand
CFC	Chlorofluorocarbons
COD	Chemical oxygen demand
DOC	Dissolved organic carbon
EP	Eco-point
EQS	Environmental Quality Standard
FY	Fiscal year
GWP	Global warming potential
HCFC	Partially halogenated CFC
HFC	Hydrofluorocarbon
JEPIX	Japan Environmental Policy Priorities Index
LCA	Life Cycle Assessment
LULUCF	Land use, land use change and forestry
NARO	National Agriculture and Food Research Organization
NMVOC	Non Methane Volatile Organic Compound
NO_X	Nitrogen oxide
NO_3-N	Nitrate nitrogen
ODP	Ozone depleting potential
ODS	Ozone depleting substances
PAH	Polycyclic aromatic hydrocarbons
PFC	Perfluorocarbon
PM	Particulate matter
POCP	Photochemical ozone creation potential
PPP	Plant protection product
PRTR	Pollutant Release and Transfer Register
TOC	Total organic carbon
VOC	Volatile organic compounds

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1 Introduction

Recent discussions and debates of biomass utilization in Japan necessitate conducting life cycle assessment (LCA). However, there are no impact assessment methods suitable for the assessment of agricultural production and biomass utilization in Japan from a comprehensive perspective. The use of the impact assessment method developed by Advance Industrial Science and Technology (LIME, N. Itsubo & Inaba 2003) could be one possibility. Unfortunately, because the method was developed for industrial purposes, it is still difficult to apply the method to agricultural production and biomass utilization as a comprehensive environmental assessment tool.

The application of eco-factors for Japan (JEPIX, Miyazaki et al. 2004), which were calculated based on the former version of Swiss ecological scarcity 1998 (Brand et al. 1998), would be another possibility. However, the adapted version did not take into account, for example, ammonium and nitrate emissions, which are crucial in assessing agricultural production and biomass utilization.

Recently a new version of ecological scarcity (Frischknecht et al. 2009) was published. The aims of this report are to complete and update the existing Japanese eco-factors according to the new version of the Swiss ecological scarcity method.

1.1 Procedure

In the framework of this study all elementary flows and environmental impacts investigated in Frischknecht et al. (2009) are considered. However, not all eco-factors are of the same importance, thus, three priority groups are defined.

- Priority 1: The eco-factors of the pollutants assessed within JEPIX 2004 are either directly used or updated based on more recent statistical information and laws and/or directives.
- Priority 2: The eco-factors of pollutants and resources relevant in the area of agriculture and biofuels are established.
- Priority 3: The eco-factors of all remaining pollutants and resources are established.

Nuclear energy related impacts and primary energy resources are classified in Priority 3 because the project does not aim at comparing biomass with nuclear electricity. Nevertheless, the authors recommend establishing eco-factors of nuclear energy related pollutants and wastes in view of a broader application of the Japanese eco-factors.

Tab. 1.1 shows an overview of all substances covered by the Swiss and Japanese ecological scarcity method. For the Japanese version further eco-factors are established for resource extraction of phosphorous and potassium emissions into top soil. Due to lack of information and unknown political targets it was not possible to include eco-factors with regard to PAH and B(a)P.

Tab. 1.1: List of elementary flows and environmental impacts and their priorities.

	Substance / environmental impact	**Priority**	**Investigated in the Swiss version**	**Investigated in the Japanese version**
Air	Climate change	1	x	x
	Ozone depletion	1	x	x
	NMVOC	1	x	x
	Nitrogen oxide	1	x	x
	Ammonia	2	x	x
	Sulphur dioxide and other acidifying gases	3	x	x
	Particulate matter	1	x	x
	Carbon monoxide	3	x	x
	Benzene	3	x	x
	Dioxins and furans	1	x	x
	Heavy metals (lead, cadmium, mercury and zinc)	3	x	x
Surface water	Nitrogen	1	x	x
	Phosphorus	1	x	x
	Organic matter (BOD, COD, DOC, TOC)	1	x	x
	Heavy metals and arsenic	3	x	x
	Radioactive releases to the Sea	3	x	x
	AOX	3	x	x
	Chloroform	3	x	a)
	PAH	3	x	-
	Benzo(a)Pyrene	3	x	-
	Endocrine disruptors	3	x	x
Ground water	Nitrate	2	x	x
Soil	Heavy metals	2	x	x
	Pesticides	2	x	x
	Potassium		-	x
Resources	Primary energy carriers	3	x	x
	Land use	2	x	x
	Gravel (and sand)	3	x	x
	Fresh water	2	x	x
	Phosphorous		-	x
Waste	Carbon content of landfilled waste	3	x	b)
	Hazardous waste (underground storage)	3	x	x
	Radioactive waste (underground storage)	3	x	x

a) Chloroform is assessed as part of AOX

b) The amount of waste disposed in landfill site is assessed independently of the carbon content

1.2 Position of the ecological scarcity method in relation to life cycle assessment (LCA)

Applied within the context of life cycle assessment (LCA), the ecological scarcity method allows an assessment of the environmental impacts caused by the release of pollutants and the extraction of resources quantified in the life cycle inventory analysis. Eco-factors, expressed as eco-points per unit of pollutant emission or resource extraction, are the key parameter used by the method. The eco-factors are determined, reflecting, on the one hand, the current emission situation, and, on the other hand, national policy targets as well as international targets supported by the respective country.

For a company or other stakeholders, it can be highly informative to assess the environmental impacts of products or of a company in this manner, as the eco-points reflect the priorities of public national environmental policy. The results of such an assessment can support decision-making in product development, and in management, procurement and consultancy.

1.3 Structure of the report

The report starts with a description of the ecological scarcity method including its formula and further specifications in Chapter 2. The derivations of the specific eco-factors are presented in Chapter 4 (emissions to air) and Chapter 5 (resources).

The structure of the description of the individual eco-factors is organized around the basic elements of the formula representation or calculation sequence:

- Ecological relevance (only in the chapters on the individual eco-factors), the general description of the environmental impacts of the substances considered is taken from Frischknecht et al. (2009)
- Political targets and situation in Japan
- Characterization (insofar as applied)
- Normalization
- Weighting (with sections presenting the current and critical flows)
- Eco-factor
- Application guidance (where necessary)

2 The ecological scarcity method

The ecological scarcity method was developed in Switzerland and first published in 1990 (Ahbe et al. 1990). A detailed description of the method is shown in Frischknecht et al. (2009), which is partly reproduced. This section summarizes the main properties of the method.

The ecological scarcity method is a “distance-to-target” method, which delivers standardized, generic weights, so-called eco-factors.

One key element of the eco-factors are environmental protection targets set at national level and, in some cases, international level. Such 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 far as possible.

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 impacts into eco-points, so that these values can be added and compared. The ecological scarcity method weights environmental impacts – i.e. pollutant emissions and resource extractions – with “eco-factors”. In its basic form, it is structured in accordance with the ISO Standards 14040 and 14044 (International Organization for Standardization (ISO) 2006a; b)) in three elements

- characterization
- normalization and
- weighting

For every elementary flow, the eco-factor is defined as follows:

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

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

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

F_n = **Normalization flow:** current annual flow, with Switzerland as 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)

EP = **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 (for instance, global warming). Here the effect of a certain pollutant (e.g. the global warming potential of methane) is placed in relation to the effect of a reference substance (carbon dioxide in this case). Characterization was already introduced in the previous version of the Swiss ecological scarcity method (climate change, ozone depletion, acidification and primary energy).

Normalization

Normalization serves to adjust the scarcity situation (weighting) to the present pollutant emissions or resource extractions in a region. ISO 14044 and the relevant SETAC publications also proposed conducting normalization on the basis of the present flows of a region.

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

Weighting

The final weighting of pollutants or resources or of characterized environmental impacts is performed on the basis of their “distance-to-target” – or **“ecological scarcity”.** To do this, the method uses on the one hand the total present flows of an environmental pressure (current flows) and, on the other hand, the flows of the same environmental pressure considered to be the maximum permissible level within the context of environmental policy goals (critical flows). Depending upon 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 major exceedance of the target value (critical flow) is weighted above-proportionately, and if the current flow is substantially lower than the critical flow this is weighted under-proportionately. This means that the higher the current impact already is, the more strongly every additional emission is weighted.

Weighting is a dimensionless quantity determined exclusively by the **ratio of the current to critical flow.** The absolute level of the flows has no influence whatsoever upon the weighting. Thus, regardless of whether, for instance, there is a current flow of 2000 t/a and a critical flow of 1000 t/a or of 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

The 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 (EP) per unit of environmental pressure”, e.g. “30 EP per gram SO_2”, or “eco-points (EP) per unit of environmental impact”, e.g. “0.31 EP per gram CO_2-equivalent”.

The representation of the formula makes it possible to determine eco-factors that are differentiated temporarily and spatially, and to determine eco-factors for sub-groups of certain pollutants – all of which are fully compatible with the basic scheme and with the annual eco-factors and can thus be combined seamlessly. More on differentiation (regionalisation, temporal differentiation) can be found in Frischknecht et al. (2009).

3 Overview of political targets in Japan

This section describes the background and legal regulations of environmental quality standards (EQS) and pollutant release and transfer register (PRTR). Both of them are used to establish the eco-factors of many substances in the framework of this study.

3.1 Environmental Quality Standards (EQS)

The Basic Environmental Law (Ministry of the Environment Government of Japan 2011, Section 3) states that: “with regard to the environmental conditions related to air pollution, water pollution, soil contamination and noise, the Government shall respectively establish environmental quality Standards, the maintenance of which is desirable for the protection of human health and the conservation of the living environment.” The next paragraph continues “the Government shall make efforts to attain the standard provided for in Paragraph 1 by comprehensively and effectively implementing policies concerning environmental pollution control which are set forth in this chapter”.

The definitions of the EQS combined with measurements from several monitoring stations helped to establish some eco-factors. A detailed description of the standards is available at the website of the Japanese Ministry of Environment[1].

The following Subchapters describe which standards are considered in the framework of this study.

3.1.1 Environmental quality standards for air

EQS with regard to air quality are defined for the substances listed in Tab. 3.1. The table gives an overview of existing EQS and its application in the framework of this study.

Tab. 3.1: Substances for which EQS are defined with regard to air emissions.

Substance	Comment
Sulfur dioxide	Used to establish weighting factor
Carbon monoxide	Used to establish weighting factor
Suspended particulate matter	Other target applied
Nitrogen dioxide	Other target applied
Photochemical oxidants	Other target applied
Benzene	Used to establish weighting factor
Trichloroethylene	Substance considered within the assessment of photochemical substances
Tetrachloroethylene	Substance considered within the assessment of photochemical substances
Dichloromethane	Substance considered within the assessment of photochemical substances
Dioxins	Other target applied
Fine Particulate Matter ($PM_{2.5}$)	Other target applied

3.1.2 Environmental quality standards for water

Two kinds of EQS are defined relating to water pollution. These are

- Environmental water quality standards for protecting human health (Tab. 3.2)
- Environmental water quality standards for protecting the living environment (Tab. 3.3)

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[1] Ministry of Environment, http://www.env.go.jp/en/standards, January 2011

For 26 substances EQS are defined for the protection of human health. Additionally, 27 other substances have been designated as “monitoring substances”. These substances have not been made directly into EQS as of the present time, but they have been identified as needing further observation. A guideline value is defined for these substances.

With regard to the protection of the living environment the definition of the standard values depends on the water quality of rivers, lakes and coastal waters.

The following tables only show standard and guideline values of the substances which are considered in the framework of this study.

Tab. 3.2: Substances for which standard and guideline values are defined for the protection of human health and which are used in this study.

Substance	Comment
Nitrate	Standard value
Mercury	Standard value
Arsenic	Standard value
Cadmium	Standard value
Lead	Standard value
Nickel	Guideline value
Molybdenum	Guideline value
Antimony	Guideline value
Manganese	Guideline value
Uranium	Guideline value
Chloroform	Guideline value, used in the assessment of AOX
Trans-1,2-dichloroethylene	Guideline value, used in the assessment of AOX
1,2-Dichloropropane	Guideline value, used in the assessment of AOX
p-Dichlorobenzene	Guideline value, used in the assessment of AOX
Dichloromethane	Standard value, used in the assessment of AOX
1,2-Dichloroethane	Standard value, used in the assessment of AOX
1,1-Dichlorethylene	Standard value, used in the assessment of AOX
Cis-1,2-Dichloroethylene	Standard value, used in the assessment of AOX
1,1,1-Trichloroethane	Standard value, used in the assessment of AOX
1,1,2-Trichlorethane	Standard value, used in the assessment of AOX
Trichloroethylene	Standard value, used in the assessment of AOX
Tetrachloroethylene	Standard value, used in the assessment of AOX
1,3-Dichloropropene	Standard value, used in the assessment of AOX

Tab. 3.3: Substances for which standard values are defined for the protection of the living environment and which are used in this study.

Substance	Comment
BOD	Standard value depends on water quality, only valid for concentrations in rivers
COD	Standard value depends on water quality, only valid for concentrations in lakes and coastal waters
Total nitrogen	Standard value depends on water quality, only valid for concentrations in lakes and coastal waters
Total phosphorous	Standard value depends on water quality, only valid for concentrations in lakes and coastal waters
Chloroform	The guideline value defined for the protection of human health is applied as that one is lower

3.1.3 Environmental quality standards for soil

The EQS for soil regulate 25 substances. Only 3 are used in this study, they are summarized in Tab. 3.4.

Tab. 3.4: Substances for which standard values are defined and which are used in this study.

Substance	Comment
Cadmium	Two standards: one is valid for sample solution and the other for the content in rice for agricultural land
Lead	In sample solution
Copper	Only valid for paddy fields

3.2 Pollutant Release and Transfer Register (PRTR)

In response to the OECD Recommendation, the Environment Agency of Japan (the present Ministry of the Environment) has accelerated the preparations for the introduction of a PRTR in Japan. Based on the Act “A Bill on Confirmation, etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof” the businesses subject to the Act started estimating the amount of the subject chemical substances that they released into the environment. They began to notify the data to the government in FY2001, and the aggregated data has been published since the end of FY2002. (Ministry of Environment 2007)

Many substances investigated in this report belong to PRTR Class I Designated Chemical Substances. They are considered to continuously exist in the environment of a considerably wide area judging from its physical and chemical properties, volume of its manufacture, import and usage, and poses a risk of being harmful to human health and ecosystem (including ozone-depleting risk).

In the PRTR system, industries are required to declare their emissions into water, air, and soil of hazardous chemicals. The Ministry of Economy, Trade and Industry and the Ministry of the Environment estimate and add emissions of diffuse sources and non-listed industries, households, and mobile sources. In total 23 industries are covered.

In cases data from the PRTR system are applied some modifications were necessary to calculate the needed flows. The PRTR database includes reported (from industry) releases of pollutants into air, water and land. Releases of pollutants from outside notification industries, households and mobile sources are estimated. No split in air, water and land is given for these emissions. Therefore, the same ratio of releases into air, water and soil as for reported emissions is assumed.

4 Emissions to air

4.1 CO_2 and further greenhouse gases

4.1.1 Environmental impact

The fourth assessment report of IPCC states that most of the observed increase in global average temperatures since the mid 20th century is very likely due to observed increase in anthropogenic greenhouse gas concentrations and that continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century (IPCC 2007).

Modelling shows that the global mean temperature can be expected to rise by 1.1 to 6.4 °C between 1990 and 2100, 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 (IPCC 2007).

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 potential (GWP) of 1 kg of the latter substances can be several thousand times greater than that of 1 kg of CO_2, their contribution to the overall emissions inventory of Japan is small (see Tab. 4.1).

4.1.2 Political targets and situation in Japan

The Kyoto Protocol entered into force in 2005, under the United Nations Framework Convention on Climate Change, and Japan made a legally binding commitment to reduce GHG emissions by 6 % compared to the base year during the first commitment period (2008-2012). In order to achieve the 6 % reduction target, the Japanese government established the Kyoto Protocol Target Achievement Plan (Cabinet Decision of April 28, 2005, totally revised March 28, 2008) based on the revision of the Law Concerning the Promotion of the Measures to cope with Global Warming.

At the G8 Hokkaido Toyako Summit, the G8 parties reached a common understanding that all parties to the convention seek to share and adopt the goal of at least halving global greenhouse gas emissions by 2050. Japan has also set the long-term goal of a 60 % to 80 % reduction from the present situation by 2050, and the Action Plan for Achieving a Low-carbon Society was approved by the Cabinet on July 29, 2008.

On international level Japan accounts for 4.3 % of the world's total CO_2 emissions resulting from energy use in 2006. This means the ninth highest, in terms of emissions per capita (Ministry of Environment 2009a).

4.1.3 Characterization

Greenhouse gases comprise the substances that contribute to global climate change. The latest publication by the IPCC (2007) provides the reference for the global warming potentials (GWPs) of the various gases. The reference substance is carbon dioxide (CO_2). The values depend upon the period of time over which the effects are integrated. It is common practice to apply the 100 years time horizon (see Tab. 4.1), which is also applied in the present method.

Tab. 4.1: Greenhouse gas emissions in Japan according to Nojiri (2009), excluding LULUCF, characterized with the GWP 100 values according to IPCC (2007).

	GWP_{100} (IPCC 2007) (CO_2-eq)	Emissions in 2007 (1000 t CO_2-eq)	Share in overall GHG emissions
CO_2	1	1'303'800	94.9%
CH_4	25	22'600	1.6%
N_2O	298	23'800	1.7%
HFCs	17–14’800	13'200	1.0%
PFCs	7’390–12’200	6'500	0.5%
SF_6	22’800	4'400	0.3%
Total		1'374'300	100.0%

4.1.4 Normalization

Japan’s climate target refers to all greenhouse gases, thus the normalization flow is identical to the current flow.

4.1.5 Weighting

Current flow

The Japanese Greenhouse Gas Inventory (Nojiri et al. 2009) reports CO_2, CH_4, N_2O, HFC, PFC, and SF_6 emissions for the years 1990 until 2007. The current annual flow of CO_2 is 1’304 Mio tons. Emissions of the other substances are shown in Tab. 4.1.

Critical flow

As described in Section 4.1.2 Japan has set the long-term goal of a 60 % to 80 % reduction from the present situation by 2050 (Ministry of Environment 2009a). Japan's mid-term goal is to cut greenhouse gas emissions by 25 percent from the 1990 level by 2020[2]. Emissions in 1990 amount to 1’207’800’000 tons.

Both eco-factors based on the mid-term and long-term target are calculated. In case of the long-term goal a reduction of 80 % from the situation by 2007 is applied.

4.1.6 Eco-factor for CO_2 and other greenhouse gases

The eco-factor is calculated according to the formula described in Chapter 2. The eco-factors of the other greenhouse gases are determined via characterization using GWP_{100} values (IPCC 2007).

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[2] A bill as to measures to counter global warming went through the Lower House on May 18, 2010 and was sent to the Upper House for deliberation. Personal communication, Hayashi Kiyotada, National Agricultural Research Center, 31.5.2010

Tab. 4.2: Eco-factor for greenhouse gas emissions.

	Mid term goal (2020)	Long term goal (2050)	Remarks	JEPIX
Normalization (1000 t CO_2-eq/a)	1'374'300	1'374'300	emissions in 2007, excl LULUCF (Nojiri et al. 2009)	1'147'945
Actual flow (1000 t CO_2-eq/a)	1'374'300	1'374'300		1'147'945
Critical flow (1000 t CO_2-eq/a)	905'850	274'860	reduction targets based on Ministry of the Environment (2009a)	299'450
Weighting (-)	2	25		
Eco-factor (EP/g CO_2-eq)	**0.0017**	**0.018**		**0.0128**

The eco-factor referring to the mid-term goal is substantially lower compared to JEPIX (Miyazaki et al. 2004), the one referring to the long term goal is higher. This is because the applied political goal (reduction of 80 %) is stronger than the one applied in JEPIX (reduction 74 %). In the final version of the method the long-term goal is applied.

Tab. 4.3 shows eco-factors of selected greenhouse gases with regard to the Japanese long-term and mid-term goal.

Tab. 4.3: Eco-factor for selected greenhouse gases with regard to the Japanese long term goal.

	Formula	GWP	Eco-factor mid term (EP/g)	Eco-factor long term (EP/g)
Carbon dioxide	CO_2	1	0.0017	0.018
Methane	CH_4	25	0.043	0.45
Nitrous oxide	N_2O	298	0.51	5.4
Sulphur hexafluoride	SF_6	22'800	39	415

Tab. 11.1 in the Appendix shows eco-factors of all greenhouse gases assessed in this study based on the long-term target. Some of them are also causing ozone layer depletion. Their ozone depletion potential will be assessed separately. The higher of the resultant eco-factors is then applied.

Diesel soot

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. The geometric mean is used as GWP in this study.

4.2 Ozone layer depletion gases

4.2.1 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 layer therefore increases, among other things, the skin cancer rate and eye diseases in humans, and the rate of mutation in all organisms. In addition, it accelerates aging in plastic polymers.

The most important ozone-depleting substances are CFCs, halons and carbon tetrachloride (CCl_4). HCFCs (partially halogenated CFCs) have the same effect, but in a significantly weaker form. At the same time, CFCs and HCFCs are contributors to human-induced climate change (Frischknecht et al. 2009).

4.2.2 Political targets and situation in Japan

Japan used to be one of the world's major producer and consumer of Chlorofluorocarbons (CFCs). CFCs were widely used in different applications ranging from the solvent sector, the foam sector, the refrigeration sector, the aerosol sector to other minor sectors. In 1988 the annual CFC production reached its peak of approx. 150’000 tons. The production of ODP substances in 2008 amount to about 1780 tons CFC-11-eq, whereby mainly HCFC’s are produced. The consumption amounts to 1050 tons CFC-11-eq/a and is driven by HCFC’s and methyl bromide (UNEP 2008).

Japan enacted “the Law concerning the Protection of the Ozone Layer through the Control of Specified Substances and Other Measures” in May 1988 and since then has implemented measures to phase out the production of ozone-depleting substances and to prevent releases/emissions of ozone depleting substances from equipment (Ministry of Environment 2001).

4.2.3 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 taken as unit. ODP values are determined in an internationally binding form in the Montreal Protocol. Tab. 4.4 presents a selection, while Tab. 11.1 in the Appendix gives the entire list. This list is expanded to include new substances as required. The status of the year 2006 is used for characterization (UNEP 2006).

Halogenated hydrocarbons that contain no chlorine or bromine atoms, but contain e.g. fluorine (HFCs) have no ozone-depleting effect. Most ozone-depleting substances also have a global warming potential. It is a principle of the ecological scarcity method that the higher of the two resulting eco-factors is used.

Tab. 4.4: Ozone depletion potentials of a number of important substances.

	Substance	**ODP (kg CFC-11-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
	Methyl bromide	0.6
Solvents	1,1,1-Trichloroethane	0.1
	Tetrachloromethane	1.1

4.2.4 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.

4.2.5 Weighting

Current flow

Some ozone depleting substances are recorded in the PRTR database (see Chapter 3.2 for further information). Emissions of 19 ozone depleting substances - among others the most important ones listed in Tab. 4.4 – are available in the PRTR database. Total emissions amount to 3750 tons CFC-11-eq/a in 2007. Tab. 4.5 gives an overview of total emissions of different substances in CFC-11-eq.

Tab. 4.5: Emissions of ozone depleting gases in Japan in FY2007 according to the PRTR database (Ministry of Environment 2007).

	Total emissions - not reported (kg/a)	Total air emissions - reported (kg/a)	Total emissions into air (kg/a)	Share of emissions not reported %	ODP (kg CFC-11-eq/kg)	Total Emissions (kg CFC-11-eq/a)
CFC-11	530814	7476	538290	98.61%	1	538'290
CFC-12	690173	12519	702692	98.22%	1	702'692
CFC-13	0	0	0	0.00%	1	0
CFC-114	0	23	23	0.00%	1	23
CFC-113	0	2758	2758	0.00%	0.8	2'206
CFC-115	6018	0	6018	100.00%	0.6	3'611
HCFC-21	0	27552	27552	0.00%	0.04	1'102
HCFC-22	7233151	393712	7626863	94.84%	0.055	419'477
HCFC-123	17012	81528	98540	17.26%	0.02	1'971
HCFC-124	0	3626	3626	0.00%	0.022	80
HCFC-133	0	19000	19000	0.00%	0.04	760
HCFC-141b	5722349	871638	6593987	86.78%	0.11	725'339
HCFC-142b	666819	23682	690501	96.57%	0.065	44'883
HCFC-225	773384	489446	1262830	61.24%	0.05	63'142
Halone-1301	14575	11004	25579	56.98%	10	255'790
Halone-2402	531	0	531	100.00%	6	3'186
Methyl bromide	1343357	279000	1622357	82.80%	0.6	973'414
1,1,1-trichloroethane	0	8280	8280	0.00%	0.1	828
Tetrachloromethane	0	8752	8752	0.00%	1.1	9'627
Total						**3'746'420**

Critical flow

The latest document referring to political laws and goals concerning use and emissions of ozone depleting substances is the CFC Management Strategy of Japan that was published in 2001 (Ministry of Environment 2001). According to this document most CFC application shall be replaced by HCFCs or HFCs. The ozone layer depletion potential of HCFCs is about 10 times lower compared to the one of CFCs. No target for the other ODP substances is known to the authors.

Thus, the critical flow is defined as the sum of emissions from HCFCs, halons, methyl bromide, trichloroethane, and tetrachloroethane plus 10 % of the ODP of all CFC emissions. A critical flow of 2630 tons CFC-11-eq results.

4.2.6 Eco-factor for ODP

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 4.6: Eco-factor for ODP.

	Actual situation	Remarks	JEPIX
Normalization (t CFC-11-eq/a)	3'746	calculated from Ministry of Environment (2007)	
Actual flow (t CFC-11-eq/a)	3'746		3'617
Critical flow (t CFC-11-eq/a)	2'624	90% reduction of CFCs	2'903
Weighting (-)	2.04		
Eco-factor (EP/g CFC-11-eq)	**540**		**429**

The resulting eco-factor is slightly higher compared to the eco-factor established in JEPIX (Miyazaki et al. 2004). The flows in JEPIX do not include HCFC, halons, methyl bromide, trichlorethane and tetrachloroethane emissions.

4.3 Nitrogen oxides (NO_x)

4.3.1 Environmental impact

Primary source of NO_X are combustion processes (burning of fossil energy carriers). Further anthropogenic sources of nitrogen oxides include construction machines and agricultural and silvicultural machines, combustion facilities/furnaces, and certain commercial and industrial processes.

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

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

NO_x appears to promote damage to built structures caused by biological processes (dissolution of carbonate materials by nitrifying microflora) (Frischknecht 2009).

4.3.2 Political targets and situation in Japan

Japan defines environmental quality standards concerning NO_X concentrations (see Chapter 3.1 for more information on EQS). The daily average for hourly values shall be within 0.04-0.06 ppm or below. The annual mean nitrogen dioxide level from all valid monitoring stations in FY2007 was 0.013 ppm at ambient air pollution monitoring stations (AAPMSs) and 0.025 ppm at roadside air pollution monitoring stations (RAPMSs). NO_X concentrations measured at AAPMs stay constant since about 1980 whereby concentrations measured at RAPMS decrease steadily since about 1995 (Ministry of Environment 2009a).

4.3.3 Normalization

The normalization flow is identical to the current flow.

4.3.4 Weighting

Current flow

Annual NO_x emissions in Japan are reported in the National Greenhouse Gas Inventory (Nojiri et al. 2009). Nitrogen oxide (NO_X) emissions in 2007 were 1’920’000 tons, a decrease by 4.7 % compared to 1990 and by 2.6 % compared to the previous year.

Critical flow

The Central Environment Council (2005) defines long term reduction targets concerning NO_X and PM10 emissions for motor vehicles and the Kanto region in particular based on FY 2000. This report was updated in 2008 but is only available in Japanese. According to Hayashi Kiyotada, National Agricultural Research Center, the expressions did not change compared to the eighth report (Central Environmental Council 2005). Reduction targets are shown in Tab. 4.7.

Tab. 4.7: NO_X reduction targets defined in Central Environment Council (2005). Reduction targets for Japan refer to motor vehicles only whereby reduction targets for the Kanto region refer to all sources, except natural ones. Base year for reduction is FY 2000.

Region	Target year	Reduction NO_X	Remarks
Japan	FY2010	41%	reduction based on the implementation of regulations up to the new long-term gasoline and diesel targets
Japan	FY2015	56%	reduction based on the implementation of regulations up to the new long-term gasoline and diesel targets
Kanto	FY2010	20%	reduction of total emissions (except natural sources)
Kanto	FY2015	25%	reduction of total emissions (except natural sources)

Total NO_X emissions in FY 2000 amount to 2’034’000 tons (OECD 2007). According to OECD (2007) about 634’000 tons derive from “mobile road sources” and according to Central Environment Council (2005) it is 670’000 tons NO_X in FY 2000. The target refers to the value published by Central Environment Council (2005) which is thus taken as reference.

The targets are applied to NO_X emissions deriving from motor vehicles and the total NO_X emissions for 2010 and 2015 recalculated. The resulting critical flow for 2015 amount to about 1’660’000 tons and comprises all NO_X emissions (except natural sources) but includes only NO_X targets concerning motor vehicles (see Tab. 4.8).

Tab. 4.8: Calculation of NOx target flow applying political goals for vehicle emissions

	Target 2010	Target 2015	Comments
Total NOx emissions FY2000 (t NOx/a)	2'034'313	2'034'313	FY 2000, OECD (2007)
NOx emissions FY2000, from motor vehicles (t NOx/a)	670'000	670'000	FY 2000, Central Environment Council (2005)
NOx emissions FY2000, from motor vehicles applying reduction target (t NOx/a)	395'300	294'800	Target see Tab. 4.7
Total NOx emissions, including reduction target for motor vehicles (t NOx/a)	**1'759'613**	**1'659'113**	

4.3.5 Eco-factor for NO_X

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 4.9: Eco-factor for NO_X.

	Actual situation	Remarks	JEPIX
Normalization (t NOx/a)	1'920'000	OECD (2007) value for 2005	
Actual flow (t NOx/a)	1'920'000		1'996'000
Critical flow (t NOx/a)	1'659'113	target for 2015 applied	1'718'437
Weighting (-)	1.3		
Eco-factor (EP/g NOx)	**0.70**		**0.68**

The eco-factor for NO_X is slightly higher compared with the previous situation.

4.4 Particulate matter (PM)

4.4.1 Environmental impact

In Frischknecht (2009) the environmental impact of PM is described as follows:

"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).

The harmfulness of particles depends on the one hand upon their size and on the other upon their composition."

Particulate matters can be differentiated into

- PM10: diameter less than 10 micrometers. PM10 comprises those particles which can move beyond the larynx and enter the lung. 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.
- Diesel soot: elemental carbon. They are considered carcinogenic and particularly 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.
- PM2.5-10: these particulates are associated more closely with coughing, asthma attacks and other diseases of the respiratory tract.
- PM2.5: this fraction correlates more with cardiac disrhythmia and an increased incidence of cardiovascular diseases. These fine particles remain much longer in the lung and accumulate there, as they are not readily coughed up.

4.4.2 Political targets and situation in Japan

Japan defines environmental quality standards concerning particulate matter concentrations (see Chapter 3.1 for more information on EQS). The daily average for hourly values shall not exceed 0.10 mg/m^3, and hourly values shall not exceed 0.20 mg/m^3. The annual mean level for SPM in FY2007 from all valid monitoring stations was 0.024 mg/m^3 at ambient air pollution monitoring stations (AAPMSs) and was 0.027 mg/m^3 at roadside air pollution monitoring stations (RAPMSs), showing gradual improvements in recent years (Ministry of Environment 2009a).

In Japan the ministry consulted the Central Environment Council in December 2008, regarding the setting of the environmental quality standards (EQSs) for fine particulate matter (PM 2.5). The expert committee on environmental standards for Fine Particulate Matter and the expert committee on monitoring methods for Fine Particulate Matter have been established and discussions have been progressed under the Council's Atmospheric Environment Committee (Ministry of Environment 2009a).

However, a differentiation between particle sizes (PM10, PM 2.5-10, PM2.5, diesel soot) is not possible with the current existing data.

4.4.3 Normalization

The normalization flow corresponds to the current flow.

4.4.4 Weighting

Current flow

Annual PM emissions reported by OECD (2007) are incomplete and if available only recorded for mobile road sources. The East Asian Air Pollutant Emissions Grid Database (EAGrid 2000) records PM emissions stemming from different sources referring to the year 2000. In FY2000 192'000 tons PM were emitted.

Critical flow

The critical flow was calculated with the same approach as for NO_X emissions (see Section 4.3.4 and Tab. 4.11). Same literature sources for reduction targets and actual PM emissions of motor vehicles are used. The overall PM emissions are adopted from EAGrid2000 (2000) because of incomplete OECD data.

Tab. 4.10: PM10 reduction targets defined in Central Environment Council (2005). Reduction targets for Japan refer to motor vehicles only whereby reduction targets for the Kanto region refer to all sources, except natural ones. Base year for reduction is FY 2000.

Region	Target year	Reduction PM10	Remarks
Japan	FY2010	77%	reduction based on the implementation of regulations up to the new long-term gasoline and diesel targets
Japan	FY2015	92%	reduction based on the implementation of regulations up to the new long-term gasoline and diesel targets
Kanto	FY2010	46%	reduction of total emissions (except natural sources)
Kanto	FY2015	52%	reduction of total emissions (except natural sources)

Tab. 4.11: Calculation of PM10 target flow applying political goals for vehicle emissions.

	Target 2010	Target 2015	Comments
Total PM emissions FY2000 (t PM/a)	192'025	192'025	FY 2000, EAGrid2000 (2000)
PM emissions FY2000, from motor vehicles (t PM/a)	79'000	79'000	FY 2000, Central Environment Council (2005)
PM emissions FY2000, from motor vehicles applying reduction target (t PM/a)	18'170	6'320	Traffic released emissions only, target see Tab. 4.7
Total PM emissions, including reduction target for motor vehicles (t PM/a)	**131'195**	**119'345**	

4.4.5 Eco-factor for particulate matter

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 4.12: Eco-factor for particulate matter.

	Actual situation	Remarks	JEPIX
Normalization (t PM/a)	192'025	EAGrid2000 (2000), value for the year 2000	
Actual flow (t PM/a)	192'025		257'812
Critical flow (t PM/a)	119'354	target for 2015 applied	225'871
Weighting (-)	2.6		
Eco-factor (EP/g PM)	**13**		**5.05**

The new eco-factor is higher compared to the factor established in JEPIX (Miyazaki et al. 2004). No literature sources accounting for all PM emissions are available at the time this report is written. Furthermore, the Future Policy for Motor Vehicle Emission Reduction (Central Environmental Council 2005) does not include targets considering PM since JEPIX established the eco-factors.

4.5 Ammonia

4.5.1 Environmental impact

In Frischknecht et al. (2009) the environmental impact of ammonia is described as follows:

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

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

4.5.2 Political targets and situation in Japan

Ammonia concentrations in air are regulated in the Offensive Odor Control Law (Ministry of Environment 1995). The legislation states the necessity and the flexibility of each prefecture to plan their original standard. It also says that reporting is not binding. The “regulated areas” are designated by the prefectural governors. They also set the standard which is between 1 and 5 ppm.

4.5.3 Normalization

The normalization flow is identical to the current flow.

4.5.4 Weighting

Current flow

The annual flow of ammonia in FY 1994 amounts to 522’300 tons/a (Akiyoshi et al. 2001).

Critical flow

The critical flow is calculated via the weighting factor and current flow.

There are limited data available on ammonia immission concentrations. The prefectures Chiba (Chiba prefecture environment research institute 2008) and Tottori (Environmental policy department 1998) publish measured data on ammonia; they are summarized in Tab. 4.13.

With the standards and the measured data a weighting factor for every investigated area is determined, which results in very low ($5.6 * 10^{-7}$) but also relatively high (1.9) weighting factors. The average of the resulting weighting factors is used to reflect an adequate weighting factor.

Tab. 4.13: Limits and measured data of ammonia for the prefectures Chiba and Tottori.

Prefecture	Investigated area	Standard ppm	Measured data ppm	Weighting factor -
Chiba	breeding area	1	0.00646	4.17E-05
	urban area	1	0.00221	4.88E-06
	suburban area	1	0.0017	2.89E-06
	mountain lands	1	0.000748	5.60E-07
	narita	1	0.06	0.0036
Tottori	night-soil treatment plant	1	0.07	0.0049
	poultry manure treatment plant	2	1.9	0.90
	meat product processing facility	5	0.62	0.015
	chemical product factory	5	0.94	0.035
	pulp industry	5	0.19	0.0014
Average				**0.096**

4.5.5 Eco-factor for Ammonia

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 4.14: Eco-factor for Ammonia.

	Actual situation	Remarks	JEPIX
Normalization (t NH_3/a)	522'252	Akiyoshi (2001)	
Actual flow (t NH_3/a)	522'252		-
Critical flow (t NH_3/a)	1'682'747	calculated via weighting factor	-
Weighting (-)	0.096	calculation described in the text (Section 4.5.4)	
Eco-factor (EP/g NH_3)	**0.18**		**-**

4.6 Sulphur dioxide (SO_2) and further acidifying substances

4.6.1 Environmental impact

In Frischknecht et al. (2009) the environmental impact of SO_2 is described as follows:

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

4.6.2 Political targets and situation in Japan

Japan defines environmental quality standards concerning sulphur dioxide emissions (see Chapter 3.1 for more information on EQS). The daily average for hourly values shall not exceed 0.04 ppm, and hourly values shall not exceed 0.1 ppm.

4.6.3 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 defined with sulphur dioxide as reference substance, and is stated as SO_2-equivalents. The “generic AP” factors given by Guinée et al. (2001, as per April 2004) are adopted as characterization factors.

Tab. 4.15: Characterization factors for the acidification potential in accordance with Guinée et al. (2001)

Substance	Formula	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
Sulphuric acid	H_2SO_4	0.65
Hydrogen sulphide	H_2S	1.88
Nitrogen oxides	NOx (as NO_2)	0.7

4.6.4 Normalization

The target for sulphur dioxide is based on its acidifying effect. Therefore, all acidifying substances would need to be taken into account to assess the normalization flow. Separate targets have been established for NO_x and NH_3. Therefore these substances are not included in the normalization. The other acidifying substances could not be taken into account for the calculation of the normalization flow due to lack of data.

4.6.5 Weighting

Current flow

Annual SO_2 emissions in Japan are reported in the National Greenhouse Gas Inventory (Nojiri et al. 2009). SO_2 emissions in 2007 were 780’000 tons, a decrease by 22.9 % compared to 1990, and by 3.0 % compared to the previous year.

Critical flow

The critical flow is determined via the weighting factor and current flow.

The weighting factor is established combining the EQS definition and measurements at 1330 monitoring stations for FY2007[3]. Data include the highest measurements per hour (with a range of 0.006 ppm to 1.67 ppm) and the 2 % trimmed daily average (with a range of 0.001 ppm to 0.116 ppm) for every monitoring station.

To calculate the weighting factor the averages of the maximum hourly value and the 2 % trimmed daily average are divided by the respective EQS. The higher of the two resulting weighting factors is used. However, both weighting factors are lower than 1. This reflects the situation in Japan that SO_2 is not a major problem and EQS are not exceeded in most cases.

4.6.6 Eco-factor for SO_2

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 4.16: Eco-factor for SO_2.

	Actual situation	**Remarks**	**JEPIX**
Normalization (t SO_2-eq /a)	780’000	National GHG inventory (Nojiri et al. 2009)	
Actual flow (t SO_2-eq /a)	780’000		-
Critical flow (t SO_2-eq /a)	1'282’312	calculated via weighting factor	-
Weighting (-)	0.37	calculation described in the text (Section 4.6.5)	
Eco-factor (EP/g SO_2-eq)	**0.47**		**-**

As the weighting factor is established combining EQS and actual measurements the critical flow is calculated via the weighting factor and actual flow.

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[3] Provided by Kiyotada Hayashi, National Agricultural Research Center, 11.6.2010

4.6.7 Eco-factor for further acidifying substances

Further substances are responsible for the acidification of ecosystems in addition to sulphur dioxide. Eco-factors can be derived for further substances by using the acidification potential, which characterizes the relative acidification attributable to a substance in relation to SO_2.

The eco-factors only assess the acidifying effect, as they are linked to SO_2 via the characterization. No account is taken of the further effects of individual acids.

Tab. 4.17: Eco-factors for substances with acidifying potential in EP/g acid, characterized with reference to sulphur dioxide

Substance	Formula	Acidification potential ($kg\ SO_2$-eq/kg)	Eco-factor (EP/g)
Ammonia	NH_3	1.88	[4]
Hydrogen fluoride	HF	1.6	0.75
Phosphoric acid	H_3O_4P	0.98	0.46
Nitric acid	HNO_3	0.51	0.24
Hydrochloric acid	HCl	0.88	0.41
Sulphuric acid	H_2SO_4	0.65	0.31
Hydrogen sulphide	H_2S	1.88	0.88
Nitrogen oxides	NO_x	0.7	[5]

4.7 Non-methane volatile organic compounds (NMVOC)

4.7.1 Environmental impact

Volatile organic compounds (VOCs) are a group of organic substances comprising a range of non-toxic to highly toxic and carcinogenic compounds. NMVOCs (non-methane volatile organic compounds) are VOCs excluding methane.

Together with nitrogen oxides, NMVOCs are important precursors for photochemical oxidants (giving rise to tropospheric ozone or “summer smog”), which can harm human health and flora. In addition, many individual VOCs such as benzene or dioxins lead to further undesirable impacts upon humans and flora and fauna. For some substances, individual eco-factors are determined (Frischknecht 2009).

4.7.2 Political targets and situation in Japan

Japan defines environmental quality standards concerning photochemical oxidant concentrations (see Chapter 3.1 for more information on EQS). Hourly values shall not exceed 0.06 ppm.

4.7.3 Characterization

Photochemical ozone creation potential (POCP) is a measure of the contribution of a molecule to ozone formation. POCP is expressed in kg ethylene-eq. They are used as characterization factors.

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[4] Ammonia is assessed separately in Chapter 4.5

[5] Nitrogen oxides are assessed separately in Chapter 4.3

4.7.4 Normalization

The normalization flow is the annual NMVOC flow characterized with the average POCP-factor for NMVOC (0.513 kg ethylene-eq/kg). A characterized flow of about 870’000 tons results.

4.7.5 Weighting

Current flow

Annual NMVOC emissions in Japan are reported in the National Greenhouse Gas Inventory (Nojiri et al. 2009). NMVOC emissions in 2006 were 1’638’000 tons, a decrease by 15.4 % compared to 1990, and a decrease by 1.1 % compared to the previous year.

Critical flow

The Japanese Air Pollution Control Law aims to reduce VOC emissions by 30 % compared to the value marked in FY2000 by FY2010 (Ministry of Environment 2005). NMVOC emissions in 2000 account to 1’800’478 tons (OECD 2007).

4.7.6 Eco-factor for NMVOC

The eco-factors are calculated according to the formula described in Chapter 2.

Tab. 4.18: Average eco-factor for NMVOC.

	Actual situation	Remarks	JEPIX
Normalization (t Ethylene-eq/a)	869'771	National GHG inventory (Nojiri et al. 2009) characterized with POCP factor for NMVOC	
Actual flow (t NMVOC/a)	1'638'000	National GHG inventory (Nojiri et al. 2009)	
Critical flow (t NMVOC/a)	1'260'335	VOC: 30% reduction compared to 2000 (Ministry of Environment 2005)	
Weighting (-)	1.69		
Eco-factor (EP/g Ethylene-eq)	**1.9**		**2.17**

NMVOC was not previously assessed as an individual substance, but as a part of the POCP group. The new form of assessment leads to an eco-factor that is slightly lower as the previous one.

Eco-factors of different substance groups are shown in Tab. 4.19, eco-factors for single substances are listed in the Appendix 11.2.

Tab. 4.19: Eco-factors for different substance groups.

Substance group	POCP (kg ethylene eq./kg)	# Substances	Eco-factor (EP/g)
NMVOC	0.513	120	**1.9**
Alkane (saturated HC)	0.391	26	**1.5**
Alkene (unsaturated HC)	0.968	16	**3.7**
Alcohols	0.382	19	**1.4**
Aldehyde	0.678	5	**2.6**
Ketone	0.161	9	**0.6**
Ester-compounds	0.222	10	**0.8**
Ether-compounds	0.290	5	**1.1**
Aromatic compounds	0.850	18	**3.2**

4.8 Dioxins

4.8.1 Environmental impact

Dioxins and furans (PCDD and PCDF) are chlorinated aromatic hydrocarbons, some of which are highly toxic to humans and animals. There are in total 76 dioxins and 135 furans. They are formed in technical but also in natural combustion processes in the presence of chlorine. These processes always generate a mixture of various individual substances, expressed as a “dioxins and furans” aggregate parameter (PCDD/F) in international toxicity equivalents (I-TEQ).[6] They accumulate in the food chain and are also embryotoxic. Dioxins impair embryonal development in several ways. In particular, they appear to give rise to miscarriage, deformity of (genital) organs, and intellectual deficits.

Dioxins and furans are scarcely volatile; their dispersal is mainly through attachment to particles. The main exposure route is via the ingestion of foods containing fat. In 1990, the WHO set the limit value for the acceptable daily intake (ADI) by humans at 10 pg 2,3,7,8-TCDD-eq per kg body weight. Based on more recent findings, the Dutch health ministry has proposed reducing the ADI limit value to 1 pg I-TEQ/kg body weight. The daily dioxin and furan intake of individuals in Western Europe is between 0.3 and 2 pg I-TEQ per kg body weight. Thanks to the drop in emissions, a reduction of the daily dioxin and furan intake can be expected (Frischknecht 2009).

4.8.2 Political targets and situation in Japan

Dioxin emissions belong to PRTR Class I Designated Chemical Substances (see Chapter 3.2 for more information about the PRTR system).

4.8.3 Normalization

Dioxins and furans are practically always stated in life cycle inventories as characterized quantities in I-TEQ. The reduction target also applies to this characterized quantity, and thus the normalization flow is identical to the (already characterized) current flow.

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[6] 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.

4.8.4 Weighting

Current flow

Annual dioxin emissions in Japan are reported in the PRTR database (Ministry of Environment 2007). The annual reported flow of dioxin emissions into air was 170 g I-TEQ/a in 2007. The annual estimated (outside notification) flow of dioxins is 134 g I-TEQ/a. It is assumed that all these emissions are released to air. In total a current flow of 304 g I-TEQ/a results.

Critical flow

The Ministry of Environment defined a reduction plan in 2005 concerning dioxin emissions. Dioxin emissions should be reduced by 15 % in 2010 compared to 2003. This aim was already achieved in 2007 with a reduction of 23 % compared to 2003 (Ministry of Environment 2009a). Emissions in 2003 amount to 387 g I-TEQ/a.

4.8.5 Eco-factor for Dioxin

The eco-factor is calculated according to the formula described in Section 2.

Tab. 4.20: Eco-factor for dioxin.

	Actual situation	**Remarks**	**JEPIX**
Normalization (gTEQ/a)	304	Ministry of Environment (2007)	
Actual flow (gTEQ/a)	304		2620-2820
Critical flow (gTEQ/a)	329	target already met	843-891
Weighting (-)	0.9		
Eco-factor (EP/gTEQ)	**2'800'000'000**		**-**

The target emission level of dioxins defined is already achieved. However, the resulting eco-factor for dioxins and furans is still very high. This is an expression of the low emission quantities (a few grams per year), and further reflects the great harmfulness of these substances.

JEPIX (Miyazaki et al. 2004) did not assess an eco-factor for dioxin emissions separately, but per kg dichlorobenzene-eq.

4.9 Carbon monoxide (CO)

4.9.1 Environmental impact

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 mircoorganisms (e.g. oxidation of methane) (Frischknecht 2009).

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 (Frischknecht 2009).

4.9.2 Political targets and situation in Japan

Japan defines environmental quality standards concerning carbon monoxide concentrations (see Chapter 3.1 for more information on EQS). The daily average for hourly values shall not exceed 10 ppm, and the average of hourly values for any consecutive eight hour period shall not exceed 20 ppm.

4.9.3 Normalization

The normalization flow is identical to the current flow.

4.9.4 Weighting

Current flow

Annual carbon monoxide emissions are derived from OECD (2006/07). They amount to about 3’000’000 tons in 2006.

Critical flow

The critical flow is calculated via the weighting factor and current flow.

The weighting factor is calculated combining the EQS for CO and concentration measurements at 365 monitoring stations for FY2008[7]. Data include the highest measurements per hour (with a range of 0.6 ppm to 12.2 ppm) and the 2 % trimmed daily average (with a range of 0.3 ppm to 2.5 ppm) for every monitoring station.

To calculate the weighting factor the averages of the maximum hourly value and the 2 % trimmed daily average are divided by the respective EQS. The higher of the two resulting weighting factors is used. However, both weighting factors are lower than 1. This reflects the situation in Japan that CO is not a major problem and EQS are not exceeded in most cases.

4.9.5 Eco-factor for CO

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 4.21: Eco-factor for CO.

	Actual situation	Remarks	JEPIX
Normalization (t CO /a)	2'979'000	OECD (2006/07)	
Actual flow (t CO /a)	2'979'000		-
Critical flow (t CO /a)	8'166'442	calculated via weighting factor	-
Weighting (-)	0.13	calculation described in the text (Section 4.9.4)	
Eco-factor (EP/g CO)	**0.045**		**-**

As the weighting factor is established combining EQS and actual measurements the critical flow is calculated via the weighting factor and actual flow.

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[7] Provided by Hayashi Kiyotada, National Agricultural Research Center, Japan, 13.10.2010

The so calculated eco-factor for CO is higher than the one derived on the basis of the global warming potential (see Appendix 11.1) but slightly lower as the one established over POCP (see Appendix 11.2). The highest factor of 52 EP/kg is applied in the method.

4.10 Benzene

4.10.1 Environmental impact

Small quantities of benzene are already present in crude oil. Further quantities are formed when mineral oil is refined and when organic matter is burnt incompletely (e.g. in forest fires). Emissions of benzene to the atmosphere result primarily from combustion processes.

Inhalation is the main exposure route for benzene. Benzene is soluble in fat and is therefore stored in the fatty tissue of the body. As women have a higher body fat ratio than men, the impacts of this pollutant are greater for women. Individuals living or working near to highly frequented roads or petrol stations are also more greatly exposed. Uptake via the skin is only relevant where benzene is handled directly (Frischknecht 2009).

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.

4.10.2 Political targets and situation in Japan

Japan defines environmental quality standards concerning benzene concentrations (see Chapter 3.1 for more information on EQS). Annual average shall not exceed 0.003 mg/m^3.

Benzene emissions belong to PRTR Class I Designated Chemical Substances (see Chapter 3.2 for more information about the PRTR system).

4.10.3 Normalization

The normalization flow is identical to the current flow.

4.10.4 Weighting

Current flow

The annual flow is reported in the PRTR database (Ministry of Environment 2007) and amounts to 12’700 tons in FY 2007.

Critical flow

The weighting factor is calculated combining the EQS for benzene and concentration measurements at 485 monitoring stations for FY2008[8]. Data include the number of days and hours exceeding the EQS but no single measurements. To calculate the weighting factor the yearly average (0.0013 mg/m^3) is divided by the respective EQS (0.003 mg/m^3).

4.10.5 Eco-factor for Benzene

The eco-factor is calculated according to the formula described in Chapter 2.

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[8] Provided by Hayashi Kiyotada, National Agricultural Research Center, Japan, 13.10.2010

Tab. 4.22: Eco-factor for benzene.

	Actual situation	Remarks	JEPIX
Normalization (t Benzene /a)	12'744	Ministry of Environment (2007)	
Actual flow (t Benzene /a)	12'744		-
Critical flow (t Benzene /a)	18'924	calculated via weighting factor	-
Weighting (-)	0.45	calculation described in the text (Section 4.10.4)	
Eco-factor (EP/g Benzene)	**36**		**-**

As the weighting factor is established combining EQS and actual measurements the critical flow is calculated via the weighting factor and actual flow.

Benzene was not previously assessed as an individual substance, but as a part of the NMVOC group. Benzene assessed over NMVOC emissions result in an eco-factor of 0.42 EP/g Benzene. The new form of assessment, based on carcinogenicity, leads to an eco-factor that is approximately 100 times greater; this is appropriate considering the severity of the problems presented by this substance compared to average NMVOCs.

4.11 Heavy metals (Zn, Cd, Pb, Hg)

4.11.1 Environmental impact

Heavy metal emissions are considered to be harmful the environment and thus should be considered in a life cycle impact assessment method. the following potential impacts of heavy metals are reported by Frischknecht et al. (2009).

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

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

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

Zinc loads impair plant growth.

4.11.2 Political targets and situation in Japan

Japan defines no direct targets concerning heavy metals emissions into air. However, they belong to PRTR Class I Designated Chemical Substances (see Chapter 3.2 for more information about the PRTR system).

4.11.3 Normalization

The normalization flow is the sum of all heavy metal emissions considered. As it is assumed that emissions to air are equal to the deposition the normalization flow amounts to about 330’000 tons (Tab. 4.23).

4.11.4 Weighting

Current flow

We assume that the current flow of heavy metal emissions to air is equal to the deposition of heavy metals given in Tab. 4.23 and reported by Kida & Sakai (2002).

Tab. 4.23: Deposition of heavy metals according to Kida & Sakai (2002).

	Deposition (t/a)
Zn	92'000
Cd	5'300
Pb	232'500
Hg	2'465

Critical flow

No political targets exist that allow establishing a critical flow. Thus, the same approach as in Frischknecht et al. (2009) is used. 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 finally enter the soil via deposition must be the same as that for direct emissions to soil. Therefore, the weighting factors for soil are applied to air emissions of heavy metals.

4.11.5 Eco-factor for heavy metal emissions into air

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 4.24: Eco-factor for zinc.

	Actual situation	Comments	JEPIX
Normalization (t/a)	332'000	sum of all heavy metals considered	
Actual flow (t Zn/a)	92'000	atmospheric deposition	-
Critical flow (t Zn/a)	47'556	calculated via weighting factor	-
Weighting (-)	3.7	same as for emissions to soil	
Ecofactor (EP/g Zn)	**11**		**-**

Tab. 4.25: Eco-factor for cadmium.

	Actual situation	Comments	JEPIX
Normalization (t/a)	332'000	sum of all heavy metals considered	
Actual flow (t Cd /a)	5'300	atmospheric deposition	-
Critical flow (t Cd /a)	3'164	calculated via weighting factor	-
Weighting (-)	2.8	same as for emissions to soil	
Ecofactor (EP/g Cd)	**8.4**		**-**

Tab. 4.26: Eco-factor for lead.

	Actual situation	Comments	JEPIX
Normalization (t/a)	332'000	sum of all heavy metals considered	
Actual flow (t Pb/a)	232'500	atmospheric deposition	-
Critical flow (t Pb/a)	53'315	calculated via weighting factor	-
Weighting (-)	19.0	same as for emissions to soil	
Ecofactor (EP/g Pb)	**57**		**-**

Tab. 4.27: Eco-factor for mercury.

	Actual situation	Comments	JEPIX
Normalization (t/a)	332'000	sum of all heavy metals considered	
Actual flow (t Hg/a)	-		-
Critical flow (t Hg/a)	-		-
Weighting (-)	-		
Ecofactor (EP/g Hg)	**3.3**	**Extrapolated from eco-factors of other heavy metals (see Section 4.11.4)**	**-**

Heavy metal emissions into air were not previously assessed in JEPIX (Miyazaki et al. 2004).

In case of mercury no eco-factor is established for soil. The eco-factor for mercury is thus calculated by weighting the eco-factors of Zn, Cd and Pb with the relation of the eco-factor to the actual flow (see Tab. 4.23).

Tab. 4.28: Calculation of the eco-factor for mercury.

Substance	Eco-factor (EP/g)	Actual flow (t/a)	Eco-factor / Actual flow	Weighting
Zn	11.00	92'000	0.00012	6.1%
Cd	8.40	5'300	0.0016	81.3%
Pb	57.00	232'500	0.00025	12.6%
Hg	3.30	2'500	0.0013	

5 Emissions into surface water

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

5.1.1 Environmental impact

In Frischknecht et al. (2009) the environmental impact of organic pollutants is described as follows:

“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 waste water. In essence all organic substances pollute waters in that they consume oxygen, thus restricting the habitat of the fauna that depends on it. In addition to this, many substances (such as chlorinated organic compounds or endocrine substances) can have specific toxic impacts which should be recorded separately.

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

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

COD (chemical oxygen demand)
COD expresses the amount of oxygen required to oxidize organic compounds. In Japan COD is used principally to determine the quality of bays and lakes. 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.

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.

If necessary DOC can be converted into COD using the estimation factor COD (in g) $\approx$ 3 DOC (in g). A lower estimate for COD can also be derived from BOD, with COD (in g) = BOD (in g). If only the TOC value has been measured, this can be regarded as equivalent to DOC for the purpose of a rough approximation, hence COD can be estimated with COD (in g) $\approx$ 3 TOC (in g) (Brand et al. 1998, Frischknecht et al. 2009).

5.1.2 Political targets and situation in Japan

Japan defines environmental quality standards (EQS) based on the required water quality (see Chapter 3.1 for more information on EQS). Several monitoring stations observe the water quality along rivers, lakes and coastal waters.

According to Ministry of the Environment (2009a) the achievement level of the EQS for Biochemical Oxygen Demand (BOD) or Chemical Oxygen Demand (COD) was 85.8 % in FY2007. By water areas, the achievement levels were 90.0 % for rivers, 50.3 % for lakes and 78.7 % for seas. The achievement rates of EQS in enclosed water areas, in terms of COD were 63.2 % for Tokyo Bay, 56.3 % for Ise Bay, 66.7 % for Osaka Bay and 78.0 % for the Seto Inland Sea excluding Osaka Bay.

5.1.3 Normalization

The normalization flow corresponds to the actual flow.

5.1.4 Weighting

Current flow

For the main 14 rivers the mean discharge in 2001 is available (Infrastructure Development Institute Japan & Japan River Association 2006) as well as the concentration at different monitoring stations for 2007 (Ministry of Environment 2009b). These 14 rivers represent 25 % of total renewable surface water per year (FAO 1998-2010). To calculate the annual BOD flow the highest mean value shown for all monitoring stations in each river is multiplied with the average annual discharge. The resulting annual BOD flow is 700’000 tons/a.

Another approach to calculate the annual BOD flow is via industrial and domestic BOD emissions. The World Bank database shows industrial BOD emissions for Japan in 2005 of about 400’000 tons/a (World Bank 2005). To estimate domestic BOD emissions the definition of “population equivalent” used in wastewater management is applied, which corresponds to 60 gram BOD_5 per day and population equivalent[9]. In total 73.30 % of the Japanese population are connected to a municipal wastewater treatment facility, 63.5 % to public sewer systems, 7.6 % to a household treatment facility and 2.3 % to an agricultural community effluent treatment facility[10]. For the first facility a BOD removal of 95 % is assumed. It is not clear which technologies are used in case of the household and agricultural community effluent treatment facilities. Thus, it is assumed that they include septic tanks and wetlands, etc. For these facilities an overall BOD removal of 60 % is assumed. The resulting domestic BOD flow amounts to 940’000 tons/a. Industrial and domestic BOD emissions amount to about 1’350’000 tons BOD.

This is considerably higher as compared to the flow calculated via measured concentrations. However, some organic substances decompose very quickly and do not reach the monitoring station. Thus, the BOD flow calculated via industrial and domestic emissions seems to be more reliable.

To avoid double counting COD flows into rivers and bays are not considered as rivers end up in lakes and bays.

Critical flow

The critical flow is determined via the weighting factor and current flow.

An average weighting factor is assessed for 14 rivers using the highest BOD concentration measured in the river (Ministry of Environment 2009b) and the respective EQS concentration. 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 river, weighted with their respective discharge volumes (Infrastructure Development Institute Japan & Japan River Association 2006). The calculation is shown in Tab. 5.1.

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[9] Definition according to OECD Glossary of statistical terms, http://stats.oecd.org/glossary/

[10] The Ministry of Environment, Japan, Rate of Development of Municipal Wastewater Treatment Facility, http://www.env.go.jp/en/statistics/water/index.html#w_54, retrieved on May 2010

Tab. 5.1: Calculation of the average BOD weighting factor for Japanese rivers based on the current and target concentrations.

River	BOD mean value (mg/l)	BOD EQS (mg/l)	Discharge volume* (m^3/s)	Weighting factor (-)
Tone river	3.3	2	290	2.72
Ishikari	1.8	3	151	0.36
Shinano	1.2	2	486	0.36
Kitakami	1.2	3	295	0.16
Kiso	1.1	2	162	0.30
Tokachi	2.3	8	99	0.08
Jodo	3.2	5	235	0.41
Agano	1.1	2	396	0.30
Mogami	1.3	3	405	0.19
Teshio	0.8	2	140	0.16
Abukuma	1.4	3	52	0.22
Tenryu	3.3	3	176	1.21
Omono	1	3	227	0.11
Yoneshiro	1	3	99	0.11
Fuji	1.3	2	75	0.42
Weighting factor for Japan				**0.53**

*discharge volume: The values shown refer to the annual average discharge volume. Depending on the season the discharge volume can increase up to a factor of 50.

5.1.5 Eco-factor for organic pollutants

As COD, BOD, DOC and TOC measure the same thing – organic carbon – care must be taken not to count them twice. To derive one factor from the other values, the rule of thumb described in Section 5.1.1 can be applied.

Tab. 5.2: Eco-factor for organic pollutants.

	Actual situation	Remarks	JEPIX
Normalization (t BOD/a)	1'350'000	estimated via domestic and industrial emissions (see Section 5.1.3)	
Actual flow (t BOD/a)	1'350'000		10'149'742
Critical flow (t BOD/a)	1'854'550	calculated via weighting factor	7'747'307
Weighting (-)	0.53	calculated via EQS (see description in Section 5.1.4)	
Eco-factor (EP/g BOD)	**0.39**		**0.169**
Eco-factor (EP/g COD)	0.39	rough approximation: BOD ≈ COD	3.272
Eco-factor (EP/g DOC)	1.2	derived from the eco-factor for COD with COD ≈ 3 DOC	
Eco-factor (EP/g TOC)	1.2	rough approximation: COD ≈ 3 DOC ≈ 3 TOC	

Due to the new derivation methodology, the new eco-factor for BOD is substantially higher than the previous one, although emissions have already dropped significantly. In case of COD the derived eco-factor is considerably lower by a factor of approximately 10. In JEPIX (Miyazaki et al. 2004) separate factors for BOD in rivers and COD in lakes and bays are assessed whereas in this study one factor for organic pollutants is established to make sure double counting is avoided.

The weighting of specific impacts of persistent bioaccumulative substances is not possible with the eco-factor for COD.

5.2 Nitrogen and phosphorous

5.2.1 Environmental impact

In Frischknecht et al. (2009) the environmental impact of nitrogen released to surface water is described as follows:

“Over 90 % of anthropogenic total nitrogen in surface waters consists of nitrate and ammonium or ammonia. Sources of nitrogen in waters are agricultural fertilizers and industrial, commercial and household effluents. The eco-factors in this chapter only evaluate the nitrogen loads in surface waters. Nitrogen compounds (notably nitrate) which are first released into groundwater and enter surface waters from there are assessed separately in the chapter on groundwater (see Section 6.1).”

Furthermore, the environmental impact of phosphorous released to surface water is described as following:

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

5.2.2 Political targets and situation in Japan

Japan defines environmental quality standards (EQS) concerning nitrogen and phosphorous concentrations for lakes and coastal waters but nor for rivers (see Chapter 3.1 for more information on EQS). The EQS are defined based on the required water quality. Several monitoring stations observe the water quality along rivers, lakes and coastal waters.

5.2.3 Normalization

The normalization flow is the total amount of nitrogen and phosphorous discharged into bays and rivers. It amounts to 358’000 tons/a in case of nitrogen and 21’000 tons/a in case of phosphorous.

5.2.4 Weighting

Current flow

Annual nitrogen and phosphorous flows into the three bays Tokyo Bay, Ise Bay, and Seto Inland Sea are estimated by the Japanese Ministry of Environment[11]. They amount to about 290’000 tons in case of nitrogen and 19’000 tons in case of phosphorous. Next to the bays the lakes are of primary interest with regard to nitrogen and phosphorous pollution.

The Ministry of Land Infrastructure Transport and Tourism (2002) published the area, elevation and perimeter of the most important 43 lakes. Annual mean concentrations at monitoring stations are available for nitrogen and phosphorous (Ministry of Environment 2009b). The actual flow of lakes is

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[11] Figures for FY2004 are available from http://www.env.go.jp/en/statistics/water/index.html#w_54, most recent figures are provided by Hayashi Kiyotada, National Agricultural Research Center 11.6.2010

calculated via the lake's volume and its average annual concentration of nitrogen and phosphorous. The lakes shown in Tab. 5.3 represent about 70 % of total surface area of lakes. The values are extrapolated to the total lake surface area of Japan. Annual nitrogen flow into lakes amounts to 70'650 tons/a and annual phosphorous flow to 1'345 tons/a.

Critical flow

The critical flow is determined via the weighting factor and current flow.

A similar approach as for the BOD weighting factor is applied (see Section 5.1.4) with regard to lakes. The weighting factor is calculated separately for every lake and an 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. 5.3).

With regard to bays the critical flow is determined by the government[11].

Tab. 5.3: Calculation of weighting factors for nitrogen and phosphorous. The lakes shown represent about 70 % of total lake surface area.

Name	Nitrogen		Phosphorous		Volume	Weighting	
	Meas-urement (mg/l)	EQS (mg/l)	Meas-urement (mg/l)	EQS (mg/l)	(km^3)	Nitrogen (-)	Phospho-rous (-)
Lake Biwa	0.26	0.2	0.013	0.01	27.5	1.690	1.690
Kasumigaura	1.4	0.4	0.1	0.03	0.848	12.250	11.111
Saroma	0.19	0.2	0.021	0.02	1.3	0.903	1.103
Inawashiro			0.003	0.01	5.4		0.090
Nakaumi	0.41	0.4	0.046	0.03	0.47	1.051	2.351
Kussharo			0.004	0.005	22.5		0.640
Shinji	0.48	0.4	0.053	0.03	0.34	1.440	3.121
Shikotsuko			0.003	0.005	20.9		0.360
Toya			0.003	0.005	8.19		0.360
Lake Hamana	0.46	0.3	0.022	0.03	0.35	2.351	0.538
Kitaura	1.3	0.4	0.16	0.03	*1.41*	10.563	28.444
Abashiri	0.89	0.6	0.059	0.05	0.232	2.200	1.392
Average weighting factor						**1.98**	**1.01**

5.2.5 Eco-factor for nitrogen and phosphorous

The eco-factor is calculated according to the formula described in Section 2.

Tab. 5.4: Eco-factor for nitrogen released into surface water.

	Lakes	Bays	combined	Remarks	JEPIX
Normalization (t N/a)	357'905	357'905	357'905	situation 2007 for lakes and 2009 for bays	
Actual flow (t N/a)	70'650	287'255	357'905		374'372
Critical flow (t N/a)	50'167	266'617	316'784	calculated via weighting factor	216'689
Weighting (-)	1.98	1.16	1.28	calculation described in the text (Section 5.2.4)	
Eco-factor (EP/g N)	5.5	3.2	**3.6**		**7.97**

Tab. 5.5: Eco-factor for phosphorus released into surface water.

	Lakes	Bays	combined	Remarks	JEPIX
Normalization (t P/a)	20'690	20'690	20'690	situation 2007 for lakes and 2009 for bays	
Actual flow (t P/a)	1'345	19'345	20'690		18'301
Critical flow (t P/a)	1'336	16'667	18'003	calculated via weighting factor	18'299
Weighting (-)	1.014	1.347	1.32	calculation described in the text (Section 5.2.4)	
Eco-factor (EP/g P)	49	65	**64**		**84.43**

The combined eco-factors are in the same order of magnitude as eco-factors with regard to bays. This is due to the higher loads and consequently higher importance of pollutants in bays. Eco-factors of nitrogen and phosphorous are lower as compared to JEPIX (Miyazaki et al. 2004).

5.3 Heavy metals and arsenic

5.3.1 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 through the food chain.

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

Cadmium is an ingredient of phosphorus fertilizers and pesticides, meaning that agriculture is another source of heavy metals. Chromium arises mainly from the corrosion of chromium steel products.

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

5.3.2 Political targets and situation in Japan

Japan defines environmental quality standards and guidelines concerning heavy metals in water (Tab. 5.6, see Chapter 3.1 for more information on EQS). Furthermore, the here investigated heavy metal emissions belong to PRTR Class I Designated Chemical Substances (see Chapter 3.2 for more information about the PRTR system).

Tab. 5.6: Standard and guideline values defined in Japan for heavy metal concentration in water

Substance	Standard value (mg/L)	Guideline value (mg/L)
Cadmium	≤ 0.01	
Lead	≤ 0.01	
Arsenic	≤ 0.01	
Total mercury	≤ 0.0005	
Nickel		-
Molybdenum		≤ 0.07
Antimony		≤ 0.02
Total manganese		≤ 0.2

5.3.3 Normalization

The normalization flow is the sum of all heavy metal emissions considered and amounts to about 1030 tons in 2007 (Tab. 5.7)

5.3.4 Weighting

Current flow

Annual flows are reported in the PRTR database (Ministry of Environment 2007). Tab. 5.7 shows the releases into water and the share of estimated releases.

Tab. 5.7: Releases into water for FY 2007 and the share of estimated releases.

Substance	Releases into water (kg/a)	Share estimated (%)
cadmium and its compounds	2'455	0%
lead and its compounds	15'181	2%
arsenic and its inorganic compounds	17'825	0%
mercury and its compounds	505	61%
molybdenum and its compounds	145'459	59%
antimony and its compounds	11'053	1%
manganese and its compounds	833'320	1%

Critical flow

The critical flow is determined via the weighting factor and current flow.

The weighting factors for cadmium, lead, arsenic and mercury are calculated combining the EQS and concentration measurements at 5630 monitoring stations for FY2008[12] (see Tab. 5.8). This information includes data about average and maximal substance concentrations. To calculate the weighting factor, the annual average concentration is divided by the respective EQS.

Tab. 5.8: Highest, lowest and average measured concentrations from 5630 monitoring stations.

Substance	Measured concentrations (mg/L)			EQS
	minimum	maximum	average	mg/L
Cadmium	0.0005	0.018	0.0013	<0.01
Lead	0.0	0.056	0.0041	<0.01
Arsenic	0.0	0.081	0.0038	<0.01
Mercury	0.0005	0.0050	0.0005	<0.0005

The weighting factors for molybdenum, antinomy and manganese are calculated using the guideline values and concentration measurements in the prefecture Ehime (Ehime Prefectural Government 2006). Measurements of several substances at 400 monitoring stations in FY2006 are available for the prefecture Ehime (Tab. 5.9). However, only 45 measurements report the substances investigated. To calculate the weighting factor of these substances the weighted average concentration is divided by the respective guideline value.

Tab. 5.9: Highest, lowest and average measured concentrations from 400 monitoring stations.

Substance	Measured concentrations (mg/L)			EQS
	minimum	maximum	average	mg/L
Molybdenum	0.005	0.02	0.008	0.07
Antimony	0.0005	0.208	0.011	0.02
Manganese	0.0001	0.0185	0.002	0.2

5.3.5 Eco-factor for heavy metals

The eco-factor is calculated according to the formula described in Chapter 2.

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[12] Provided by Hayashi Kiyotada, National Agricultural Research Center, Japan, 13.10.2010

Tab. 5.10: Eco-factor for cadmium.

	Actual situation	Comments	JEPIX
Normalization (t/a)	1'026	sum of all heavy metal emissions considered	
Actual flow (t Cd/a)	2.5	Ministry of Environment (2007)	-
Critical flow (t Cd/a)	20	calculated via weighting factor	-
Weighting (-)	0.02		
Eco-factor (EP/g Cd)	**15**		-

Tab. 5.11: Eco-factor for lead.

	Actual situation	Comments	JEPIX
Normalization (t/a)	1'026	sum of all heavy metal emissions considered	
Actual flow (t Pb/a)	15	Ministry of Environment (2007)	-
Critical flow (t Pb/a)	37	calculated via weighting factor	-
Weighting (-)	0.17		
Eco-factor (EP/g Pb)	**170**		-

Tab. 5.12: Eco-factor for arsenic.

	Actual situation	Comments	JEPIX
Normalization (t/a)	1'026	sum of all heavy metal emissions considered	
Actual flow (t As/a)	18	Ministry of Environment (2007)	-
Critical flow (t As/a)	47	calculated via weighting factor	-
Weighting (-)	0.14		
Eco-factor (EP/g As)	**140**		-

Tab. 5.13: Eco-factor for mercury.

	Actual situation	Comments	JEPIX
Normalization (t/a)	1'026	sum of all heavy metal emissions considered	
Actual flow (t Hg/a)	0.505	Ministry of Environment (2007)	-
Critical flow (t Hg/a)	0.504	calculated via weighting factor	-
Weighting (-)	1.00		
Ecofactor (EP/g Hg)	**980**		-

Tab. 5.14: Eco-factor for molybdenum.

	Actual situation	Comments	JEPIX
Normalization (t/a)	1'026	sum of all heavy metal emissions considered	
Actual flow (t Mo/a)	145	Ministry of Environment (2007)	-
Critical flow (t Mo/a)	1'255	calculated via weighting factor	-
Weighting (-)	0.013		
Eco-factor (EP/g Mo)	**13**		-

Tab. 5.15: Eco-factor for antimony.

	Actual situation	Comments	JEPIX
Normalization (t/a)	1'026	sum of all heavy metal emissions considered	
Actual flow (t Sb/a)	11	Ministry of Environment (2007)	-
Critical flow (t Sb/a)	20.1	calculated via weighting factor	-
Weighting (-)	0.30		
Ecofactor (EP/g Sb)	**290**		-

Tab. 5.16: Eco-factor for manganese.

	Actual situation	Comments	JEPIX
Normalization (t/a)	1'026	sum of all heavy metal emissions considered	
Actual flow (t Mn/a)	833	Ministry of Environment (2007)	-
Critical flow (t Mn/a)	103'304	calculated via weighting factor	-
Weighting (-)	0.0001		
Ecofactor (EP/g Mn)	**0.06**		-

Eco-factors for some heavy metals are rather high even though the weighting factor is below 1. This reflects the great harmfulness of these substances. Heavy metal emissions into water were not previously assessed in JEPIX (Miyazaki et al. 2004).

5.4 Radioactive releases

5.4.1 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).

5.4.2 Political targets and situation in Japan

There are no political targets nor laws for radioactive emissions but a guideline value is defined for uranium, which is 0.002 mg/L (see Chapter 3.1 for more information on EQS). In FY2007 8.4 % of all monitoring stations exceeded these guideline value[13].

With regard to radioactive water emissions not only the operation of plants but also reprocessing of used fuels are important. Japan is starting up a major (800 t/yr) plant at Rokkasho while having had most of its used fuel reprocessed in Europe meanwhile. Until 2006 it had a small (90 t/yr) reprocessing plant operating at Tokai Mura[14].

5.4.3 Characterization

Due to the relatively short distances to the Sea, we propose to use the characterization factors developed for radionuclide emissions to the Sea. The characterization of radioactive emissions released to the Sea is developed in Frischknecht et al. (2009). The environmental impact of the emission of radioactive elements is characterized according to its carcinogenic impact on humans. Impacts on ecosystems are not considered.

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[13] http://www.env.go.jp/council/09water/y095-09/mat03_6.pdf, January 2011

[14] World nuclear association, http://www.world-nuclear.org, January 2011

Tab. 5.17: Characterization factors for radioactive discharges to the Sea, 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	5.75E-05
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

5.4.4 Normalization

The normalization flow represents the characterized current flow of radionuclide emissions from nuclear reactor operation and fuel reprocessing in liquid effluent. It amounts to 1000 GBq-eq/a. The reprocessing plant stopped its operation in 2006. In 2012 the new reprocessing plant at Rokkasho is expected to start operation[14], thus liquid emissions from reprocessing plants are considered even if no such emissions occur at the moment.

Radionuclide emissions of nuclear reactor operation are shown in UNSCEAR (2000) and UNSCEAR (2008) for the years 1977-2002. Tritium emissions are reported separately, all other emissions are summarized in the category “other radionuclide emissions”. Individual substance emissions need to be known for the characterization. The shares of an individual isotope to the total emissions are calculated based on Dones (2005) and assigned to the category “other radionuclide”.

Radionuclide emissions of nuclear fuel reprocessing are reported by UNSCEAR (2008) for the years 1998-2002. In general, emissions are separated in tritium, C-14, Co-60, Sr-90, Ru-106, I-129, and Cs-137. Unfortunately, for the Japanese plant in Tokai only few emissions are reported. From the reported substances, as e.g. Tritium, it can be concluded that emissions per ton reprocessed fuel were about 7 times lower in Tokai (J) than in La Hague (F) and Sellafield (UK) in 2000 until 2002. For these two reprocessing plants more detailed emissions are reported and also shown in Frischknecht et al. (2009). To estimate the radionuclide emissions of the Japanese reprocessing plant, emissions of La Hague and Sellafield are scaled to the amount processed in Tokai and divided by a factor of 7 to represent the lower emission situation.

Tab. 5.18: Liquid emissions of nuclear electricity operation plants and nuclear fuel reprocessing plants in Japan. Characterized flow is calculated with factors given in Tab. 5.17. n.r.: not reported

	Operation (GBq)	**Repro-cessing (GBq)**	**Total (GBq)**	**Characterization (C-14 kBq-eq/kBq)**	**Characterized amount (C14 GBq-eq)**
Americum-241	n.r.	0.28	0.28	25.8	7.21
Carbon-14	n.r.	114	114	1.00	114
Curium-alpha	n.r.	0.05	0.05	47.5	2.41
Cobalt-60	0.0044	5.99	6.00	0.33	1.95
Cesium-134	0.00004	2.54	2.54	0.07	0.17
Cesium-137	0.0019	47.8	47.8	0.07	3.15
Cesium-144	n.r	4.45	4.45	0	0.00
Tritium	386'247	77'773	464'020	0.00006	26.7
Iodine-129	n.r.	9.94	9.94	83.3	829
Plutonium-alpha	n.r.	1.53	1.53	6.17	9.42
Ruthenium-106	n.r.	64.7	64.7	0.12	7.54
Antimony-125	0.00018	40.4	40.4	0.01	0.50
Strontium-90	0.00001	101	101	0.003	0.34
Uranium-234	n.r.	n.r.	n.r.	0.0192	-
Uranium-235	n.r.	n.r.	n.r.	0.0208	-
Uranium-238	n.r.	n.r.	n.r.	0.0192	-
Total					**1002**

5.4.5 Weighting

Due to the data situation no current and critical flow are assessed in terms of released amount per year. The weighting factor is thus calculated combining EQS and concentration measurements of uranium. The so derived weighting factor is applied to all radionuclide emissions.

Measurements of uranium concentrations are available for 8 monitoring stations of rivers and areas (Ministry of Environment 2008). The average concentration exceeding the guideline value is 0.0027 mg/L. 61 out of 725 monitoring stations exceed the guideline value.

For these 61 monitoring station a value of 0.0027 mg/l is applied. For the remaining 664 monitoring stations 10% of the guideline value is applied. Weighting these concentrations with the number of monitoring stations result in an average concentration of 0.0004 mg/l for all monitoring stations. To calculate the weighting factor the average concentration is divided by the guideline value.

In the same way the weighting factor can be elaborated applying the data measured in the prefecture Ehime (Ehime Prefectural Government 2006). This results in a very similar weighting factor.

5.4.6 Eco-factor for radionuclides

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 5.19: Eco-factor for radionuclides emitted to the Sea.

	Actual situation	Comments	JEPIX
Normalization (GBq C14-eq/a)	1002	see description in text (Section 5.4.4)	
Actual flow (mg U/l)	0.00042	weighted concentration	
Critical flow (mg U/l)	0.002	guideline value	
Weighting (-)	0.04		
Ecofactor (EP/kBq C14-eq)	**43**		

The eco-factor is assigned for the first time here.

Using the characterization it is possible to calculate eco-factors for selected isotopes. These are listed in Tab. 5.20.

Tab. 5.20: Eco-factor for individual isotopes emitted to the Sea.

Substance	Characterization	Eco-factor (EP/kBq)
Americum-241	25.83	1100
Carbon-14	1.00	43
Curium-alpha	47.50	2000
Cobalt-60	0.33	14
Cesium-134	0.07	2.8
Cesium-137	0.07	2.8
Tritium	0.00006	0.0025
Iodine-129	83.33333	3600
Plutonium-alpha	6.17	270
Ruthenium-106	0.12	5
Antimony-125	0.01	0.54
Strontium-90	0.0033	0.14
Radioactive species, Nuclides, unspecified	0.02	0.86
Actinides, radioactive, unspecified	0.05	2.2

5.5 AOX

5.5.1 Environmental impact

AOX (adsorbable organic halogenated compounds) is an aggregate parameter including halogenated (mostly chlorinated) organic substances. Materials of both anthropogenic and natural origin, such as chlorinated non-aromatic hydrocarbons (e.g. chloroform), chlorinated aromatic hydrocarbons, polychlorinated biphenyls (PCBs) and certain pesticides fall into this group (Frischknecht 2009).

The toxicity and environmental impact of the compounds in the AOX group varies widely. An important criterion for toxicity is the ability of the substance to accumulate in an organism. This is possible for fat-soluble substances. The greater the chlorination, the more toxic the substance, as they are fat-soluble and thus bioavailable. Because of this the eco-factor in the following is determined in relation to the chlorine, so that the eco-factor of a substance rises in proportion to the number of chlorine atoms (Frischknecht 2009).

The creation of an eco-factor for AOXs is a compromise. The weighting of very different toxic substances with a common eco-factor can lead to inaccurate statements in respect of environmental pollution. Nevertheless an eco-factor is derived for AOXs, partly because life cycle inventories often still state this value and partly because subdividing AOXs into distinct, homogeneous substance classes or even individual substances is only practicable to a limited extent.

5.5.2 Political targets and situation in Japan

No environmental quality standard or guideline value exists for AOX as sum parameter. However, for some substances falling into the AOX group standard or guideline values are available (see Tab. 5.21, see Chapter 3.1 for more information on EQS). These substances belong to PRTR Class I Designated Chemical Substances (see Chapter 3.2 for more information about the PRTR system).

Tab. 5.21: AOX substances for which a standard or guideline value is defined.

Substance	Standard values (mg/l)	Guideline values (mg/l)	Formula
Chloroform		0.06	$CHCl_3$
Trans-1,2-dichloroethylene		0.04	$C_2H_2Cl_2$
1,2-Dichloropropane		0.06	$C_3H_6Cl_2$
p-Dichlorobenzene		0.2	$C_6H_4Cl_2$
Dichloromethane	0.02		CH_2Cl_2
1,2-Dichloroethane	0.004		$C_2H_4Cl_2$
1,1-Dichlorethylene	0.02		$C_2H_2Cl_2$
Cis-1,2-Dichloroethylene	0.04		$C_2H_2Cl_2$
1,1,1-Trichloroethane	1		$C_2H_3Cl_3$
1,1,2-Trichlorethane	0.006		$C_2H_3Cl_3$
Trichloroethylene	0.03		C_2HCl_3
Tetrachloroethylene	0.01		C_2Cl_4
1,3-Dichloropropene	0.002		$C_3H_4Cl_2$

5.5.3 Characterization

AOX are characterized via the chemical formula, i.e. the number of Cl^- atoms.

5.5.4 Normalization

The normalization flow corresponds to the current flow.

5.5.5 Weighting

Current flow

The current flow for all AOX emissions corresponds to the characterized flow. Annual flows of the investigated substances to water are recorded in the PRTR database (Ministry of Environment 2007). Tab. 5.22 shows the releases into water and the share of estimated releases.

Tab. 5.22: Releases into water for FY 2007 and the share of estimated releases.

Substance	Releases into water (kg/a)	Characterized releases (kg Cl^-/a)	Share estimated
Chloroform	118'720	356'159	11%
Trans-1,2-dichloroethylene	14	29	0%
1,2-Dichloropropane	6	12	0%
p-Dichlorobenzene	664	1'327	16%
Dichloromethane	6'474	12'948	100%
1,2-Dichlorethan	70	141	0%
1,1-Dichlorethylen	6'252	12'504	0%
Cis-1,2-Dichlorethylen	91'559	183'118	0%
1,1,1-Trichloroethane	9'677	29'031	0%
1,1,2-Trichlorethan	4'248	12'744	0%
Trichloroethylene	2'688	8'063	13%
Tetrachloroethylene	18'042	72'169	10%
1,3-Dichloropropene	558'825	1'117'650	100%
Total		**1'805'895**	

Critical flow

The critical flow is calculated via the weighting factor and current flow. Weighting factors are elaborated for every single substance for which standard or guideline values are defined.

For the substances dichloromethane, 1,2-dichloroethylene, cis-1,2 dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethylene and tetrachloroethylene measurements of 5630 monitoring stations for FY2008 are available[15]. This information includes data about average and maximal substance concentrations. To calculate the weighting factor for every single substance the annual average concentration is divided by the respective standard or guideline value.

Concentration measurements of the other substances are available for the Ehime prefecture (Ehime Prefectural Government 2006). However, only 45 measurements report the substances investigated. To calculate the weighting factor of these substances the average concentration is divided by the respective standard or guideline value.

An overall average weighting factor for AOX is then assessed weighted with the respective characterization factors of the single substances.

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[15] Provided by Hayashi Kiyotada, National Agricultural Research Center, Japan, 13.10.2010

Tab. 5.23: Calculated average concentration, standard or guideline value, weighting, and characterization factors of some AOX substances.

Substance	Average concentration (mg/l)	Standard or guideline value (mg/l)	Calculated weighting factor	Characterization
Chloroform	0.0012	0.06	0.0004	3
Trans-1,2-dichloroethylene	0.0008	0.04	0.0004	2
1,2-Dichloropropane	0.0012	0.06	0.0004	2
p-Dichlorobenzene	0.0060	0.2	0.0009	2
Dichloromethane	0.0020	0.02	0.2000	2
1,2-Dichlorethan	0.0004	0.004	0.0098	2
1,1-Dichlorethylen	0.0019	0.02	0.0101	2
Cis-1,2-Dichlorethylen	0.0037	0.04	0.0086	2
1,1,1-Trichloroethane	0.0200	1	0.0084	3
1,1,2-Trichlorethan	0.0006	0.006	0.0004	3
Trichloroethylene	0.0020	0.03	0.0095	3
Tetrachloroethylene	0.0007	0.01	0.0046	4
1,3-Dichloropropene	0.0002	0.002	0.0126	2

5.5.6 Eco-factor for AOX

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 5.24: Eco-factor for AOX.

	Actual situation	Comments	JEPIX
Normalization (t AOX as Cl^-/a)	56	PRTR database (Ministry of Environment 2007)	
Actual flow (t AOX as Cl^-/a)	56		-
Critical flow (t AOX as Cl^-/a)	472	calculated via weighting factor	-
Weighting (-)	0.02		
Ecofactor (EP/ g AOX as Cl^-)	**310**		**-**

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 of prime concern.

5.6 PAH (polycyclic aromatic hydrocarbons) and Benzo(a)pyrene

For these substances neither information on actual flows nor political targets are known to the authors. Thus, these two substances are not assessed in the current method.

5.7 Endocrine disruptors

5.7.1 Environmental impact

In Frischknecht et al. (2009) the impact of endocrine disruptors is described as follows:

“Hormones are chemical messengers between tissues and cells that regulate processes in the body. Sex hormones play an important role in reproduction and the development of an organism. Hormones are already effective in very small concentrations.

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

Endocrine disruptors can operate in two ways:

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

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

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

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

Hormonal effects have been proven in the case of the following substances and substance groups:

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

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

5.7.2 Political targets and situation in Japan

Japan’s research on the mechanisms of endocrine disruption has progressed, along with environmental monitoring, test development and implementation through the Millennium Project, as well as annual international symposia and collaborative research between Japan and the United Kingdom of Great

Britain and Northern Ireland, or between Japan and the Republic of Korea (Ministry of the Environment 2005).

5.7.3 Characterization

The same characterization factors as in Frischknecht et al. (2009) are applied, based on Rutishauser et al. (2004). Listed are the oestrogenic potentials (kg E2-eq/kg) of a number of endocrine disruptors. This figure describes the strength of the impacts of an endocrine disruptor in relation to 17β-oestradiol (abbreviation E2). The equivalence factors were determined by using YES (yeast estrogen screening), as other methods can easily produce inaccurate factors. The YES procedure is well accepted in scientific circles.

The figures for oestrogenic potential in Tab. 5.25 can be used as characterizations for calculating the eco-factors of individual substances. To determine eco-factors for 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. 5.25: Characterization factors for some endocrine disruptors, based on their oestrogenic potential according to Rutishauser et al. (2004).

Name of substance	Abbreviation	Oestrogenic potential (kg E2-eq/kg)
Oestrone	E1	0.38
17β-oestradiol	E2	1
Oestriol	E3	$2.40 * 10^{-3}$
17α-ethinyloestradiol	EE2	1.19
Bisphenol A	BPA	$1.10 * 10^{-4}$
Nonylphenol	NP	$2.50 * 10^{-5}$
4-tert-octylphenol	OP	$7.80 * 10^{-6}$
Mestranol	MES	0.013
β-oestradiol-17-valerate	E2-Val	0.21

5.7.4 Normalization

The normalization flow is identical to the current flow.

5.7.5 Weighting

Current flow

The discharge of endocrine disruptors from anthropogenic sources to surface waters are extrapolated from concentration measurements of wastewater treatment plan effluents. Based on the estimated average concentration of endocrine disruptors (10 ng/l E2-eq according to Johnson et al. (2007)) and the total annual treated wastewater in Japan (13 Mio m^3, Tajiama et al. 2002) the load for Japan is calculated at 133 kg E2-eq/a.

According to Yinga et al. (2002) the effluent concentration of 17β-Estradiol in sewage treatment plants in Japan was between 3.2 and 55 ng/l (average 14 ng/l) in 1999 for summer samples. The characterization factor of this substance is 1, thus the average concentration given in Johnson et al. (2007) seems to be at the lower end.

Critical flow

Statutory limits or required values for an endocrine disruptor aggregate parameter do not yet exist. Experts assume that at a concentration below 0.5 ng E2-eq./l (predicted no effect concentration – PNEC) no further chronic effects should arise and that this value can therefore be used as the quality target (according to Frischknecht et al. (2009)).

The total critical load of Japan is thus calculated over the estimated total Japanese runoff (see Chapter 5.1) of about 100’000 Mio m^3/a to 52 kg E2-eq/a.

5.7.6 Eco-factor for endocrine disruptors

The eco-factor is calculated according to the formula described in Chapter 2.

Tab. 5.26: Eco-factor for endocrine disruptors.

	Actual situation	**Comments**	**JEPIX**
Normalization (kg E2-eq/a)	133	see description in text (Section 5.7.4)	
Actual flow (kg E2-eq/a)	133		
Critical flow (kg E2-eq/a)	52	calculated via scientific threshold	
Weighting (-)	7		
Ecofactor (EP/g E2-eq)	**50'000'000**		

The eco-factor should be regarded as a lower estimate, as the estimate of the critical flow is rather high. By using characterization eco-factors can be established for further substances for which the oestrogenic potential is known (Tab. 5.27).

Tab. 5.27: Eco-factors of some endocrine disruptors in EP/g.

Name of substance	**Abbreviation**	**Oestrogenic potential (kg E2-eq/kg)**	**Ecofactor (EP/g)**
Oestrone	E1	0.38	19'000'000
17β-oestradiol	E2	1	50'000'000
Oestriol	E3	$2.40 * 10^{-3}$	120'000
17α-ethinyloestradiol	EE2	1.19	59'500'000
Bisphenol A	BPA	$1.10 * 10^{-4}$	5'500
Nonylphenol	NP	$2.50 * 10^{-5}$	1'250
4-tert-octylphenol	OP	$7.80 * 10^{-6}$	390
Mestranol	MES	0.013	650'000
β-oestradiol-17-valerate	E2-Val	0.21	10'500'000

6 Emissions to groundwater

6.1 Nitrate (NO_3)

6.1.1 Environmental impact

Especially in areas where farming practices are intensive nitrate concentrations in groundwater often exceed the required limits for groundwater that is used or reserved for use, and in some cases even exceed the tolerance value for drinking water. Nitrogen fertilizer applied to fields is readily washed from the soil into groundwater (Frischknecht et al. 2009).

6.1.2 Political targets and situation in Japan

According to the Japanese Ministry of Environment (2009a) the general monitoring survey of groundwater quality in FY2007 result that 7.0 % (325 wells) out of the 4631 wells tested exceed EQS limits. EQS limits were most exceeded by nitrate-nitrogen or nitrite-nitrogen, an excess of 4.1 %, caused by farmland fertilization, livestock excreta and domestic wastewater. Countermeasures against them have become an urgent issue. The EQS is defined as maximal concentration of NO_3-N of 10 mg/l (see Chapter 3.1 for more information on EQS).

6.1.3 Normalization

The normalization flow is identical to the current flow.

6.1.4 Weighting

Current flow

To derive the current flow the critical flow is multiplied with the square root of the weighting factor.

To establish the weighting factor a similar approach as for the BOD weighting factor is applied (see Section 5.1.4). From Kumazawa (2002) minimum and maximum NO_3-N concentrations in groundwater and wells located in different land use types are available. In Subchapters 7.3 and 8.1 the area of the respective land use types is established and described. With the average of the concentrations a weighting factor for every land use type is calculated.

An average weighting factor is determined on the basis of the sum of the weighting factors of each land use type, weighted with their respective area. The calculation is shown in Tab. 6.1.

The resulting current flow amounts to 272’373 ton NO_3-N/a.

Tab. 6.1: Calculation of the weighting factor for NO_3-N.

Land use type	No. of sites	Area of land use type (ha)	Minimum concentration (mg/l)	Maximum concentration (mg/l)	EQS (mg/l)	Weighting factor -
Forest	69	20'072'000	0	3.91	10	0.04
Forest on a slope of plateau	38	5'018'000	0.05	2.76	10	0.02
Grassland	8	280'000	0.61	7.16	10	0.15
Paddy field	51	1'665'000	0	39.91	10	3.98
Upland field	104	2'038'000	0	67.98	10	11.55
Orchard	19	271'600	0.34	35.9	10	3.28
Green or vinyl hosue region	15	100'000	0	2.85	10	0.02
Village	16	1'072'544	0.11	27.89	10	1.96
Urban district	34	2'107'456	0	22.19	10	1.23
Others	10	3'815'400	0.06	6.49	10	0.11
Average weighting factor						**1.02**

Critical flow

The annual renewable groundwater amount is available from FAO (1998-2010) and amounts to 27 km^3. The maximum allowed concentration according to the EQS is 10 mg/l NO_3-N. This results in an annual flow of 270’000 t/a NO_3-N and corresponds to the critical flow.

6.1.5 Eco-factor for NO_3-N and NO_3

The eco-factor is calculated according to the formula described in Section 2.

Tab. 6.2: Eco-factor for NO_3-N and NO_3.

	Actual situation	Remarks	JEPIX
Normalization (t NO_3-N/a)	272'373	calculation described in text	
Actual flow (t NO_3-N/a)	272'373		-
Critical flow (t NO_3-N/a)	270'000	calculation described in text	-
Weighting (-)	1.02	calculation described in text	
Eco-factor (EP/g NO_3-N)	**3.7**		-
Eco-factor (EP/g NO_3)	**0.84**		-

7 Emissions to soil

7.1 Heavy metals to soil (Pb, Cd, Cu, Zn)

7.1.1 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 can lead to chronic poisoning. Moreover, major resource inputs are required to clean up soils contaminated with heavy metals (Frischknecht 2009).

7.1.2 Political targets and situation in Japan

Japan defines environmental quality standards (EQS) for the heavy metals investigated, except zinc (see Chapter 3.1 for more information on EQS):

- Lead: 0.01 mg/l or less in sample solution
- Cadmium: 0.01 mg/l in sample solution and less than 0.4 mg/kg in rice for agricultural land
- Copper: less than 125 mg/kg in soil for agricultural land (paddy fields only)

As zinc is considered to be harmful to plants if available in high concentrations an eco-factor for zinc is included.

7.1.3 Normalization

As the weighting refers to agricultural land, loads from sewage sludge, fertilizer, peat, and deposition to agricultural land and forests are considered in the normalization flow. From Kida & Sakai (2002) annual maximum and minimum loads from several sources to soil are available for different heavy metals. The arithmetic mean of the maximum and minimum values is used. Tab. 7.1 shows the normalization flows for the heavy metals investigated.

Tab. 7.1: Inputs of heavy metals to agricultural soil from sewage sludge, fertilizer, peat and deposition. Average values from Kida & Sakai (2002).

	Sewage sludge (t/a)	Fertilizer (t/a)	Peat (t/a)	Deposition (to agricultural land and forests) (t/a)	Normalization value (t/a)
Lead (Pb)	6'250	1'360	1'525	190'453	199'588
Cadmium (Cd)	270	140	55	4'342	4'807
Copper (Cu)	12'950	315	1'075	153'182	167'522
Zinc (Zn)	37'500	680	1'825	75'362	115'367

Following the methodology of assessment of eco-factors of heavy metals into air and surface water the sum of all heavy metals corresponds to the normalization flow. It amounts to about 490’000 t per year.

7.1.4 Weighting

The same approach as in Frischknecht et al. (2009) is used. To maintain soil fertility no accumulation of heavy metals in the soil should happen, i.e. the maximum input must not exceed the output.

The EQS for cadmium and copper are valid for rice fields only, thus the situation in rice fields is considered to establish the weighting factor. Following literature sources are available and applied due to lack of other data.

- Kikuchi et al (2006) report the yearly uptake of cadmium by rice as well as yearly loads by irrigation, atmospheric deposition, and fertilizer application.
- Okazaki & Saito (1989) report the yearly uptake of copper and zinc by rice as well as yearly loads by irrigation and fertilizer application.
- Mori et al. (2004) reports the uptake rate of lead referring to grass and forage crops. It includes the input by farmyard manure.

Current flow

The current flow of heavy metals to soils is made up of direct input given in the different literature sources mentioned above.

Tab. 7.2: Overview of information available for different heavy metals.

	Cu	Zn	Cd	Pb
EQS valid for	Paddy fields	No EQS defined	Rice	General
Considered crops	Rice	Rice	Rice	Forage crops and grass
Considered flows	Irrigation and fertilizer	Irrigation and fertilizer	Irrigation, deposition and fertilizer	Farmyard manure

Critical flow

To maintain soil fertility no accumulation of heavy metals in the soil should happen, i.e. the maximum input must not exceed the output. The output via rice, forage crops and grass is assessed in Kikuchi et al (2006), Okazaki & Saito (1989) and Mori et al. (2004) and this is used as a first approximation for the critical flow. Transfers of heavy metals into groundwater or transport through erosion were not investigated. However, except for antimony and chromium (VI) which are not assessed in this method, this effect is of little relevance.

7.1.5 Eco-factor for heavy metals

The eco-factors are calculated according to the formula described in Section 2.

Tab. 7.3: Eco-factor for lead.

	Actual situation	Remarks	JEPIX
Normalization (t Pb/a)	487'284	emission to soil due to deposition and fertilizer (Kida & Sakai 2002)	
Actual flow (t Pb/a)	11.6	grass and forage crops based on Mori et al. (2004)	-
Critical flow (t Pb/a)	2.7	grass and forage crops based on Mori et al. (2004)	-
Weighting (-)	19		
Eco-factor (EP/g Pb)	**39**		**-**

Tab. 7.4: Eco-factor for cadmium.

	Actual situation	Remarks	JEPIX
Normalization (t Cd/a)	487'284	emission to soil due to deposition and fertilizer (Kida & Sakai 2002)	
Actual flow (t Cd/a)	3.4	rice based on Kickuchi et al (2006)	-
Critical flow (t Cd/a)	2.0	rice based on Kickuchi et al (2006)	-
Weighting (-)	2.8		
Eco-factor (EP/g Cd)	**5.8**		**-**

Tab. 7.5: Eco-factor for copper.

	Actual situation	Remarks	JEPIX
Normalization (t Cu/a)	487'284	emission to soil due to deposition and fertilizer (Kida & Sakai 2002)	
Actual flow (t Cu/a)	77.0	rice based on Okazaki & Saito (1989)	-
Critical flow (t Cu/a)	33.6	rice based on Okazaki & Saito (1989)	-
Weighting (-)	5.3		
Eco-factor (EP/g Cu)	**11**		**-**

Tab. 7.6: Eco-factor for zinc.

	Actual situation	Remarks	JEPIX
Normalization (t Zn/a)	487'284	Emission to soil due to deposition and fertilizer (Kida & Sakai 2002)	
Actual flow (t Zn/a)	532	Rice based on Okazaki & Saito (1989)	-
Critical flow (t Zn/a)	275	Rice based on Okazaki & Saito (1989)	-
Weighting (-)	3.7		
Eco-factor (EP/g Zn)	**7.7**		**-**

7.2 Potassium (K)

7.2.1 Environmental impact

Agricultural crops require potassium. The exact roles of potassium in plants are not well known but K is believed to be involved in photosynthesis, carbohydrate and protein metabolism and water relations of plants (Traynor 1980).

A deficiency of potassium results in more diseases, lower quality and shelf life of the crops. The consequences of potassium excess in soils are controversial. Some state that it negatively affects the harvest rates of cultivations due to plant disorder. Others mention no harm of higher potassium contents than the recommendation limit due to its absorption characteristics (Shimono 1987; Souma 1986; Watanabe 2009; Yamazaki 1987).

7.2.2 Normalization

The normalization flow corresponds to the input of potassium into agricultural soils. Inputs derive mainly from fertilizers and manure. The amount of fertilizer consumption for the year 2007 is given in the Japanese handbook of fertilizer (Association of Agriculture and Forestry Statistics 2008) and amounts to about 350’000 tons.

The amount of K_2O input with manure is estimated with the values given in Mutert (1995). About 5 tons/ha of manure with a K_2O content of 4 kg/t are used in Asian countries. A total amount of about 41’000 tons K_2O results when considering the area harvested.

7.2.3 Weighting

Three different eco-factors are established for potassium inputs to rice fields, crop/vegetable and fruit plantations.

Current flow

The actual potassium concentration in soil is calculated from Oda et al. (1987), taking into account the average concentration, soil thickness and compactness.

Tab. 7.7: **Average potassium concentration in soils.**

Product	Potassium concentration (kg K/10a)
Rice	6.9
Crops/vegetables	22.3
Fruits	29.0

Critical flow

The ideal potassium concentration in agricultural soils is used as the target flow. A list of ideal potassium concentrations for rice, different crops/vegetables and fruits is given in Tab. 7.8. These concentrations are established by taking into account the standards (MAFF 2011a; b) of the five most important producing prefectures. A weighted average concentration is calculated for rice, crops/vegetables, and fruits considering the production volume of each product.

Tab. 7.8: **Critical flows for different agricultural products. The values represent the average standards of the five most important producing prefectures and the respective production coverage and production volume. A weighted average is calculated for the categories rice, crop/vegetable, and fruits.**

Product	Average standard (kg/10a)	Production coverage (%)	Production volume (t)	weighted average (kg/10a)
rice	8.64	30%	8'483'000	**8.64**
crop/vegetable				**15.7**
Japanese radish	10.2	43%	1'593'000	
lettuce	14.6	49%	141'100	
spinach	12.7	44%	286'300	
green pepper	23.2	65%	142'700	
Chinese cabbage	19.8	59%	924'100	
green onion	14.3	47%	508'400	
carrot	14.9	59%	650'100	
eggplant	27.4	39%	349'100	
tomato	19.3	40%	717'600	
onion	19.0	81%	1'161'000	
potato	13.5	87%	2'459'000	
Eddoe	15.7	47%	182'400	
cucumber	15.4	42%	620'200	
cabbage	19.0	57%	1'385'000	
wheat etc.	9.50	74%	732'100	
beans	8.33	47%	222'500	
tea	23.0	86%	384'700	
fruit				**10.7**
apple	7.25	92%	786'500	
peach	11.5	82%	136'700	
Tangerine	12.9	65%	786'000	
sand pear	13.3	46%	258'700	
Japanese apricot	12.9	57%	20'900	
cherry	10.0	83%	19'700	
Japanese plum	13.4	73%	92'400	

7.2.4 Eco-factors for potassium input to soil

The eco-factors are calculated according to the formula described in Section 2.

Tab. 7.9: Eco-factor for potassium input into paddy rice fields.

	Actual situation	Remarks	JEPIX
Normalization (t K/a)	392'489	emission to soil due to fertilizer and manure	
Actual flow (kg/10a)	6.9	see Tab. 7.7.	-
Critical flow (kg/10a)	8.6	see Tab. 7.8	-
Weighting (-)	0.6		
Eco-factor (EP/g K)	**1.6**	**paddy rice fields**	**-**

Tab. 7.10: Eco-factor for potassium input into crop/vegetable fields.

	Actual situation	Remarks	JEPIX
Normalization (t K/a)	392'489	emission to soil due to fertilizer and manure	
Actual flow (kg/10a)	22	see Tab. 7.7.	-
Critical flow (kg/10a)	16	see Tab. 7.8	-
Weighting (-)	2.0		
Eco-factor (EP/g K)	**5.1**	**crop/vegetables fiels**	**-**

Tab. 7.11: Eco-factor for potassium input into fruit plantations.

	Actual situation	Remarks	JEPIX
Normalization (t K/a)	392'489	emission to soil due to fertilizer and manure	
Actual flow (kg/10a)	29	see Tab. 7.7.	-
Critical flow (kg/10a)	11	see Tab. 7.8	-
Weighting (-)	7.3		
Eco-factor (EP/g K)	**19**	**fruits plantations**	**-**

Furthermore, from the three eco-factors above a weighted average potassium eco-factor is calculated.

Tab. 7.12: Average eco-factor for potassium emissions in agricultural soil.

	Actual situation	Remarks	JEPIX
Normalization (t K/a)	392'489	emission to soil due to fertilizer and manure	
Actual flow (kg/10a)	17		-
Critical flow (kg/10a)	12		-
Weighting (-)	2.0		
Eco-factor (EP/g K)	**5.1**		**-**

7.2.5 Calculating specific potassium eco-factors

Every user may calculate specific potassium eco-factors based on the specific project scope. In Tab. 7.8 critical flows for individual crops, vegetables and fruits are shown. Applying these critical flows instead of the average critical flows per crop type results in local and crop specific eco-factors (see Tab. 7.13).

These eco-factors are calculated according to the formula described in Section 2.

Tab. 7.13: Eco-factor for potassium emissions into soil.

	Actual situation	Remarks	JEPIX
Normalization (t K/a)	392'489	emission to soil due to fertilizer and manure	
Actual flow (kg/10a)	a	measured by the user, site specific concentration in kg/10a	-
Critical flow (kg/10a)	c	see Tab. 7.8	-
Weighting (-)	$w = a^2/c^2$	calculated by the user	
Eco-factor (EP/g K)	**Eco-factor = w/392’489*1’000’000**	calculated by the user taking into account the weighting factor and normalization flow (formula in Chapter 2)	**-**

7.3 Plant protection products (PPPs)

7.3.1 Environmental impact

The environmental problems associated with the use of PPPs 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. (Frischknecht et al. 2009)

One of their purposes can be to destroy undesired plants or parts of plants. In a field trial in Denmark, Esbjerg (2002) demonstrated not only that the pesticide dose correlates with plant diversity (which is the desired effect, particularly in the case of herbicides), but also that it reduces the diversity of creatures outside the target group, such as spiders, myriapoda and birds.

Meanwhile, the movement of soil particles in the wind and atmospheric transport of plant protection products has also led to the detection of active agents in mountain lakes and in rain. Human health impacts of these products arise notably from the use of groundwater as drinking water.

The eco-factor assessment mainly addresses chemical-synthetic plant protection products.

7.3.2 Political targets and situation in Japan

The positive maximum residue limit (MRL) system[16], a so-called positive list system for regulating pesticide residues in food has been active in Japan since May 2006. The system aims at prohibiting the distribution of foods that contain agricultural chemicals, veterinary drugs and food additives unless MRLs have been established for them under the Food Sanitation Law. The positive list system primarily aims to control pesticide residues in imported crops from foreign countries, because MRLs were previously established only for pesticides used in Japan. However, a default level of 0.01 ppm is uniformly applied to chemicals for which MRLs have not been determined (Umetsu 2006).

Extensive residue analyses conducted by the Japanese authorities showed rates for pesticide residue detection of about 0.5 % of the samples with levels exceeding the MRL in only about 0.01 % of the samples, indicating a quite low level of pesticide residues in crop foods distributed in Japan (Umetsu 2006).

7.3.3 Characterization

The same method as in Frischknecht (2009) is applied to characterize PPPs.

The recommended dose for plant protection products (PPPs) – in terms of the quantity of the active agent – varies by approximately a factor of 1000 between traditional PPPs which are applied at the rate 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 2003).

It is assumed that the standard weighted dose (expressed in kg/ha) of a plant protection product represents as first approximation a 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 in relation to the intended effect and the side effects runs parallel. 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. Due to the present data availability standard doses of herbicides are calculated in another way than the standard doses of other PPPs (fungicides, insecticides and growth regulators). Detailed data about amount of herbicides used per hectare, active ingredients as well as the area these herbicides are applied to are available for Japan (JAPR 2008; 2009). These data permit a calculation of the standard dose for every active ingredient. The data on the standard dose of the other plant protection products are adopted from the Swiss directory of plant protection products (Bundesamt für Landwirtschaft 2010). In order to obtain an average standard dose these values are weighted with the area of Japan under cultivation.

The standard dose of an average plant protection product used in Japan in FY 2004 was calculated from OECD statistics on agricultural area and pesticide use (OECD 2004a). The average standard dose is 13.4 kg of active ingredient per hectare. This amount is used as a reference unit to perform the characterization.

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[16] The MRL database can be accessed at http://www.m5.ws001.squarestart.ne.jp/foundation/search.html, The Japan Food Chemical Research Foundation.

7.3.4 Normalization

As a characterization is performed, the normalization flow corresponds to the characterized quantities. Characterized quantities are calculated for herbicides and due to lack of specific information extrapolated to insecticides and fungicides. This corresponds to a normalization load of 773’000 t/a of active ingredients.

7.3.5 Weighting

Current flow

The quantity of plant protection products used is available from OECD (2004a). It corresponds to 63’215 tons of active ingredient for FY2004.

Critical flow

The critical flow is determined as a reduction of 30 % compared to the use level in 1990/92[17]. This corresponds to a critical flow of 62'378 t/a of active ingredient.

7.3.6 Eco-factor for PPP’s

The eco-factor is calculated according to the formula described in Section 2.

Tab. 7.14: Eco-factor for average plant protection product.

	Actual situation	Remarks	JEPIX
Normalization (t PPP-eq/a)	773'314	extrapolated from herbicides	
Actual flow (t PPP/a)	63'125	OECD (2004a)	-
Critical flow (t PPP/a)	62'378	30% reduction compared to 1990/92	-
Weighting (-)	1.02		
Eco-factor (EP/g PPP-eq)	**1.3**		**-**

Tab. 7.15 shows eco-factors for selected plant protection products. The full list is shown in the Appendix 11.3.

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[17] Figure is provided by Kiyotada Hayashi, National Agriculture and Food Research Organization, 11.6.2010

Tab. 7.15: Eco-factors for individual plant protection products.

Active agent	Standard dose (g/ha)	Characterization factor (kg PPP-eq/kg)	Eco-factor (EP/g)
Herbicides			
Azimsulfuron	7	1840	**2'400**
Daimuron	650	21	**27**
Carbam-sodium	150'000	0.09	**0.12**
Insecticides			
Bifenthrin	18	760	**990**
Chlorpyrifos-ethyl	690	19	**25**
Fungicides	37'900	0.35	
Folpet			**9.0**
Copper	1'930	6.9	**4.0**
Metconazole	4'375	3.1	**200**
Average PPP	90	150	**1.3**

8 Resources

8.1 Land use

8.1.1 Introduction

The Ministry of Land, Infrastructure Transport and Tourism (Ministry of Land Infrastructure Transport and Tourism 1995-2006) classifies the area of Japan, which totals 377’900 km^2, into the following types of use:

- 4.9 % buildings (residential and industrial land and other)
- 3.5 % roads
- 12.6 % farmland (cultivated land, meadows and pastures)
- 66.4 % forests
- 9.0 % other

Growth in settlement area in Japan is driven by growing levels of land take per person. According to population growth projections Japanese population already reached the peak level and is decreasing (Department of Population Dynamics Research 2000).

8.1.2 Characterization

Characterization of land use follows the method adopted in Frischknecht et al. (2009). Köllner (2001) assesses the various land covers in accordance with their respective plant biodiversity. Köllner (2001) derives EDP (Ecosystem Damage Potential) factors for various land-use types, which reflect the anticipated number of species and the actually encountered number of species for the specific type of land use. Positive EDP factors of a land use mean that plant biodiversity is below average, while negative EDP factors indicate a plant diversity that is above the average.

The non-linear EDP factors ($EDP_{total\text{-}nonl\text{-}pla}$) are used to derive the characterization factors. “Settlement area” is taken as the reference type of land cover (see the full list in Appendix 11.3).

In order to reach a degree of detail that is suitable for life cycle assessments, the extended CORINE nomenclature set out in Köllner (Köllner & Scholz 2007a; b) is adopted. The same approach as in Frischknecht et al. (2009) is applied in case of missing data, water surfaces, abandoned land and unknown uses.

8.1.3 Normalization

The normalization flow is calculated as a characterized quantity. The surface areas of the land-use types, with their respective characterization factors, result in a normalization flow of 40’495 km^2*a SA-eq.

8.1.4 Weighting

Current flow

The current flow relate to the Japanese settlement area of 31’800 km^2. Settlement area includes buildings, industrial area and infrastructure (such as roads, railways, etc.)

Critical flow

No target is defined concerning land use in Japan. Japanese population will decrease in future but space requirements of each person increase. Due to these reasons it is assumed that the settlement area should not increase in future which means that the critical flow is equal to the current flow.

8.1.5 Eco-factor for land use

The eco-factor is calculated according to the formula described in Section 2.

Tab. 8.1: Eco-factor for land use.

	Actual situation	Remarks	JEPIX
Normalization (km^2*a SA-eq)	40'495		
Actual flow (km^2)	31'800	according to Ministry of Land Infrastructure Transport and Tourism (2000)	-
Critical flow (km^2)	31'800	assumption: no increase of settlement area	-
Weighting (-)	1.0		
Eco-factor (EP/m^2*a SA-eq)	**25**	eco-factor for settlement area (SA) (EDP: 0.56)	-

The "settlement area" land-use type used as the reference is a mixture of highly disparate types, ranging from green urban areas to industrial estates. The differentiated eco-factors should therefore be used wherever possible (see Section 11.3).

Tab. 8.2 shows eco-factors and characterization factors for typical land use types.

Tab. 8.2: Eco- and characterization factors of different land use types.

CORINE+	Land use	EDP	Charact. factor (m² SA-eq./m^2)	Eco-factor (EP/m^{2}a)
	Settlement area			
REF	Settlement area (reference)	0.56	1.0	25
111	Urban fabric, continuous, >80 % sealed	0.68	1.2	30
112	Urban fabric, discontinuous, <80 % sealed	0.54	0.96	24
121	Industrial or commercial units	0.573	1.0	25
122	Road and rail networks and associated land	0.56	1.0	25
	Agricultural areas			
211b	Arable land, non-irrigated, IP	0.32	0.57	14
211c	Arable land, non-irrigated, organic	0.15	0.27	6.8
245	Agricultural fallow	-0.1	-0.18	-4.5
213	Rice fields	0.24	0.43	11
	Forests			
311	Forest, broad-leaved	0.0378	0.068	1.7
313	Forest, mixed	-0.02	-0.036	-0.9
314	Forest, forest edge	-0.11	-0.20	-5
	Other use			
-	Unknown use	0.435	0.78	20

8.2 Freshwater consumption

8.2.1 Introduction

An eco-factor for freshwater use is useful when considering water-poor locations. The Swiss ecological scarcity (Frischknecht et al. 2009) distinguishes three types of eco-factors for freshwater, these are

- Country-specific
- Average of OECD countries (applicable as a first approximation in cases in which the life cycle inventory does not list water consumption levels in a regionally differentiated manner)
- For six different scarcity situations (low, moderate, medium, high, very high and extreme)

In the framework of elaborating Japanese eco-factors country specific and an average OECD eco-factor for freshwater use are calculated. The six different scarcity situations are adapted accordingly. The resulting eco-factors are not the same as for Switzerland because of different normalization flows based on the Japanese perspective. The Japanese eco-factors are based on the same literature sources and methodology like the eco-fators used in the Swiss ecological scarcity method 2006.

According to the OECD (2004b, p. 24) the scarcity of freshwater resources (water stress index) is expressed as the annual gross water consumption in a region divided by the annual available renewable water resources (precipitation, plus inflows from neighbouring states, minus evaporation).

In accordance with the OECD (2004b) and FAO (2005) water consumption includes all extractions of freshwater for production or consumption processes but excludes water used by hydroelectric facilities to generate electricity.

8.2.2 Normalization

Normalization is based on the current annual Japanese water consumption of 88 km^3/a (FAO 2005).

8.2.3 Weighting

Current flow

According to FAO (2005) the current Japanese freshwater consumption is 88 km^3/a. This includes potable water consumption as well as water extraction to irrigate agricultural area and for use in industrial processes. The annual available water resource in Japan is 430 km^3 (FAO 2005).

Frischknecht et al. (2009) calculate the water consumption of all OECD countries (excluding the Slovak Republic, due to lack of data) to be 1018 km^3/a (calculated from data in FAO (2005)). Tab. 11.5 lists the data for the individual OECD states. This figure includes mine water, water extracted for irrigation measures and the extraction of water that was already used once and was returned to a body of surface water. Water used in hydropower facilities is considered in-situ consumption and is therefore excluded.

Critical flow

According to OECD (2004b) a moderate to medium water stress is considered tolerable, and the critical flow is therefore set at 20 % of the available annual renewable water resource. The critical flow for Japan is 86 km^3/a, the one for the OECD countries is 2043 km^3/a.

8.2.4 Eco-factor for Japanese freshwater use

The eco-factor is calculated according to the formula described in Chapter 2. Tab. 8.3 shows the eco-factor for freshwater consumption in Japan and Tab. 8.4 the average value for the OECD countries. Tab. 8.5 gives an overview of the six scarcity situations and Tab. 11.5 shows country-specific eco-factors. All eco-factors are normalized based on the Japanese perspective.

Tab. 8.3: Eco-factor for freshwater consumption in Japan.

	Actual situation	Remarks	JEPIX
Normalization (km^3/a)	88	FAO (2005)	
Actual flow (km^3/a)	88	FAO (2005)	
Critical flow (km^3/a)	86	FAO (2005)	
Weighting (-)	1.1		
Eco-factor (EP/m^3)	**12**		

The eco-factor shown in this report does not capture temporarily and spatially limited situations. Where such situations need to be assessed, users of the method can derive eco-factors in accordance with the methodology described in Frischknecht et al. (2009).

Tab. 8.4: Average eco-factor for freshwater consumption in OECD countries from a Japanese perspective.

	Actual situation	Remarks	JEPIX
Normalization (km^3/a)	88	FAO (2005)	
Actual flow (km^3/a)	1018	FAO (2005)	
Critical flow (km^3/a)	2043	FAO (2005)	
Weighting (-)	0.25		
Eco-factor (EP/m^3)	**2.8**		

This average value should be applied when the water consumed is of unknown or unspecified origin. The eco-factor is positioned between the categories of low and moderate water scarcity (see Tab. 8.5), which is considered plausible. 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 are not taken into account by this average annual eco-factor.

Tab. 8.5: Eco-factor for freshwater consumption in six water stress classes from a Japanese perspective.

	Water scarcity ratio	Normalization (km^3/a)	Weighting (-)	Eco-factor (EP/m^3)
low	<0.1	88.43	0.0625	0.71
moderate	0.1 to <0.2	88.43	0.563	6.4
medium	0.2 to <0.4	88.43	2.25	25
high	0.4 to <0.6	88.43	6.25	71
very high	0.6 to <1.0	88.43	16	180
extreme	≥1	88.43	56.3	640

Numerous countries show a “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.

8.3 Energy resources

8.3.1 Environmental relevance

In Frischknecht et al. (2009) the relevance of energy resources is described as follows:

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

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

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

For renewable and non-renewable energy resources alike, the assessed energy corresponds to the energy yield – the energy content of the biomass harvested, the rotation energy in the case of wind and hydroelectric power plants, 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.

The eco-factor for energy consumption assesses the scarcity of the energy resource; account is taken of the environmental impacts of energy uses caused by emissions through the corresponding eco-factors for air, water and soil pollution.”

8.3.2 Political targets and situation in Japan

The Strategic Energy Plan of Japan articulates the fundamental direction of energy policy in Japan, based on the Basic Act of Energy Policy (Ministry of Economy Trade and Industry 2010). Among others, targets toward 2030 are to double the energy self-sufficiency ratio and the self-developed fossil fuel supply ratio. To reach all the targets the share of nuclear power and renewable energy carriers are expanded. The share of renewable energy in primary energy consumption should reach 13 % and nuclear power increases to 24 %. The total energy consumption decreases by about 15 %.

8.3.3 Characterization

The basis for characterization is the relative increase (or decrease) in the use of primary energy sources. Fossil energy carriers will decrease by 62 % until 2030 compared to 2007. Nuclear power will increase by 199 % until 2030 compared to 2007, renewable energy will increase by 179 % (calculation based on Ministry of Economy Trade and Industry (2010)). Conventional energy supply with fossil energy carriers is the reference (i.e. a characterization factor of 1 MJ oil-eq./MJ fossil energy).

This results in a politically established characterization factor of 0.31 MJ oil-eq/MJ for nuclear power and 0.35 MJ oil-eq/MJ for renewable energy. In other words, about 3 MJ energy from nuclear sources is rated as being equivalent to 1 MJ from fossil sources.

Tab. 8.6: Characterization factors for fossil, nuclear and renewable resources.

	Characterization factor (MJ oil-eq/MJ)	**Comments**
Fossil	1	Decrease of 62%until 2030 compared to 2007
Nuclear	0.31	Increase of 199% until 2030 compared to 2007
Renewable	0.35	Increase of 179% until 2030 compared to 2007

8.3.4 Normalization

The normalization flow corresponds to the current flow.

8.3.5 Weighting

Current flow

The Ministry of Economy Trade and Industry (2010) presents the energy balance of Japan for FY 2007 and FY 2030 according to energy carriers (Tab. 8.7). Detailed figures for FY 2007 are presented in the Japanese statistical yearbook (Ministry of Internal Affairs and Communication 2007). The current flow comprises the characterized flows. For this, renewable and non-renewable energy consumption is multiplied by the corresponding characterization factors (see Tab. 8.6). This results in a normalization flow of 21’300 PJ oil-eq/a (Tab. 8.7).

Critical flow

The goal of the energy policy for FY 2030 (Ministry of Economy Trade and Industry (2010)) is applied to determine the critical flow. To reach all the targets the share of nuclear power and renewable energy carriers are expanded. The total energy consumption decreases by about 15 %. The shares of the different energy carriers are shown in Tab. 8.7. The characterized critical flow amounts to 14’800 PJ oil-eq/a.

Tab. 8.7: Primary energy consumption in FY 2007 and 2030 and its conversion into characterized primary energy consumption.

	Primary energy consumption				**Characterized primary energy consumption**			
	2007		**2030**		**2007**		**2030**	
	PJ		**PJ**		**PJ oil-eq**		**PJ oil-eq**	
Total	*23'855*		*19'737*		*21'277*		*14'799*	
Renewable	1'431	6%	2'566	13%	496	2%	889	6%
Nuclear	2'386	10%	4'737	24%	743	3%	1'476	10%
Natural gas	4'294	18%	3'158	16%	4'294	20%	3'158	21%
Coal	5'248	22%	3'355	17%	5'248	25%	3'355	23%
LPG	716	3%	592	3%	716	3%	592	4%
Petroleum	9'781	41%	5'329	27%	9'781	46%	5'329	36%

8.3.6 Eco-factor for primary energy carriers

The eco-factor is calculated according to the formula described in Section 2.

Tab. 8.8: Eco-factor for primary energy consumption.

	Actual situation	Remarks	JEPIX
Normalization (PJ oil-eq/a)	21'277	Statistics (see text description)	
Actual flow (PJ oil-eq/a)	21'277		-
Critical flow (PJ oil-eq/a)	14'799	Target for 2030	-
Weighting (-)	2.07		
Eco-factor (EP/MJ oil eq)	**0.10**	Non-renewable primary energy	-
Eco-factor (EP/MJ oil eq)	**0.030**	Nuclear primary energy	-
Eco-factor (EP/MJ oil eq)	**0.034**	Renewable primary energy	-

The energy content of energy resources not used for energy production (feedstock energy content, for instance when hydrocarbons are used as refrigerants or wood is used in a building) is also assessed with a primary energy factor.

Tab. 8.9 presents the application of the energy eco-factors to the energy resources listed in the ecoinvent database. If a life cycle inventory is based on other assumptions concerning energy content and transformation ratio, the eco-factors can be adjusted to that specific situation following the same method.

Tab. 8.9: Eco-factors for the consumption of primary energy resources. Calculated using the eco-factors from Tab. 8.8 and the energy values in Frischknecht et al. (2007).

	Energy content		Eco-factor primary energy	
Fossil energy				
Crude oil (before refining)	45.8	MJ/kg	4.5	EP/kg
Natural gas (before refining)	40.3	MJ/Nm^3	3.9	EP/Nm^3
Mine gas	39.8	MJ/Nm^3	3.9	EP/Nm^3
Hard coal (in mine)	19.1	MJ/kg	1.9	EP/kg
Lignite (in mine)	9.9	MJ/kg	1.0	EP/kg
Nuclear energy				
Uranium (in ore)	560'000	MJ/kg	108'300	EP/kg
Biomass				
Energy in biomass	1	MJ/MJ	0.17	EP/MJ
Energy in biomass, primary forest clear-cut	1	MJ/MJ	0.17	EP/MJ
Hardwood, standing a)	19.6	MJ/kg	3.41	EP/kg
Softwood, standing a)	20.4	MJ/kg	3.55	EP//kg
Hydro				
Potential energy of water in impoundment b)	0.95	MJe/MJ	0.17	EP/MJ
Further renewables				
Kinetic energy in wind b)	0.93	MJe/MJ	0.16	EP/MJ
Solar energy in solar radiation b)	0.91	MJe a. t/MJ	0.16	EP/MJ
Geothermal energy b)	1.00	MJt/MJ	0.17	EP/MJ

a) Wood may only be assessed here if it is not already taken account of as energy in biomass, as otherwise double counting would occur.

b) According to the ecoinvent v2 dataset, the transformation ratio (ratio of final to primary energy) is: hydro = 0.95; wind = 0.93; solar = 0.91 (average of photovoltaics (0.935) and solar thermal (0.885)); geothermal = 1.00.

8.4 Gravel and sand extraction

8.4.1 Political targets and situation in Japan

Professor Izumi Washitani (Tokyo University, Japan) states in a key note speech of an international symposium on biodiversity (Washitani 2010) that “shallow marine areas were reclaimed by about 40 km^2 annually during the rapid economic growth period from the late 1950s to around 1980, and the volume of marine sand and gravel extracted between the 1970s and the late 1990s amounted to about 70 million to 90 million tons or more a year. Since 1990, reclaimed land and the volume of marine sand and gravel removed were reduced to around 10 km^2 and less than 40 million tons a year, respectively, but environmental alteration in coastal areas still continues.

Due to repeated extraction of marine sand and gravel, the Seto Inland Sea, Ariake Sea, and Yatsushiro Sea have lost many of the sand banks that had been formed by tidal currents in shallow waters and that had provided ideal habitats for finless porpoises and lancelets. Presumably, such marine sand and gravel extraction also resulted in: the reduction of zostera beds, the occurrence of oxygen-deficient water, and the deterioration of the habitats for marine benthic organisms”.

8.4.2 Normalization

The normalization flow is equal to the current flow.

8.4.3 Weighting

Current flow

The current flow corresponds to the annual extracted amount of sand and gravel (incl. pebble and cobble) and was 113’000’000 m^3 in FY2006 (Ministry of Economy Trade and Industry 2006).

Critical flow

No quantitative target for the use of sand and gravel exists. However, the Ministry of Environment (2009a) states that “in order that a Sound Material-Cycle Society can be established, the Second Fundamental Plan for Establishing a Sound Material-Cycle Society … has set new goals for the indexes concerning the “Entrance”, “Exit” and “Circulation” of materials. This refers to the three different sections of the material flow (meaning the flow of materials and goods), where appropriate and balanced measures for reduction, reuse, recycling and disposal of resources should be developed.”

The report (Ministry of Environment 2009a) shows that the cyclical use rate should reach 15 % in the year 2015. Applying this reduction rate a critical flow of about 96 Mio. m^3 results.

8.4.4 Eco-factor for sand and gravel

The eco-factor is calculated according to the formula described in Section 2.

Tab. 8.10: Eco-factor for gravel and sand extraction.

	Actual situation	Remarks	JEPIX
Normalization (m^3 gravel/a)	113'151'036	extraction of gravel	
Actual flow (m^3 gravel/a)	113'151'036		-
Critical flow (m^3 gravel/a)	96'178'380	cyclical use rate in 2015 should reach 15%	-
Weighting (-)	1.38		
Eco-factor (EP/cm^3 gravel)	**0.012**		-
Eco-factor (EP/g gravel)	**0.008**	density: 1600 kg/m^3	-

The eco-factor for gravel is defined for the first time here. It reflects the presently tolerated extraction volume.

8.5 Phosphorous extraction

8.5.1 Environmental relevance

Phosphorous is an essential element for all creatures. It is a primary accumulator of hereditary information and part of the metabolism. Bones and teeth mainly consist of phosphorous and its derivatives.

Modern agriculture is dependent on phosphorus derived from phosphate rock. Thus, concerns have been expressed about a possible “peak” in world phosphate rock production[18]. Cordell et al. (2008), for example, mention that the expected global peak in phosphorus production is predicted to occur around 2030 and that current global reserves may be depleted in 50-100 years. However, two recent studies (USGS 2011, IFDC 2010) reassessed the phosphate rock reserves and resources of important phosphate producing countries. Global phosphate rock resources seem to be more extensive than previously estimated. The United States Geological Survey (USGS) estimated global available resources of phosphate rock to about 18 Mia. tons in the 2010 report and to about 65 Mia. tons in the 2011 report (USGS 2010, USGS 2011).

Nevertheless, phosphorous is a non-renewable and limited resource. Much phosphorous is lost in crops waste, food spoilage, and animal and human waste which is not in line with a “sound material-cycle society” as claimed by the Japanese annual report of the environment (Ministry of Environment 2009a).

8.5.2 Political targets and situation in Japan

Japan wants to realize a sound material-cycle society in line with the 3Rs (Reduce, Reuse, Recycle), ensuring the appropriate management of material cycles and waste disposal. The National Institute for Environmental Studies[19] supports such a social transition in the near future through relevant research activities such as developing advanced technologies and systems and proposing policy options that are in accordance with international principles. Among others the target is to develop win-win resource recycling technology for waste biomass. They are developing material recycling and energy recovery

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[18] According to the International Fertilizer Association (IFA) http://www.fertilizer.org/ifa/HomePage/SUSTAINABILITY/Phosphorus-peak-phosphate, January 2012

[19] National Institute for Environmental Studies, http://www.nies.go.jp/gaiyo/bunya/pcycleandwaste-e.html, January 2011

technology systems that efficiently convert waste materials into industrial/agricultural resources and renewable energy. One of the research target is to develop "technologies to efficiently produce hydrogen, methane, biofuel, feedstuff, and bioplastics from waste biomass, *to recover phosphorus from wastewater treatment processes*, and to improve the energy efficiency of material recycling systems".

In Japan pilot plants for phosphor recovery from sewage sludge and industrial P-recovery processes are already operational or in the testing phase.[20]

8.5.3 Normalization

The normalization flow is equal to the current flow.

8.5.4 Weighting

Current flow

Mineral fertilizers account for about 80 % of phosphate use in the world (Althaus 2007). Other applications are detergents, animal feeds and speciality applications. The current imports and production of P fertilizer in Japan was 470'000 tons in 2007 (Association of Agriculture and Forestry Statistics 2008). Assuming that fertilizer use corresponds to 80 % of total use, a current flow of about 565'000 tons P results.

Critical flow

No quantitative political target with regard to phosphorous exists. From the targets of The National Institute for Environmental Studies (see Subchapter 8.5.2) political motivations to recover phosphorous are present. Thus, the target formulated in the Japanese annual report on the environment (Ministry of Environment 2009a), which is to reach a cyclical use rate of 15 % in the year 2015, is applied.

8.5.5 Eco-factor for phosphorous

The eco-factor is calculated according to the formula described in Section 2.

Tab. 8.11: Eco-factor for phosphorous resource consumption

	Actual situation	**Remarks**	**JEPIX**
Normalization (t P/a)	565'417		
Actual flow (t P/a)	565'417		-
Critical flow (t P/a)	480'605	cyclical use rate in 2015 should reach 15%	-
Weighting (-)	1.38		
Eco-factor (EP/g P)	**2.00**		**-**

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[20] Technical University, Darmstadt, http://www.phosphorus-recovery.tu-darmstadt.de/, January 2011

9 Wastes

9.1 Landfilled waste

9.1.1 Environmental relevance

In Japan, there were 18.2 billion tons of total material input, and 750 million, about half, were used in the construction of buildings and infrastructures in FY 2006. Moreover, 170 million tons were exported as products, 490 million tons were used in the energy consumption and manufacturing process and 580 million tons of wastes were generated. Out of these items, 230 million tons were subjected to cyclical use, equivalent to 12.5 % of the total material input amount. About 29 million tons of wastes are disposed in landfill sites (Ministry of Environment 2009a).

9.1.2 Political targets and situation in Japan

Japan aims to establish a Sound Material-Cycle Society. Therefore, the Second "Fundamental Plan for Establishing a Sound Material-Cycle Society" (A Cabinet decision in March 2008), has set new goals for the indexes concerning the "Entrance", "Exit" and "Circulation" of materials. This refers to the three different sections of the material flow (meaning the flow of materials and goods), where appropriate and balanced measures for reduction, reuse, recycling and disposal of resources should be developed" (Ministry of Environment 2009a).

Landfills are classified into three types: isolated, leachate-controlled, and non-leachate-controlled. Isolated landfills are used for the disposal of hazardous industrial wastes. Leachate-controlled landfills are used for the disposal of both municipal and industrial wastes other than hazardous and stable wastes. Non-leachate-controlled landfills are used for the disposal of stable wastes, namely, waste plastics, rubber scrap, metal scrap, waste glass, ceramics, and demolition waste. The standards for landfill site structure and those for landfill site operation and maintenance have been established in accordance with landfill type.[21]

In 2006, the number of final disposal facilities (landfill sites) authorized by governors was 2'335.[22]

9.1.3 Normalization

The normalization flow corresponds to the current flow.

9.1.4 Weighting

Current flow

The actual amount of landfilled waste was 29'000'000 tons in 2006 (Ministry of Environment 2009a).

Critical flow

In the framework of Japan's "Fundamental Plan for Establishing a Sound Material-Cycle Society" the aim is to reduce the landfilled waste to 23'000'000 tons by 2015 (Ministry of Environment 2009a).

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[21] According to the website of the Japanese Ministry of Environment, http://www.env.go.jp/en/recycle/manage/waste.html, January 2011

[22] According to the website of Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, http://www.basel.int, January 2011

9.1.5 Eco-factor for landfilled waste

Tab. 9.1: Eco-factor for landfilled waste.

	Actual situation	Remarks	JEPIX
Normalization (t/a)	29'000'000	landfilled waste	
Actual flow (t/a)	29'000'000		76'035'457
Critical flow (t/a)	23'000'000	should be reached by 2015	36'000'000
Weighting (-)	1.59		4.46
Eco-factor (EP/g landfilled waste)	**0.055**		**0.01**

The resulting eco-factor is lower compared to the one established in JEPIX (Miyazaki et al. 2004). The amount of deposited waste decreased considerably in the last few years and the political target is less strict compared to the targets applied in JEPIX.

This eco-factor may be linked to an elementary flow such as “waste, to landfill site, kg”. If no such elementary flow is available (like for instance in datasets from the ecoinvent database), the eco-factor may be linked to the landfill site land transformation using the CORINE land use types (data and procedure described in Frischknecht et al. (2007)). The landfill types as defined in ecoinvent are applied. The adapted eco-factor must be differentiated for the different landfill types. A proposal to assign Japanese landfill types to the Swiss landfill types (ecoinvent landfill types) is shown in Tab. 9.3. Using these modified eco-factors, each kilogram landfilled waste will be attributed a constant burden of 50 eco-points (Tab. 9.1). In case no differentiation of landfill types is possible the authors recommend applying the derived eco-factor for sanitary landfills. Alternatively a new elementary flow per kg waste to landfill site may be generated.

Tab. 9.2: Land types for landfills and eco-factors for landfill areas

CORINE code	Landfill type	Waste density (kg/m^3)	Landfill depth (m)	kg waste per m^2 landfill area	eco-points/m^2 landfill area
132b	dump site, sanitary landfill	1000	20	20'000	**1’000’000**
132c	dump site, slag compartment	1500	15	22'500	**1’200’000**
132d	dump site, residual material landfill	1600	10	16'000	**880’000**
132e	dump site, inert material landfill	1500	15	22'500	**1’200’000**

Tab. 9.3: Proposal to assign Japanese landfill types to Swiss landfill types as they are used in ecoinvent.

Japanese landfill type	Waste type	Corresponding Swiss landfill type	Comments
Isolated landfill	Hazardous waste	Underground deposit	see Section 9.2
Leachate controlled landfill	municipal and industrial wastes <5 % carbon content	Residual landfill	
	municipal and industrial wastes >5 % carbon content	Sanitary landfill	
Non-leachate-controlled landfills	metal scrap, waste glass, ceramics, and demolition waste	Inert material landfill	
	plastics, rubber scrap	Sanitary landfill	in Switzerland plastic is disposed in a sanitary landfill

9.2 Hazardous waste to landfill site

9.2.1 Environmental relevance

Industrial production results in hundreds of millions of tons of wastes worldwide every year. These wastes include chemical by-products that are hazardous to human health and the environment because they are poisonous, eco-toxic, explosive, corrosive, flammable, or infectious (UNEP 2002).

9.2.2 Political targets and situation in Japan

Japan signed and ratified the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. This convention aims to regulate the transboundary movements of hazardous and other wastes. Second, the Convention obliges its Parties to ensure that hazardous and other wastes are managed and disposed of in an environmentally sound manner. To this end, Parties are expected to minimize the quantities that are moved across borders, to treat and dispose of wastes as close as possible to their place of generation and to prevent or minimize the generation of wastes at source (UNEP 2002).

Two national legislations regulate transboundary movement of waste (in broad sense) in Japan. One is the Law for the Control of Export, Import and Others of Specified Hazardous Wastes and Other Wastes (hereinafter “Basel Law”). The other is the Waste Management and Public Cleansing Law (hereinafter “Waste Management Law”). The two legislations define waste in different ways, and control transboundary movement of waste independently. Definition of “waste” under the Basel Law is exactly the same like the definition in the Basel Convention. On the other hand, the Waste Management Law defines "waste" as “refuse, bulky refuse, ashes, sludge, excreta, waste oil, waste acid and alkali, carcasses and other filthy and unnecessary matter, which are in solid or liquid state (excluding radioactive waste and waste polluted by radioactivity)”. If a cargo is “waste” under the Waste Management Law and “hazardous waste” under the Basel Convention, the cargo is subject to both laws independently.

9.2.3 Normalization

The normalization flow is equal to the current flow.

9.2.4 Weighting

Current flow

The amount of hazardous waste handled in Japan (including imports and exports) is about 3’300’000 tons/a. The most recent data are published by OECD (2006/07) and refer to 1999. The share of landfilled hazardous waste is unknown. Most of hazardous waste is generated by industry and 4.8 % of industry waste is disposed in a landfill site[23]. Thus, it is assumed that 4.8 % of generated hazardous wastes are landfilled.

Critical flow

No quantitative target with regard to hazardous waste exists. But as Japan ratified the Basel Convention they are obliged to decrease the amount of generated hazardous waste. Thus, the target formulated in the Japanese annual report on the environment (Ministry of Environment 2009a), which is to reach a cyclical use rate of 15 % in the year 2015, is applied.

9.2.5 Eco-factor for hazardous waste

The eco-factor is calculated according to the formula described in Section 2.

Tab. 9.4: Eco-factor for hazardous waste disposed in landfill site

	Actual situation	**Remarks**	**JEPIX**
Normalization (t waste/a)	158'641	amount of hazardous waste to be handled	
Actual flow (t waste/a)	158'641		-
Critical flow (t waste/a)	134'845	cyclical use rate in 2015 should reach 15%	-
Weighting (-)	1.38		
Eco-factor (EP/g waste)	**9.0**		-
Eco-factor (EP/cm^3 waste)	**14**	density 1600 kg/m^3	

This eco-factor relates exclusively to hazardous wastes stored in underground repositories. The final storage of wastes – including hazardous wastes – on normal aboveground landfills is assessed via the eco-factors for land use and for emissions to air, water and groundwater.

9.3 Radioactive waste

9.3.1 Political targets and situation in Japan

The generation of electricity in nuclear power plants produces radioactive wastes that must eventually be consigned to final storage. Low-level radioactive waste is already disposed of by underground burial. High-level radioactive waste must be maintained safely for a long period of times, so that its radioactivity will not have any significant effect on the environment where people live. No final repository could yet be constructed in Japan (Atomic Energy Commission 2000).

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[23] Website of Japanese Ministry of Environment, http://www.env.go.jp/press/press.php?serial=11977, January 2011

In Japan, the Specified Radioactive Waste Final Disposal Act was enacted in 2000, under which basic policies on final disposal have been made and an implementation organization for the disposal business has been established (Atomic Energy Commission 2000).

9.3.2 Normalization

No characterization is performed. The normalization flow is thus identical to the current flow.

9.3.3 Weighting

Current flow

The current flow is estimated using the installed nuclear capacity in Japan in 2007 (49’467’000 kW, Ministry of Internal Affairs and Communication 2007 and the waste production of low- and high-level waste per installed capacity unit (ecoinvent Centre 2010). The annual flow of low-level waste amounts to 20’556 m^3/a and the high-level flow to 3’643 m^3/a.

Critical flow

Following aspects need to be considered when assessing the critical flow (adapted from Frischknecht et al. 2009:

- **Low-level waste**: a disposal solution for low-level waste is already established in Japan. Thus, a weighting factor of 1 is justifiable.
- **High-level waste:** In Japan there is presently no repository capacity for high-level and long-lived wastes. At the present time, radioactive wastes therefore cannot be disposed of (as envisaged by the legislator) in an environmentally sound manner. It would follow from this consideration that the critical flow would need to be set at zero. Possible repositories that could accept the wastes arising in existing nuclear power plants are in a planning stage. Although no statement can be made as to the point in time at which such a facility may commence operations nor at which site, it is possible that sufficient repository capacity will exist in future. This consideration would suggest that the current flow should equal the critical flow.

Thus, the critical flow is estimated in the same was as in Frischknecht et al. (2009), except that the critical flow corresponds to half of the flow in FY 2030.

“The critical flow used to determine the eco-factor is therefore positioned between the current flow and zero. In a first, rough approximation, the critical flow is set at half of the current flow. This reflects the present situation, in which there are efforts to find a final repository, but no specific construction project is under way.

This determination of the critical flow is not based on a political consensus: Those who have confidence in technology view the overall present waste quantity as unproblematic, while those who hold a critical position consider even a minimum quantity of radioactive wastes to be unacceptable.”

9.3.4 Eco-factor for radioactive waste

The eco-factor is calculated according to the formula described in Section 2.

Tab. 9.5: Eco-factor for low-level radioactive waste.

	Actual situation	Remarks	JEPIX
Normalization (m^3/a)	20'556	see description in text	
Actual flow (m^3/a)	20'556		-
Critical flow (m^3/a)	20'556	see description in text	-
Weighting (-)	1.00		
Eco-factor (EP/cm^3 waste)	**49**		**-**

Tab. 9.6: Eco-factor for high-level radioactive waste.

	Actual situation	Remarks	JEPIX
Normalization (m^3/a)	3'643	see description in text	
Actual flow (m^3/a)	3'643		-
Critical flow (m^3/a)	2'497	see description in text	-
Weighting (-)	2.13		
Eco-factor (EP/cm^3 waste)	**580**		**-**

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11 Appendix A – Eco-factors for further substances determined by characterization

11.1 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 is used for the calculation. The GWP values are in accordance with IPCC (2007), the ODP values are in accordance with UNEP (2006).

Tab. 11.1: Eco-factors for greenhouse gases with regard to the Japanese long-term goal (2050) and for ozone-depleting substances.

	Formula	CAS-Nr.	GWP (CO_2-eq.)	ODP (R11-eq.)	Ecofactor (EP/g)	Basis
Carbon dioxide	CO2	124-38-9	1	-	0.018	GWP
Carbon monoxide	CO	630-08-0	1.57	-	0.029	GWP
Methane	CH4	74-82-8	25	-	0.45	GWP
Dinitrogen oxide	N2O	10024-97-2	298	-	5.4	GWP
Chlorofluorocarbons (CFCs)						
CFC-11	CCl3F	75-69-4	4'750	1	540	ODP
CFC-12	CCl2F2	75-71-8	10'900	1	540	ODP
CFC-13	CClF3	75-72-9	14'400	1	540	ODP
CFC-111	C2Cl5F	354-56-3	-	1	540	ODP
CFC-112	C2Cl4F2	76-12-0	-	1	540	ODP
CFC-113	CCl2FCClF2	76-13-1	6'130	0.8	430	ODP
CFC-114	CClF2CClF2	76-14-2	10'000	1	540	ODP
CFC-115	CF3CClF2	76-15-3	7'370	0.6	320	ODP
CFC-211	C3Cl7F	422-78-6	-	1	540	ODP
CFC-212	C3Cl6F2	3182-26-1	-	1	540	ODP
CFC-213	C3Cl5F3	2354-06-5	-	1	540	ODP
CFC-214	C3Cl4F4	29255-31-0	-	1	540	ODP
CFC-215	C3Cl3F5	4259-43-2	-	1	540	ODP
CFC-216	C3Cl2F6	661-97-2	-	1	540	ODP
CFC-217	C3ClF7	422-86-6	-	1	540	ODP
Hydrofluorocarbons (HFCs)						
HFC-23	CHF3	75-46-7	14'800	-	270	GWP
HFC-32	CH2F2	75-10-5	675	-	12	GWP
HFC-41	CH3F	593-53-3	92	-	2	GWP
HFC-125	CHF2CF3	354-33-6	3'500	-	64	GWP
HFC-134	CHF2CHF2	359-35-3	1'100	-	20	GWP
HFC-134a	CH2FCF3	811-97-2	1'430	-	26	GWP
HFC-143	CHF2CH2F	430-66-0	353	-	6.4	GWP
HFC-143a	CF3CH3	420-46-2	4'470	-	81	GWP
HFC-152	CH2FCH2F	624-72-6	53	-	0.96	GWP
HFC-152a	CH3CHF2	75-37-6	124	-	2.3	GWP
HFC-161	CH3CH2F	353-36-6	12	-	0.22	GWP
HFC-227ea	CF3CHFCF3	431-89-0	3'220	-	59	GWP
HFC-236cb	CH2FCF2CF3	677-56-5	1'340	-	24	GWP
HFC-236ea	CHF2CHFCF3	431-63-0	1'370	-	25	GWP
HFC-236fa	CF3CH2CF3	690-39-1	9'810	-	180	GWP
HFC-245ca	CH2FCF2CHF2	679-86-7	693	-	13	GWP
HFC-245fa	CHF2CH2CF3	460-73-1	1'030	-	19	GWP
HFC-365mfc	CF3CH2CF2CH3	406-58-6	794	-	14	GWP
HFC-43-10mee	CF3CHFCHFCF2CF3	138495-42-8	1'640	-	30	GWP
Partially halogenated chlorofluorocarbons (HCFCs)						
HCFC-21	CHCl2F	75-43-4	151	0.04	22	ODP
HCFC-22	CHClF2	75-45-6	1'810	0.055	33	GWP
HCFC-31	CH2FCl	593-70-4	-	0.02	11	ODP

	Formula	CAS-Nr.	GWP (CO$_2$-eq.)	ODP (R11-eq.)	Ecofactor (EP/g)	Basis
HCFC-121	CHCl2CCl2F	354-14-3	-	0.04	22	ODP
HCFC-122	CHCl2CClF2	354-21-2	-	0.08	43	ODP
HCFC-123	CHCl2CF3	306-83-2	77	0.02	11	ODP
HCFC-124	CHFClCF3	2837-89-0	609	0.022	12	GWP
HCFC-131	CH2ClCCl2F	359-28-4	-	0.05	27	ODP
HCFC-132	C2H2F2Cl2	1649-08-7	-	0.05	27	ODP
HCFC-133a	CH2ClCF3	75-88-7	-	0.06	32	ODP
HCFC-141	CH2ClCHClF	430-57-9	-	0.07	38	ODP
HCFC-141b	CH3CFCl2	1717-00-6	725	0.11	59	ODP
HCFC-142b	CH3CF2Cl	75-68-3	2'310	0.065	42	GWP
HCFC-151	C2H4FCl	110587-14-9	-	0.005	2.7	ODP
HCFC-221	C3HFCl6	422-26-4	-	0.07	38	ODP
HCFC-222	C3HF2Cl5	422-49-1	-	0.09	49	ODP
HCFC-223	C3HF3Cl4	422-52-6	-	0.08	43	ODP
HCFC-224	C3HF4Cl3	422-54-8	-	0.09	49	ODP
HCFC-225	C3HF5Cl2	127564-92-5	-	0.07	38	ODP
HCFC-225ca	CF3CF2CHCl2	422-56-0	122	0.025	14	ODP
HCFC-225cb	CClF2CF2CHClF	507-55-1	595	0.033	18	ODP
HCFC-226	C3HF6Cl	431-87-8	-	0.1	54	ODP
HCFC-231	C3H2FCl5	421-94-3	-	0.09	49	ODP
HCFC-232	C3H2F2Cl4	460-89-9	-	0.1	54	ODP
HCFC-233	C3H2F3Cl3	7125-84-0	-	0.23	120	ODP
HCFC-234	C3H2F4Cl2	425-94-5	-	0.28	150	ODP
HCFC-235	C3H2F5Cl	460-92-4	-	0.52	280	ODP
HCFC-241	C3H3FCl4	666-27-3	-	0.09	49	ODP
HCFC-242	C3H3F2Cl3	460-63-9	-	0.13	70	ODP
HCFC-243	C3H3F3Cl2	460-69-5	-	0.12	65	ODP
HCFC-244	C3H3F4Cl	134190-50-4	-	0.14	76	ODP
HCFC-251	C3H4FCl3	421-41-0	-	0.01	5.4	ODP
HCFC-252	C3H4F2Cl2	819-00-1	-	0.04	22	ODP
HCFC-253	C3H4F3Cl	460-35-5	-	0.03	16	ODP
HCFC-261	CH3CClFCH2Cl	420-97-3	-	0.02	11	ODP
HCFC-262	C3H5F2Cl	421-02-3	-	0.02	11	ODP
HCFC-271	C3H6FCl	430-55-7	-	0.03	16	ODP
Perfluorocarbons (PFCs)						
Methane, perfluoro-	CF4	75-73-0	7'390	-	130	GWP
Ethane, perfluoro-, (FC-14)	C2F6	76-16-4	12'200	-	220	GWP
Propan, octafluor-, (FC-218)	C3F8	76-19-7	8'830	-	160	GWP
Propane, hexafluorocyclo-	c-C3F6	931-91-9	17'340	-	320	GWP
Butane, decafluoro-	C4F10	355-25-9	8'860	-	160	GWP
Butane, octafluorocyclo-	c-C4F8	115-25-3	10'300	-	190	GWP
Pentane, dodecafluoro-	C5F12	678-26-2	9'160	-	170	GWP
Hexane, tetradecafluoro-	C6F14	355-42-0	9'300	-	170	GWP
PFC-9-1-18	C10F18	77115-10-7	9'500	-	170	GWP
Trifluoromethyl sulphur pentafluoride	SF5CF3	373-80-8	21'200	-	390	GWP
Brominated hydrocarbons						

	Formula	CAS-Nr.	GWP (CO_2-eq.)	ODP (R11-eq.)	Ecofactor (EP/g)	Basis
Methane, bromo-	CH3Br	74-83-9	5	0.6	320	ODP
Methane, dibromo-	CH2Br2	74-95-3	2	-	0.028	GWP
Methane, bromochloro-	CH2BrCl	74-97-5	-	0.12	65	ODP
Methan, bromfluor-	CH2FBr	373-52-4	-	0.73	390	ODP
Methane, bromodifluoro-	CHBrF2	1511-62-2	404	0.74	400	ODP
Methan, dibromfluor-	CHFBr2	1868-53-7	-	1	540	ODP
Halon 1211 (methane, bromochlorodifluoro-)	CBrClF2	353-59-3	1'890	3	1'600	ODP
Halon 1301 (methane, bromotrifluoro-)	CBrF3	75-63-8	7'140	10	5'400	ODP
Methan, dibromfluor-	CHFBr2	1868-53-7	-	1	540	ODP
Methan, bromfluor-	CH2FBr	373-52-4	-	0.73	390	ODP
Ethan, Tetrabromfluor-	C2HFBr4	-	-	0.8	430	ODP
Ethan, Tribromdifluor-	C2HF2Br3	-	-	1.8	970	ODP
Ethan, Dibromtrifluor-	C2HF3Br2	-	-	1.6	860	ODP
Ethan, Bromtetrafluor-	C2HF4Br	-	-	1.2	650	ODP
Ethan, Tribromfluor-	C2H2FBr3	-	-	1.1	590	ODP
Ethan, Dibromdifluor-	C2H2F2Br2	-	-	1.5	810	ODP
Ethan, Bromtrifluor-	C2H2F3Br	-	-	1.6	860	ODP
Ethan, Dibromfluor-	C2H3FBr2	-	-	1.7	920	ODP
Ethan, Bromdifluor-	C2H3F2Br	-	-	1.1	590	ODP
Ethan, Bromfluor-	C2H4FBr	-	-	0.1	54	ODP
Propan, Hexabromfluor-	C3HFBr6	-	-	1.5	810	ODP
Propan, Pentabromdifluor-	C3HF2Br5	-	-	1.9	1'000	ODP
Propan, Tetrabromtrifluor-	C3HF3Br4	-	-	1.8	970	ODP
Propan, Tribromtetrafluor-	C3HF4Br3	-	-	2.2	1'200	ODP
Propan, Dibrompentafluor-	C3HF5Br2	-	-	2.0	1'100	ODP
Propan, Bromhexafluor-	C3HF6Br	-	-	3.3	1'800	ODP
Propan, Pentabromfluor-	C3H2FBr5	-	-	1.9	1'000	ODP
Propan, Tetrabromdifluor-	C3H2F2Br4	-	-	2.1	1'100	ODP
Propan, Tribromtrifluor-	C3H2F3Br3	-	-	5.6	3'000	ODP
Propan, Dibromtetrafluor-	C3H2F4Br2	-	-	7.5	4'100	ODP
Propan, Brompentafluor-	C3H2F5Br	-	-	14.0	7'600	ODP
Propan, Tetrabromfluor-	C3H3FBr4	-	-	1.9	1'000	ODP
Propan, Tribromdifluor-	C3H3F2Br3	-	-	3.1	1'700	ODP
Propan, Dibromtrifluor-	C3H3F3Br2	-	-	2.5	1'400	ODP
Propan, Bromtetrafluor-	C3H3F4Br	-	-	4.4	2'400	ODP
Propan, Tribromfluor-	C3H4FBr3	-	-	0.3	160	ODP
Propan, Dibromdifluor-	C3H4F2Br2	-	-	1.0	540	ODP
Propan, Bromtrifluor-	C3H4F3Br	-	-	0.8	430	ODP
Propan, Dibromfluor-	C3H5FBr2	-	-	0.4	220	ODP
Propan, Bromdifluor-	C3H5F2Br	-	-	0.8	430	ODP
Propan, Bromfluor-	C3H6FBr	-	-	0.7	380	ODP
Chlorinated hydrocarbons						
Methane, tetrachlore-, (CHC-10)	CCl4	56-23-5	1'400	1.1	590	ODP
Chloroform, (CHC-20)	CHCl3	67-66-3	31	-	0.56	GWP
Methane, monochloro-, (CHC-40)	CH3Cl	74-87-3	13	-	0.24	GWP
Methane, dichloor-, (CHC-	CH2Cl2	75-09-2	9	-	0.16	GWP

	Formula	**CAS-Nr.**	**GWP (CO_2-eq.)**	**ODP (R11-eq.)**	**Ecofactor (EP/g)**	**Basis**
30)						
Ethane, 1,1,1-trichloro-, (CHC-140)	CH3CCl3	71-55-6	146	0.1	54	ODP
Further halogenated hydrocarbon compounds						
Methane, trifluoroiodo-	CF3I	2314-97-8	0	-	0.0073	GWP
1-propanol, 2,2,3,3,3-pentafluoro-	CF3CF2CH2OH	422-05-9	42	-	0.76	GWP
2-Propanol, 1,1,1,3,3,3-hexafluoro-	(CF3)2CHOH	920-66-1	195	-	3.5	GWP
Nitrogen trifluoride	NF3	7783-54-2	17'200	-	310	GWP
Sulphurhexafluoride	SF6	2551-62-4	22'800	-	410	GWP
Ethers and halogenated ether compounds						
Ether, dimethyl-	CH3OCH3	115-10-6	1	-	0.018	GWP
Ether, methyl perfluoroisopropyl-	(CF3)2CFOCH3	22052-84-2	343	-	6.2	GWP
HCFE-235da2	CF3CHClOCHF2	26675-46-7	350	-	6.4	GWP
HFE-125	CF3OCHF2	3822-68-2	14'900	-	270	GWP
HFE-134	CHF2OCHF2	1691-17-4	6'320	-	110	GWP
HFE-143a	CH3OCF3	421-14-7	756	-	14	GWP
HCFE-235da2	CF3CHClOCHF2	26675-46-7	350	-	6.4	GWP
HFE-245cb2	CF3CF2OCH3	-	708	-	13	GWP
HFE-245fa2	CF3CH2OCHF2	-	659	-	12	GWP
HFE-254cb2	CHF2CF2OCH3	-	359	-	6.5	GWP
HFE-347mcc3	CF3CF2CF2OCH3	-	575	-	10	GWP
HFE-347pcf2	CHF2CF2OCH2CF3	-	580	-	11	GWP
HFE-356pcf3	CHF2CF2CH2OCHF2	-	502	-	9.1	GWP
HFE-374pc2	CHFCF2OCH2CH3	-	557	-	10	GWP
HFE-7100	C4F9OCH3	-	297	-	5.4	GWP
HFE-7200	C4F9OC2H5	-	59	-	1.1	GWP
H-Galden 1040x	CHF2OCF2OC2F4OCHF2	-	1'870	-	34	GWP
HG-10	CHF2OCF2OCHF2	-	2'800	-	51	GWP
HG-01	CHF2OCF2CF2OCHF2	-	1'500	-	27	GWP
Perfluoropolyethers						
PFPMIE	CF3OCF(CF3)CF2OF2OCF3	-	10'300	-	190	GWP
Others						
Diesel soot		-	1'537	-	23	GWP

11.2 Eco-factors for POCP substances

Eco-factors for individual POCP substances (see Subchapter 4.4)

Tab. 11.2: Eco-factor for individual substances.

Substance	Formula	CAS-Nr.	POCP (kg ethylen eq./kg)	Eco-factor (EP/g)	
Acetaldehyde	CH3CHO	75-07-0	0.64	**1.2**	
Acetone	CH3COCH3	67-64-1	0.09	**0.18**	
Benzaldehyde	C7H6O	100-52-7	-0.09	**-0.18**	
Benzene	C6H6	71-43-2	0.22	**0.42**	a)
Benzene, ethyl-	C8H10	100-41-4	0.73	**1.4**	
1-Propyl Benzene	C9H12	103-65-1	0.64	**1.2**	
Butadiene	C4H6	106-99-0	0.85	**1.7**	
Butane	C4H10	106-97-8	0.35	**0.68**	
Isopentane	C5H12	78-78-4	0.41	**0.79**	
2,2-Dimethylbutane	C6H14	75-83-2	0.24	**0.47**	
2.3- Dimethylbutane	C6H14	79-29-8	0.54	**1.1**	
Butyraldehyde	C4H8O	123-72-8	0.80	**1.5**	
1-Butanol	C4H10O	71-36-3	0.62	**1.2**	
2-Methylbutan-1-ol	C5H12O	137-32-6	0.49	**0.95**	
3-Methylbutan-1-ol	C5H12O	123-51-3	0.43	**0.84**	
2-Methylbutan-2-ol	C5H12O	75-85-4	0.23	**0.44**	
3-Methylbutan-2-ol	C5H12O	598-75-4	0.41	**0.79**	
2-butanone	C4H8O	78-93-3	0.37	**0.72**	
Methyl-Isopropylketone	C5H10O	563-80-4	0.36	**0.71**	
2-Methyl-1-Butene	C5H10	563-46-2	0.77	**1.5**	
3-Methyl-1-Butene	C5H10	563-45-1	0.67	**1.3**	
1-Butyl Acetate	C6H12O2	123-86-4	0.27	**0.52**	
Chloroform	CHCl3	67-66-3	0.00	**0.00**	b)
Decane	C10H22	124-18-5	0.38	**0.75**	
Diisopropylether	C6H14O	108-20-3	0.40	**0.77**	
Dimethyl carbonate	C3H6O3	616-38-6	0.03	**0.05**	
Dodecane	C12H26	112-40-3	0.36	**0.69**	
Acetic acid	CH3COOH	64-19-7	0.10	**0.19**	
Ethane	C2H6	74-84-0	0.12	**0.24**	
Ethylene Glycol	C2H6O2	107-21-1	0.37	**0.72**	
Ethanol	C2H5OH	64-17-5	0.40	**0.77**	
2-Butoxy-Ethanol	C6H14O2	111-76-2	0.48	**0.94**	
2-Ethoxy-Ethanol	C4H10O2	110-80-5	0.39	**0.75**	
2-Methoxy-Ethanol	C3H8O2	109-86-4	0.31	**0.60**	
Ethyne	C2H2	74-86-2	0.09	**0.17**	
Ethene	C2H4	74-85-1	1.00	**1.9**	
Ethene, tetrachloro-	C2Cl4	127-18-4	0.03	**0.06**	
Ethene, trichloro-	C2HCl3	79-01-6	0.33	**0.63**	
Dimethyl ether	CH3OCH3	115-10-6	0.19	**0.37**	d)
Formaldehyde	CH2O	50-00-0	0.52	**1.0**	
Heptane	C7H16	142-82-5	0.49	**0.96**	
Hexane	C6H14	110-54-3	0.48	**0.94**	
2-Methylhexane	C7H16	591-76-4	0.41	**0.80**	
3-Methylhexane	C7H16	589-34-4	0.36	**0.71**	
Hexan-2-one	C6H12O	591-78-6	0.57	**1.1**	
Hexan-3-one	C6H12O	589-38-8	0.60	**1.2**	
Cyclohexanol	C6H12O	108-93-0	0.52	**1.0**	
Cyclohexanone	C6H10O	108-94-1	0.30	**0.58**	
1-Hexene	C6H12	592-41-6	0.87	**1.7**	

Substance	**Formula**	**CAS-Nr.**	**POCP (kg ethylen eq./kg)**	**Eco-factor (EP/g)**	
isopropyl acetate	C5H10O2	108-21-4	0.21	**0.41**	
Carbon monoxide, biogenic	CO	630-08-0	0.00	**0.00**	
Carbon monoxide, fossil	CO	630-08-0	0.03	**0.05**	
Methane, dichloro-, HCC-30	CH2Cl2	75-09-2	0.07	**0.13**	d)
Dimethoxy methane	C3H8O2	109-87-5	0.16	**0.32**	
Methane, monochloro-, R-40	CH3Cl	74-87-3	0.00	**0.00**	b)
Methanol	CH3OH	67-56-1	0.14	**0.27**	
t-Butyl methyl ether	C5H12O	1634-04-4	0.18	**0.34**	
Methyl Acetate	C3H6O2	79-20-9	0.06	**0.11**	
Nonane	C9H20	111-84-2	0.41	**0.80**	
Octane	C8H18	111-65-9	0.45	**0.88**	
Pentane	C5H12	109-66-0	0.40	**0.77**	
2-Methylpentane	C6H14	107-83-5	0.42	**0.82**	
3-Methylpentane	C6H14	96-14-0	0.48	**0.93**	
3-Pentanol	C5H12O	584-02-1	0.60	**1.2**	
Methyl propyl Ketone	C5H10O	107-87-9	0.55	**1.1**	
Diacetone alcohol	C6H12O2	123-42-2	0.31	**0.60**	
Diethylketone	C5H10O	96-22-0	0.41	**0.80**	
Pentanaldehyde	C5H10O	110-62-3	0.77	**1.5**	
1-Pentene	C5H10	109-67-1	0.98	**1.9**	
Propane	C3H8	74-98-6	0.18	**0.34**	
Neopentane	C5H12	463-82-1	0.17	**0.34**	
isobutane	C4H10	75-28-5	0.31	**0.60**	
1,2-Propanediol	C3H8O2	57-55-6	0.46	**0.89**	
Isopropanol	C3H8O	67-63-0	0.19	**0.37**	
1-Methoxy-2-propanol	C4H10O2	107-98-2	0.36	**0.69**	
isobutyraldehyde	C4H8O	78-84-2	0.51	**1.0**	
isobutanol	C4H10O	78-83-1	0.36	**0.70**	
Propene	C3H6	115-07-1	1.12	**2.2**	
isobutene	C4H8	115-11-7	0.63	**1.22**	
Propanal	C3H6O	123-38-6	0.80	**1.6**	
Propionic acid	C3H6O2	79-09-4	0.15	**0.29**	
1-Propylacetate	C5H10O2	109-60-4	0.28	**0.55**	
Styrene	C8H8	100-42-5	0.14	**0.28**	
Toluene	C6H5CH3	108-88-3	0.64	**1.2**	
1-Undecane	C11H24	1120-21-4	0.38	**0.75**	
m-Xylene	C6H4(CH3)2	108-38-3	1.11	**2.2**	
o-Xylene	C6H4(CH3)2	95-47-6	1.05	**2.0**	
Sulfur dioxide	SOx as SO2	7446-09-5	0.05	**0.09**	c)

a) Assessed separately (to be done)
b) Assessed via GWP (Section 4.1.6) which results in higher eco-factor
c) Assessed separately (Chapter 4.5) which results in higher eco-factor
d) Assessed via GWP (Section 3.1.5) which results in lower eco-factor

11.3 Eco-factors for PPP

Tab. 11.3: Eco-factor for individual plant protection products.

Active agent	Standard dose (g/ha)	Characterization factor (kg PPP-eq/kg)	Eco-factor (EP/g)
Herbicides			
(R)-2-(4-Chloro-2-methylphenoxy)propionic acid potassium salt	1560	8.6	11
2,4-D	1080	12.4	16
2,4-PA isopropylamine	1000	13.4	17
Aclonifen	2400	5.6	7.3
Alachlor	875	15.3	20
Amidosulfuron	38.2	350	460
Asulam	8860	1.51	2
Atrazine	533	25.1	33
Azimsulfuron	7.27	1840	2400
Benazolin	281	48	62
Benfuresate	507	26.5	34
Bensulfuron methyl	57	235	310
Bentazone	1710	7.85	10
Benthiocarb	3700	3.62	4.7
Benzobicyclon	197	68.1	89
Benzofenap	846	15.9	21
Bethrodine	3470	3.86	5
Bialaphos	1190	11.3	15
Bifenox	769	17	22
Bispyribac sodium	60.3	223	290
Bromacil	4500	2.98	3.9
Bromobutide	801	16.7	22
Bromoxynil	352	38	49
Butachlor	788	17	22
Butamifos	1690	7.93	10
Cafenstrole	272	49.4	64
CAN	2440	5.49	7.1
Carbam-sodium	150000	0.0894	0.12
Carbetamide	2190	6.1	7.9
carfentrazone-ethyl	73	184	240
CAT	556	24.1	31
Chlorate	99000	0.135	0.18
Chloridazon	2260	5.9	7.7
Chlorophthalim	2500	5.36	7
Chloropicrin	240000	0.0559	0.073
Chlorothalonil	1500	8.9	12
Chlorotoluron	13500	0.99	1.3
Clodinafop-propargyl	69	190	250
Clethodim	115	117	150
Cloquintocet-mexyl	17.3	780	1000
Clomeprop	338	39.6	51
Cumyluron	864	15.5	20
Cyanate	24000	0.559	0.73
Cyanazine	1620	8.27	11

Active agent	**Standard dose (g/ha)**	**Characterization factor (kg PPP-eq/kg)**	**Eco-factor (EP/g)**
Cyclosulfamuron	176	76.4	99
Cyhalofop butyl	196	68.4	89
Daimuron	650	20.6	27
Dalapon	18300	0.735	0.96
Dazamet	294000	0.0456	0.059
DBN	5390	2.49	3.2
DCBN	3510	3.82	5
DCMU	3360	4	5.2
Desmedipham	115	117	150
Dicamba	132	100	130
Dichlobenil	277	48	62
Dichlorprop-P	646	21	27
Diflufenican	72.8	184	240
Diflufenzopyr-sodium	66.7	200	260
Dimefuron	663	20	26
Dimethachlor	656	20	26
Dimethenamid	1260	11	14
Dimethametryn	59.3	226	290
Dimethenamide	803	16.7	22
Dinoseb	5160	2.6	3.4
DNOC	18300	0.73	0.95
Diquat	727	18.4	24
Dithiopyr	534	25.1	33
endothal-sodium	2040	6.56	8.5
Esprocarb	1660	8.07	10
Ethofumesate	750	18	23
Ethoxysulfuron	209	64	83
Etobenzanide	1500	8.94	12
Fenmedifam	711	18.9	25
Fentrazamide	238	56.4	73
Flazasulfuron	49	274	360
Florasulam	16.3	822	1100
Fluazifop P	175	76.6	100
Fluazifop-p-butyl	252	53	69
Flumioxazin	200	67.1	87
Fluroxypyr	207	65	85
Fosetyl	6250	2.15	2.8
Foramsulfuron	90	150	200
Frenock	5300	2.53	3.3
Glufosinate	1110	12.1	16
Glycine, N-(phosphonomethyl)-, potassium salt	2380	5.64	7.3
Glyphosate ammonium salt	2020	6.64	8.6
Glyphosate isopropylamine	2040	6.59	8.6
Glyphosate-trimesium	1430	9.41	12
Halosulfuron-methyl	126	106	140
Imazamox	21.3	631	820
Imazapyr	1870	7.17	9.3
Imazaquin	340	39.4	51
Imazethapyr	89	150	200
Imazosulfuron	89.1	150	200
Indanofan	140	96.1	120

Active agent	Standard dose (g/ha)	Characterization factor (kg PPP-eq/kg)	Eco-factor (EP/g)
Iodosulfuron-methyl-sodium	20	671	870
Ioxynil	450	29.8	39
IPC	892	15	20
Isoproturon	1280	11	14
Isouron	2220	6.03	7.8
Isoxaben	240	55.8	73
Karbutilate	6090	2.2	2.9
Lenacil	838	16	21
Linuron	664	20.2	26
MCPA ethyl	360	37.3	48
MCPA sodium	549	24.4	32
MCPA (sal isopropilamina)	3490	3.84	5
MCPB-ethylester	240	55.9	73
MCPP dimethylamine	2810	4.77	6.2
MDBA	2690	4.98	6.5
Mecoprop	770	17	22
Mecoprop-P	788	17	22
Mefenacet	1000	13.4	17
Metamitron	3500	3.83	5
Metazachlor	1000	13	17
Metolachlor	836	16	21
Metribuzin	531	25.3	33
Metsulfuron methyl	12	1120	1500
Molinate	2390	5.61	7.3
Napropamide	2400	5.59	7.3
Nicosulfuron	50	268	350
Orthobencarb	6750	1.99	2.6
Oryzalin	1200	11.2	15
Oxadiargyl	428	31.3	41
Oxadiazon	403	33.3	43
Oxaziclomefone	80	168	220
PAC	600	22.3	29
Paraquat	500	26.8	35
Pendimethalin	1000	13.4	17
Penoxsulam	36	373	480
Pentoxazone	213	63.1	82
Polycarbamate	12500	1.07	1.4
Pretilachlor	423	31.7	41
Prodiamine	656	20.5	27
Prohexadione calcium	150	89.4	120
Prometryn	528	25.4	33
Propyzamide	2010	6.67	8.7
Pyraclonil	193	69.4	90
Pyraflufen-ethyl	11.6	1160	1500
Pyrazolate	1420	9.45	12
Pyrazosulfuron-ethyl	23.1	579	750
Pyrazoxyfen	1340	10	13
Pyributicarb	578	23.2	30
Pyriftalid	165	81.4	110
Pyriminobac methyl	48.1	279	360
Quinazalofop-ethyl	174	76.9	100

Active agent	Standard dose (g/ha)	Characterization factor (kg PPP-eq/kg)	Eco-factor (EP/g)
Rimsulfuron	17.6	761	990
Sethoxydim	399	33.6	44
Siduron	7100	1.89	2.5
Symetryne	446	30	39
Tebuthiuron	7390	1.82	2.4
Tepraloxydim	100	134	170
Terbacil	1340	10	13
Thenylchlor	182	73.5	96
Thifensulfuron methyl	57.5	233	300
TPN	1330	10.1	13
Traiziflam	300	44.7	58
Trichlopyr	2240	5.99	7.8
Trifloxysulfuron-sodium	32.4	414	540
Trifluralin	922	14.5	19
Plant growth regulator			
Chlormequat	690	19	25
Chlormequat Chloride	690	19	25
Ethephon	234	57	74
Hexythiazox	100	130	170
Maleic hydrazide	2000	6.7	8.7
Mepiquat chloride	338	40	52
Trinexapac-ethyl	250	54	70
Seed dressings			
Fenpiclonil	44.3	300	390
Fipronil	90	150	200
Gibberellin	10.8	1200	1600
Insecticides			
Acetamiprid	40.1	330	430
Bifenthrin	17.6	760	990
buprofezin	10	1300	1700
Carbofuran	2500	5.4	7
Carbosulfan	12500	1.1	1.4
Chlorantraniliprole	12	1100	1400
Chlorpyrifos	690	19	25
Cyfluthrin	44.5	300	390
Cypermethrin	50	270	350
Cyromazine	150	89	120
Deltamethrin	6.9	1900	2500
diazinon	286	47	61
Diflubenzuron	125	110	140
Dimethoate	400	34	44
Emamectin benzoate	0.0608	220000	290000
Endosulfan	945	14	18
Esfenvalerate	15.6	860	1100
Etofenprox	86.3	160	210
Flonicamid	60.5	220	290
Indoxacarb	43	310	400
Lambda-cyhalothrin	5.83	2300	3000

Active agent	**Standard dose (g/ha)**	**Characterization factor (kg PPP-eq/kg)**	**Eco-factor (EP/g)**
Lufenuron	0.0318	420000	550000
Malathion	910	15	20
Novaluron	2.41	5600	7300
Oils, biogenic	4330	3.1	4
Oils, unspecified	37900	0.35	0.46
Paraffin	1210	11	14
Parathion	1000	13	17
Permethrin	2000	6.7	8.7
Phosalone	428	31	40
Pirimicarb	75	180	230
pymetrozine	244	55	72
Pyraclostrobin	219	61	79
Tau-fluvalinate	48	280	360
Thiacloprid	71.4	190	250
Molluscicides			
Metaldehyde	7500	1.8	2.3
Fungicides			
Azoxystrobin	214	63	82
Benomyl	800	17	22
Benthiavalicarb-isopropyl	30.5	440	570
Boscalid	350	38	49
Captan	1600	8.4	11
Carbendazim	319	42	55
Copper	4380	3.1	4
Copper oxychloride	58.5	230	300
Copper oxysulfate	6.25	2100	2700
Cyazofamid	80	170	220
Cymoxanil	120	110	140
Cyproconazole	80	170	220
Cyprodinil	600	22	29
Diethofencarb	0.398	34000	44000
Difenoconazole	125	110	140
Dimethomorph	150	89	120
Dithianon	600	22	29
Epoxiconazole	93.8	140	180
Famoxadone	150	89	120
Fenamidone	150	89	120
Fenbuconazole	100	130	170
Fenpropidin	300	45	59
Fenpropimorph	750	18	23
Fentin acetate	414	32	42
Fentin hydroxide	328	41	53
Fluazinam	250	54	70
Fludioxonil	297	45	59
Fluopicolide	89	150	200
Fluquinconazole	79.7	170	220
Flusilazole	165	81	110
Folpet	1930	6.9	9
Fosetyl-aluminium	2400	5.6	7.3

Active agent	**Standard dose (g/ha)**	**Characterization factor (kg PPP-eq/kg)**	**Eco-factor (EP/g)**
Hexaconazole	169	79	100
Imazamox	40	340	440
Iodosulfuron	4.93	2700	3500
Iprodione	550	24	31
Kresoxim-methyl	138	97	130
Lindane	1500	8.9	12
Mancozeb	1900	7.1	9.2
Mandipropamid	150	89	120
Maneb	2030	6.6	8.6
Mesotrione	125	110	140
Metconazole	90	150	200
Myclobutanil	84	160	210
Prochloraz	450	30	39
Propamocarb HCl	758	18	23
Propiconazole	125	110	140
Pyraclostrobin	219	61	79
Spiroxamine	752	18	23
Sulfur	32500	0.41	0.53
Tebuconazole	188	71	92
Thiophanat-methyl	934	14	18
Thiram	1630	8.2	11
Tolclofos-methyl	315	43	56
Triadimenol	40	340	440
Tridemorph	268	50	65
Trifloxystrobine	172	78	100
Vinclozolin	375	36	47

11.4 Eco-factors for different land use types

The EDP (Ecosystem Damage Potential) values are adopted or derived from Köllner (2001) (see notes at the end of Tab. 11.4). The characterization factors are calculated using the EDP of 0.56 for the reference land-cover type (settlement area – SA).

Tab. 11.4: Eco-factor for different land use types.

CORINE+	Land use	EDP	Charact. factor (m^2 SA-eq./m^2)	Eco-factor (EP/m^2)	Remark
REF	Settlement area (reference)	0.56	1.0	25	
111	Continuous urban	0.68	1.2	30	a)
112	Discontinuous urban	0.54	0.96	24	a)
113	Urban fallow	-0.08	-0.14	-3.5	a)
114	Rural settlement	0.48	0.86	22	a)
121	Industrial units	0.573	1.00	25	b)
121a	Industrial area built up part	0.68	1.2	30	c)
121b	Industrial area with vegetation	0.52	0.93	23	a)
122	Road and rail networks	0.56	1.0	25	d)
122a	Road networks	0.56	1.0	25	d)
122b	Road embankments	0.46	0.82	21	e)
122c	Rail networks	0.56	1.0	25	d)
122d	Rail embankments	0.45	0.8	20	a)
122e	Rail fallow	-0.01	-0.018	-0.45	a)
125	Industrial fallow	-0.09	-0.16	-4	a)
131	Mineral extraction sites	0.56	1.0	25	d)
132	Dump sites	0.56	1.0	25	d)
133	Construction sites	0.56	1.0	25	d)
134	Mining fallow	-0.08	-0.14	-3.5	a)
14	Artificial, non-agricultural vegetated areas	0.56	1.0	25	b)
141	Green urban areas	0.46	0.82	21	a)
142	Sport and leisure facilities	0.66	1.2	30	a)
Agricultural areas					
211	Non-irrigated arable land	0.27	0.48	12	b)
211a	Intensive arable (conventional)	0.27	0.48	12	a)
211b	Integrated (IP)	0.32	0.57	14	a)
211c	Organic arable	0.15	0.27	6.8	a)
211d	Fiber/energy crops	0.28	0.5	13	a)
211e	Agricultural fallow	-0.1	-0.18	-4.5	a)
211f	Artificial meadow	0.24	0.43	11	f)
22	Fruit trees and berry plantations	0.105	0.19	4.8	b)
221	Intensive orchards	0.24	0.43	11	f)
221a	Organic orchards	-0.03	-0.054	-1.4	a)
221b	Pastures and meadows	0.24	0.43	11	b)
222	Intensive pasture and meadows	0.21	0.38	9.5	a)
222a	Less intensive pasture and meadows	0	0.0	0.0	a)
222b	Organic pasture and meadows	-0.12	-0.21	-5.3	a)
231	Agricultural fallow with hedgerows	-0.12	-0.21	-5.3	a)
213	Rice fields	0.24	0.43	11	f)
Forests and shrub					
311	Broad leafed forest	0.038	0.068	1.7	b)
311a	Broad leafed plantations	0.26	0.46	12	g)
311b	Semi-natural broad-leafed forests	-0.02	-0.036	-0.9	a)
312	Coniferous forest	0.038	0.068	1.7	b)
312a	Coniferous plantations	0.26	0.46	12	g)
312b	Semi-natural coniferous forests	-0.02	-0.036	-0.9	h)
313	Mixed forest	-0.02	-0.036	-0.9	h)

CORINE+	**Land use**	**EDP**	**Charact. factor (m^2 SA-eq./m^2)**	**Eco-factor (EP/m^2)**	**Remark**
313a	Mixed broad-leafed forest	-0.02	-0.036	-0.9	h)
313b	Mixed coniferous forest	-0.02	-0.036	-0.9	h)
313c	Mixed plantations	0.26	0.46	12	g)
314	Forest Edge	-0.11	-0.20	-5	a)
321	Semi-natural grassland	-0.09	-0.16	-4	a)
322	Moors and heath land	0.03	0.054	1.4	a)
323	Sclerophyllous Vegetation	-0.03	-0.054	-1.4	i)
324	Transitional woodland/shrub	-0.03	-0.054	-1.4	i)
325	Hedgerows	-0.1	-0.18	-4.5	a)
Other uses					
-	Occupation, unkown	0.435	0.78	20	b)

SA:	Settlement area
a)	Derived from the values in Tab. App. 6a-1 in Köllner (2001)
b)	Derived via weighted average of subcategories
c)	Equal to factor for Corine 111
d)	Derived using the “Artificial high-intensity” average factor in accordance with Köllner (2001)
e)	Derived using the “Artificial low-intensity” average factor in accordance with Köllner (2001)
f)	Derived using the “Agriculture high-intensity” average factor in accordance with Köllner (2001)
g)	Derived using the “Forest high-intensity” average factor in accordance with Köllner (2001)
h)	Derived using the “Forest low-intensity” average factor in accordance with Köllner (2001)
i)	Derived using the “non use” average factor in accordance with Köllner (2001)
j)	Equal to the factor for Corine 22

11.5 Eco-factors for water consumption

The eco-factors listed in the following table are only to be used for specific or sufficiently detailed life cycle inventories. Normally the classification in scarcity categories as set out in Section 8.2.3 can be applied.

Tab. 11.5: Country specific eco-factors for freshwater consumption (all OECD countries) from a Japanese perspective.

	Scarcity ratio	Normalization (km^3/a)	Actual flow (km^3/a)	Critical flow (km^3/a)	Weighting (-)	Eco-factor (EP/m^3)
Australia	0.049	88.43	23.9	98.4	0.0591	0.669
Austria	0.027	88.43	2.11	15.5	0.0184	0.208
Belgium-Luxembourg	0.42	88.43	8.98	4.28	4.4	49.8
Canada	0.016	88.43	46	580	0.00627	0.0709
Czech Republic	0.2	88.43	2.58	2.63	0.962	10.9
Denmark	0.21	88.43	1.27	1.2	1.12	12.7
Finland	0.023	88.43	2.48	22	0.0127	0.143
France	0.2	88.43	40	40.7	0.962	10.9
Germany	0.31	88.43	47.1	30.8	2.33	26.4
Greece	0.1	88.43	7.77	14.9	0.274	3.10
Hungary	0.073	88.43	7.64	20.8	0.135	1.53
Iceland	0.00088	88.43	0.15	34	0.0000195	0.000221
Ireland	0.022	88.43	1.13	10.4	0.0118	0.134
Italy	0.23	88.43	44.4	38.3	1.34	15.2
Japan	0.21	88.43	88.4	86	1.06	12.0
Korea	0.12	88.43	9.02	15.4	0.342	3.87
Luxembourg	a)	88.43	a)	a)	a)	a)
Mexico	0.17	88.43	78.2	91.4	0.732	8.27
Netherlands	0.087	88.43	7.94	18.2	0.19	2.15
New Zealand	0.0065	88.43	2.11	65.4	0.00104	0.0118
Norway	0.0057	88.43	2.19	76.4	0.000822	0.00929
Poland	0.26	88.43	16.2	12.3	1.73	19.6
Portugal	0.16	88.43	11.3	13.7	0.672	7.59
Slovak Republic	b)	88.43	b)	b)	-	-
Spain	0.32	88.43	35.6	22.3	2.55	28.9
Sweden	0.017	88.43	2.96	34.8	0.00723	0.0818
Switzerland	0.048	88.43	2.57	10.7	0.0577	0.652
Turkey	0.18	88.43	37.5	42.7	0.772	8.73
UK (Great Britain & Northern Ireland)	0.065	88.43	9.54	29.4	0.105	1.19
USA	0.16	88.43	479	610	0.617	6.98
OECD	0.1	88.43	1018	2043	0.248	2.81

a) see Belgium (contained there)

b) no data available

12 Appendix B – FAQ

12.1 Criticism raised on distance to target methods

Itsubo and Inaba (2010) criticize on the distance to target methods. This Subchapter contains comments on some issues raised by Itsubo and Inaba.

Statement Itsubo and Inaba (2010) (translated)	**Authors' comment**
However, this methodology has following issues to be considered. Even though the targets are set from authorized values, it still has the possibility to result in different outcomes according to which targets to be used. For instance, in the case of global warming, by selecting the target of Kyoto Protocol or setting it to the level where global warming would not be present completely alters the weighting factors. Another example is eutrophication. In Japan, every lake has its own environmental standard which could be set in eutrophic or oligotrophic level. Thus, weighting factor differs significantly depending on which lake is selected as the target value. This implies that the worst case values could end up in very high weighting factor.	- In case of global warming we agree with this statement. - With regard to eutrophication the formula of the 2006 version, and of ecological scarcity Japan, regionalised eco-factors may be established. From there a national average impact factor for eutrophying substances can be calculated. In the Swiss version, this has been done for phosphorous emissions to rivers and lakes. A weighted average eco-factor was developed using lake specific actual and target concentrations and the size of the lake. In the Japanese version, regionalization was not possible due to lack of data.
As mentioned above, there are multiple options for setting the target. This target is selected by criteria of the inventor of the assessment technique, whether they think it is appropriate or not. This indicates that there is high degree of arbitrariness of weighting factor. In order to avoid this arbitrariness, it is necessary to have discussions concerning what standard shall be adapted and by which range of target values are appropriate to fulfil such standards. However, there are still no discussions about equivalence between targets set for each impact variables.	Indeed there is a risk of arbitrariness in the selection of the appropriate political target. That is why, national administrations should ideally be involved in establishing the eco-factors. And they should have the opportunity to comment on the final set of eco-factors, whether or not it adequately represents the environmental policy of the respective country.
Moreover, evaluation formula of environmental impact itself differs within DtT method. For example, in Eco-scarcity method, weighting factor is derived by dividing the current value with square value of the target (eq.3.1-A). Meanwhile, most of the methodology that belongs to midpoint-type impact assessment methodology normalizes the characterized value and multiplies the ratio of status quo and the target (eq.3.1-1). This difference results in stressed values in Eco-scarcity method for particles having stricter targets. Having a premise that assumes the difference between the target and the status quo represents the environmental impact, it cannot be verified for which calculation method better reflects the true impact.	- Concerning normalisation by individual elementary flows or with characterised values: Depending on how the national target is defined, either individual pollutants or a group of pollutants is used in normalisation. We recently discussed the issue of a consistent characterization of all pollutants and resources within the update project of the Swiss method. However, we had to abandon this idea because many targets for particular pollutants take their multiple environmental effects into account. Characterising all pollutants would result in substantial double counting. - Concerning linear or square function of the weighting factor: The two equations result in the same eco-factor as long as normalization flow is identical with the actual flow.
From all the reasons above, there are few methodology developments that are based on such approaches in recent LCIA research.	It is true that recently the method is not being developed in many countries or regions. In general, only a few LCIA methods are being developed in the recent past (be it damage oriented or distance to target).

12.2 Trade-offs

Is it possible to compare the severity between greenhouse gas emissions and ammonia emissions in composting?

As long as decisions are taken considering environmental impacts, trade-offs between e.g. the effects of greenhouse gas emissions and ammonia emissions need to be resolved (either explicitly or implicitly). In other words, an assessment of the severity of greenhouse gas and ammonia emissions is required in any case (either implicitly or explicitly, either quantified or in a qualitative way).

Any trade-offs involve value judgements. The damage oriented method Lime (Norihiro Itsubo & Inaba 2004) uses monetary approaches (willingness to pay, damage costs), while ReCiPe 2008 (Goedkoop et al. 2009) or Eco-indicator 99 (Goedkoop & Spriensma 2000) base these judgements on a (limited) panel of experts. The distance to target method uses politically agreed emission targets (and their relation to the actual emission situation).

External damage costs could be seen as an ideal approach to quantify the damage caused by different pollutants. However, there are several challenges to cope with:

- discounting (is a far future damage equal to the same damage occurring today?)
- purchasing power parity (is the life of a person living in a rather poor country equal to the life of a person in a rich country?)
- price of non-traded environmental services such as forests or biodiversity (how to assess the external damage costs of an extinct species?)

From the author’s point of view it is a matter of personal preference of the decision makers, how to tackle trade-offs in decision situations. It is a question of “how” rather than a question of “whether or not it is possible” to judge the severity of different pollutants.

Lichtenstein & Slovic (2006) address a broad range of questions arising from the preference construction theory such as e.g. how do we construct preferences? What factors, either internal or external, influence our preferences? How do these factors affect our choice of construction methods? This theory is the foundation for the conjoint analysis which is used in Lime (Norihiro Itsubo & Inaba 2004). Conjoint analysis allows for the identification of preferences per individual project or decision. The predefined weighting factors used in Lime may be replaced by individually derived preferences.

Weidema (2009) presents a way to use budget constraint to monetarise impact assessment results. The three safeguard subjects (human, ecosystem, resources) are expressed in monetary values to assess the environmental impacts. Impacts on human well-being are assessed with the annual average income, which is the maximum that an average person can pay for an additional life year. The value of ecosystems is expressed as the share of our well-being that we are willing to sacrifice to protect the ecosystems. Weidema states that this trade-off should preferably be done by choice modelling.

In the Ecological Scarcity method, preferences are modelled by political targets and thus are fixed from the outset. The decision maker does not have the freedom of the selection, i.e. handling trade-offs within the official version of the ecological scarcity method is determined by the method’s authors and/or authorised by the commissioner. However, a company may establish its own set of reduction targets and derive the company-specific eco-factors from these targets. Such a procedure may be especially useful for multinational companies that face several different national legal frameworks.

12.3 Coordination between global goals and domestic goals

Is it possible to integrate the global goals and domestic goals at the same time?

The ecological scarcity method allows for applying global, international, regional or national/domestic goals. Even the use of local goals is supported by the method. One main prerequisite is that the nation for which the eco-factors are established, signed regional, international or global protocols, acts or directives from which the regional, international or global targets are derived. One example: Switzerland is member of the OSPAR (Oslo and Paris Convention, The Convention for the Protection of the marine Environment of the North-East Atlantic). Hence, we applied the emission targets established by OSPAR agreements on Nitrogen emitted to rivers and on radionuclides emitted to the Sea. Depending on the area covered by the regional, international or global legal framework, an adjustment regarding normalization is needed (a kind of scaling). Regarding radionuclides emitted to the Sea (being a landlocked country, Switzerland does NOT emit radionuclides to the Sea directly), we used the share of Swiss nuclear power production on the total European nuclear power production (see Frischknecht et al. 2006).

If there are two legally binding goals (global and domestic), the more strict one should be preferred (which usually will be the domestic one).[24] However, rules may be specified on how to generally proceed in such cases.

12.4 Global relevance

Is it possible to make this type of method as a global standard?

There is currently no ecological scarcity (or distance to target) community, in which approaches and methodological issues could be discussed and preferably harmonised. There were and are some national implementations. Gernuks et al. (2006) recommend the use of the ecological scarcity approach in environmental management systems of large companies such as VW.

Rather than to launch an international standardisation process within ISO, the authors recommend establishing an informal co-operation among those institutes, administrations and companies interested in using and further developing the ecological scarcity concept.

12.5 Similarity to multi-objective programming (reference point approaches)

It seems that this method is similar to reference point approaches in multi-objective programming (e.g. a method proposed by Marek Makowski). Is it a right understanding?

This is a (technically) difficult question. The two approaches, multi-objective programming and distance to target, are applied on two different levels. With multi-objective programming and optimisation one tries to find the pareto optimum within a given set of possibly conflicting objectives. In an LCA the conflicting objectives are the cumulative emissions of CO_2, NH_3, phosphorous resource use and the like (or impact category indicator results such as greenhouse gas emissions etc.) of different options (product or process alternatives). One would need to define a reference option to be able to find the best, pareto optimal product or process. The cumulative emissions of the different product or process options often represent discrete points but not continuous functions, which make it difficult to find a pareto optimum.

The eco-factor formula and the weighting factor (squared ratio of actual flow divided by critical flow) are applied on units of pollutants and resource consumptions (typically 1 kg) but not on the cumulative emissions of a particular product or process. The various objectives (the individual pollutants and resources) are not interlinked. For instance, an increase in the distance of CO_2 (which means a more strict target regarding CO_2, let us say minus 80 % instead of minus 30 %) does not imply a less strict target in PO_4 emissions (let us say minus 10 % instead of minus 20 %). All targets are basically defined independently. Thus, there is no pareto optimum to be found on the level of eco-factors (weighting factors per kg pollutant).

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[24] For instance, two targets exist for Phosphorous emissions in Switzerland. One regarding total annual flows released to the North-East-Atlantic (OSPAR) and one regarding the situation of Swiss lakes. The latter one is more strict.

12.6 The concept of distance

The commonly used distance from the target is the Minkowski distance such as the Euclidean distance. Why does the ecological scarcity method use a ratio for the distance?

The multi-objective optimisation is performed on the level of the environmental impacts of particular product or process alternatives. To identify the most optimal solution (as compared to a reference state) one may use the Euclidean distance.

The ecological scarcity method delivers weighting factors for individual pollutants and resources. Without particular applications, Euclidean distances cannot be used because there is no optimisation problem on a per kg pollutant basis (see also answer to question in Subchapter 12.5 above).

13 Appendix C – Application of the method

13.1 Japanese annual emissions and resource extractions

The annual environmental impacts of Japan assessed with the method developed in this report are shown in Figure 1. Greenhouse gases are responsible for about 34 % of the overall impacts, heavy metals into air for 19 %, other air emissions for 13 % and water emissions for 13 %. The high importance of greenhouse gas emissions reflects the ambitious political targets in Japan. Furthermore, deposition rates of lead are high which explains the relatively high importance of heavy metal emissions into air.

Waste is another important aspect contributing to the overall impacts with about 8 %. The importance of waste corresponds well with the Japanese political targets to reduce solid waste and increase cyclical use rate. In case of soil emissions the highest share stems from potassium emissions, followed by pesticide and heavy metal emissions. With respect to energy consumption, fossil resources contribute with about 90 % to these impacts. This reflects very well the Japanese target to reduce the use of fossil resources in future. Water consumption and land use are of minor importance. In case of land use 66 % of the country is covered by forests for which a rather low eco-factor is applied.

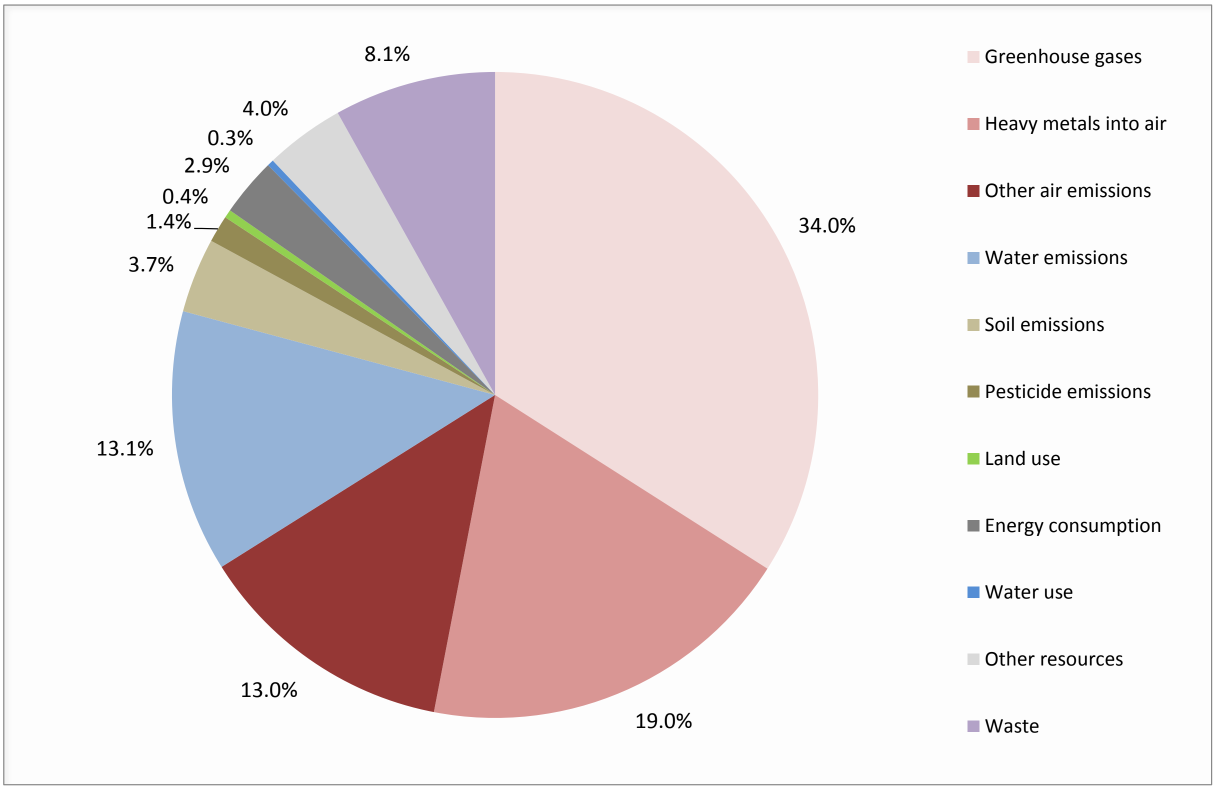

Figure 1: Overall annual environmental impacts of Japan. The graph represents the actual flows of all substances for which an eco-factor is established in the method "ecological scarcity Japan". All emissions and resource consumptions are assessed with the developed eco-factors.

13.2 EcoBalance conference paper 2010

The development of the method was presented at the EcoBalance Conference in Tokyo 2010. In this paper the life cycle inventories of five different crops grown in Japan, conventional and improved cultivation, are introduced. The results are based on a set of indicators (greenhouse gases, particulate matter, NMVOC, nitrogen and phosphorous emitted to surface water, and plant protection products).