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Feasibility of environmental product information based on life cycle thinking and recommendations for Switzerland

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Abstract

In the recent past, several initiatives have been launched to reveal the carbon footprint of consumer products or provide other life cycle based environmental information. The presentation of environmental product information (EPI) may contribute to better informed purchase decisions. It would help to direct the attention of companies to more eco-efficient products and production processes. Yet several key aspects still need clarification. The strengths and weaknesses, the opportunities and the limits of environmental information about products have been investigated in a feasibility study in detail. This article discusses the main challenges facing the provision of meaningful information to direct consumer decisions.

As a first step, we evaluate different methodological approaches towards calculating environmental information about products based on life cycle thinking. This shows that a carbon footprint might be insufficient for full environmental information and thus the use of life cycle assessment (LCA) is recommended for this purpose.

The level of decision-making addressed by the approach must be considered. It describes which type of decisions is assisted. Here we recommend starting with higher levels of decision-making, i.e. calculating average impacts of product groups and addressing the general differences between these groups. Consumers would thus see the relevance of different buying decisions and could e.g. compare the environmental impacts of traveling with these of food consumption. After that, the approach may be refined and analyses carried out of individual products within a product group.

The consideration of the use and end-of-life phases of products is a special issue to be defined within an EPI. These phases may be very important, depending on the type of product. However, the use phase often exhibits major variability, as it is influenced by disparate products and consumer behaviour. Furthermore, the use and final disposal of a product can only partly be influenced by the producer. We think that it is not feasible to systematically include the full life cycle in an EPI. Therefore we recommend that the environmental information should be shown for the product as it is bought in the shop (life cycle from cradle to shop). Thus, the system boundary of the environmental LCA coincides with the system boundary of the price of the product purchased. The impacts of the full life cycle could be shown additionally and separately if they are relevant for the total impact. Consequently it is necessary to show the environmental impacts relative to a functional unit.

For the assessment of environmental impacts in Switzerland we suggest using the Swiss ecological scarcity method. The communication of the respective LCA results in a simplified form is another issue to consider. For simplifying communication, the environmental impacts of a product should be related to overall an environmental goal, similar to normalization. The so called “eco-time” use can then be applied as an understandable unit in business to consumer communication.

There are several obstacles to putting life cycle based environmental information for products into practice. It is questionable whether one particular approach towards environmental product information can serve all kinds of purposes, starting from supporting comparative assertions of different brands of a product offered in a supermarket to comparing different consumption patterns of households. The approach proposed here should help to focus the attention of consumers first on the most important aspects for sustainable consumption.

Keywords

consumer products; environmental product information; environmental targets; eco-time; environmental time unit; life cycle assessment; levels of decision-making

1. Introduction

In the recent past there were several initiatives for showing the carbon footprint or other environmental impacts on consumer products (e.g. AFNOR 2008; Carbon Trust & DEFRA 2008). An important sector of application is the food sector. After initial enthusiasm about the usefulness of such approaches, difficulties are more and more recognized.

We evaluated the possibilities for such environmental product information (EPI) in detail within a feasibility study commissioned by the Swiss Federal Office for the Environment (FOEN) (Jungbluth et al. 2011a). In this article, we summarize and highlight some of the main challenges for meaningful EPI. The chapter on threshold limits in this article builds on a second study that investigated the environmental impacts of Swiss consumption (Jungbluth et al. 2011b). Further issues are only roughly mentioned and can be read in the cited publications.

1.1 Background of the study

The main aim of the study was to develop an approach for all types of final consumer products, while the chosen indicators should also be applicable on a higher level of national consumption. The feasibility study also investigated how results of such an impact assessment can be communicated to consumers in an easy and understandable way and which restrictions have to be considered. In pursuit of its main goal, the study investigates e.g. the following sub-questions (Jungbluth et al. 2011a):

- Which national and international activities are on-going in the field of environmental product information based on life cycle approaches?
- Which guidelines have to be developed for the inventory modelling in order to allow a fair comparison and to cover all relevant aspects in the life cycle?
- How large are uncertainties and data variations of quantitative information in view of the differentiation of several products?
- Which impacts related to resources, ecosystem quality and human health concerns cannot be covered by the indicators chosen?
- How can results best be communicated to consumers in order to assist their purchasing decisions?

The goal of the study was not to develop a full guideline for environmental product information, but to highlight all relevant aspects to be considered for such a development. In order to judge the appropriateness of different possibilities the criteria shown in Tab. 1 have been defined for the comparison of different approaches.

Tab. 1 ***Criteria set for the development of the EPI methodology***

C1	The approach should have high explanatory power, i.e. all key environmental impacts (emissions, and energy and resource consumption) should be taken into account across the entire life cycle of products (comprehensiveness and relevance).
C2	Results need to be reproducible and comparable (transparency).
C3	It should be possible to standardise the approach, i.e. to apply it to diverse product groups.
C4	Implementation must involve reasonable costs and working time for diverse products. The approach should be guided by the availability of data and it should avoid asymmetric product assessments.
C5	The approach should be scalable, i.e. fundamentally suited as a basis for higher levels of aggregation: the aggregate environmental impacts of entire product ranges, entire consumption sectors, the consumption behaviour of private households, and the consumption of a whole country or of a group of countries.
C6	The approach should be fundamentally transferable to other countries. This is a matter not only of technical feasibility, but also of political and societal acceptance.
C7	It should be possible to transform the assessment results into technically meaningful and widely understandable product information.
C8	Value judgements and policy goals which play a role in the environmental assessment should be clearly distinguishable from scientifically based assessment steps. It should be possible to characterise them in an explicit and simple manner in order to allow ex-post weighting.

1.1. Aspects covered in this article

In this article we highlight some of the key aspects to be considered in the development of EPI. First we explain that decisions of consumers can be made on different levels of decision-making. Then we compare several basic methodologies and indicators that can be used in order to calculate EPI. Another important question is the system boundaries used in the calculation of EPI. Finally we elaborate a threshold limit on environmental impacts caused by consumption in Switzerland. This is necessary in order develop a new approach for a simplified way of communicating the EPI to consumers as explained in the last sub-chapter of the following section.

2. Challenges for environmental product information

2.1. Levels of decision making addressed

In Tab. 2 different levels of decision-making (DML) are shown (Jungbluth 2000). It is essential to clearly define which type of comparisons or decisions should be assisted with EPI. A consumer can decide to shift money from one field of need (e.g. mobility, nourishing) to another. This might be environmentally relevant if one spends, for example, less on travelling, but more on eating in an organic-food restaurant. Within the need field of nourishing one can decide, for example, to eat mainly in fast-food restaurants or at home. Closely related is the level of decision among different product groups (e.g. vegetarian diet). In one product group (e.g. meat), one can choose to buy more pork or more beef. Purchasing decisions within one product category (e.g. cabbage) with different products (e.g. cauliflower, red cabbage, etc.) are also possible e.g. depending on the availability of certain products. Often the choices among variants of a product (e.g. organic or conventionally grown carrots) are made by consumers. If the decision has been made for one product, there is still a possibly relevant choice, e.g. for a certain packaging. The consumer can also decide about the processing (e.g. cooling, cooking) of a product in the household which is not only related to the decisions made in the shop. At the end all levels of decision-making are relevant for the overall environmental impact of individual consumption patterns.

The higher levels of decision-making are often more relevant for behavioural changes and reduction of total environmental impacts than the lower DML are. With regard to environmental product information, it has to be clearly defined which level of decision-making is mainly supported with the information. Due to the necessary setting of system boundaries it will not be possible to find a single methodology and approach that can be used to address all levels of decision making and thus all types of possible questions at the same time.

We suggest addressing higher levels of decision-making at the first step of EPI and refining the approach to lower levels at a later point of time. The EPI can start with generic values assisting the higher level of decision-making, e.g. meat vs. vegetables or car vs. train. With more experience, it is possible to refine the approach by differentiating information within need fields. Further on, one could differentiate within product groups or individual products. Such information would help consumers to better understand the relevance of buying decision and give attention on the most important decisions.

In any case, it is necessary to begin by defining the DML to be addressed with EPI. This determines the workload, the choice of the functional unit and the limits of the system.

Tab. 2 ***Levels of environmental decision-making (Jungbluth 2000).***

Level of decision making (DML)	Example
9 All need fields	Spending money for mobility, nourishing, entertainment, ...
8 One need field	Eating a meal at home, take-away, restaurant, canteen, …
7 Product groups	Eating mainly meat, vegetarian, vegan, ...
6 One product group	Buying a type of meat, e.g. beef, pork, poultry, …
5 Product category	Choosing a type of salad, e.g. lettuce, chive, chicory, ...
4 Variants of a product	Buying a specific product with a label. E.g. organic, integrated production, conventional
3 One product	Choice for the types of packaging, ...
2 Processing	Cooking, cooling, freezing, …
1 Pre-product and additives	Cleaning agents for dish washing, …

2.2. Comparison of basic methodologies used in EPI

In the public debate different methods are named that can be used for providing EPI, such as carbon, water or ecological footprint, life cycle assessment or material intensity per service unit. It is not always clear how and what defines such a methodology. In order to choose the appropriate method for EPI it is necessary to know the main attributes of each method.

Tab. 3 shows different methods defined by the way the inventory table of emissions and resource uses is investigated. The summary also shows the level of decision-making from Tab. 2 that can be addressed by them. Input-Output Analysis and Hybrid Analysis are difficult to apply in Switzerland due to the lack of a consistent database. Material flux accounting is usually not appropriate to investigate and compare individual products and services. Food miles also do not provide a sufficient picture about total environmental impacts. Thus, process chain analysis as used in LCA is the most appropriate method to be used in data collection for an EPI in Switzerland.

Besides this also indicators like carbon, water or ecological footprint, energy demand and materials intensity are often named as possible methods for an EPI. But, these are not full methodologies on their own because the necessary background data for the calculation have to be investigated with one of the methods shown in Tab. 3. These indicators are than derived by the life cycle impact assessment (LCIA). Thus, they are discussed in more detail in chapter 2.3.

Tab. 3 Summary of the criteria for evaluating different inventory driven methods for investigating the environmental impacts of consumer products. Level of decision-making addressed by the methods (product = product and/or service).

Method	Principle	Indicators and weighting principle	Data availability	Methodological background	Strength, Purpose, Level of decision-making	Weaknesses
Process-chain-analysis also often referred to as Life Cycle Assessment (LCA) or life cycle inventory analysis (LCI)	Investigation of environmental impacts over all stages in the life cycle of a product. An inventory of inputs and outputs is elaborated for each processing step (unit process) in the life cycle. Data are often generic and not regionalized.	Different characterisation methods by which elementary flows are assigned to impact or damage categories based on their effect or damage potential (e.g. global warming potential per kg) or based on political targets.	Good background data for different types of products and services (e.g. ecoinvent Centre 2010). Several case studies on all types of consumer products. Specific software tools (e.g. PRé Consultants 2011).	Different journals, LCA group within SETAC, ISO-standard, specialised software for data analysis.	Structured and flexible approach for inventory and weighting principles. Detailed analysis of environmental impacts (DML 1-8)	High data requirement for individual products. Some methodological problems while accounting for specific environmental problems, e.g. noise, desalination, erosion.
Input-Output Analysis (IOA)	Economic flows among different sectors of economy are used to calculate energy (or environmental) intensities for goods from different economic sectors. Inputs and outputs are recorded for a sector of the economy e.g. "forestry" that can produce several different products. Normally done for one country or region (e.g. Europe).	Different indicators such as cumulative energy demand, greenhouse gas emissions or LCIA indicators per economic value created (energy or environmental intensity, e.g. MJ/CHF).	Good in some countries (e.g. USA, Germany, the Netherlands, Switzerland), poor in others.	Developed as a tool for economic research. Publications in different journals.	Easy to apply in the analysis of a full range of household activities. (DML 8-9)	Not specific for different environmental impacts and not suited for decisions about individual products because of high level of aggregation.
Hybrid Analysis	Combination of input-output and process-chain analysis to calculate the energy intensity of a large number of consumed products.	Primary energy content of energy resources or greenhouse gas emissions used per household expenditure for a certain product (energy intensity, e.g. MJ/CHF). Other indicators would be possible as well.	High initial effort in a country. Good database for the Netherlands.	Developed mainly in the Netherlands.	Easy to apply for the analysis of a range of products. (DML 4-9).	High initial effort in a country to establish an input-output database and the basic methodology. No standardised software available.

Method	Principle	Indicators and weighting principle	Data availability	Methodological background	Strength, Purpose, Level of decision-making	Weaknesses
Material Flux Analysis (MFA)	Assessment of material flows or energy uses due to certain activities in a system defined in most cases defined by geographical boundaries (e.g. household, factory, country, EU).	Analysis of indicator elements or energy use regarded as environmentally relevant, and aggregation of chemical substances with the content of the indicator element (e.g. total C mass from CO_2, CH_4, etc.).	Data from different statistics and information about production processes. Data availability depends on the case study investigated.	Several working groups in e.g. Germany, Austria, Switzerland.	Good for a system analysis and flexible in terms of weighting environmental problems. (Different levels between 1 and 9 are addressed in case studies).	Equivalence of different emissions with unequal environmental impacts. No clear procedure to choose indicator elements and to assess their environmental relevance. Not directly related to consumer decisions.
Food miles	Assessment of transported distances over some or all stages of the life cycle of a product.	All modes of transport are aggregated. Indicator is the total distance of freight movement in kilometres or indication of tonne-kilometres.	No good public databases for different transport steps. Information relatively easy to obtain from producers.	Neither standardised method nor community. Mainly developed by single persons in Germany and Sweden. Single case studies for food products.	Easy to communicate. Yardstick for the analysis of transport related impacts due to globalisation. (DML 3).	Transports do not show a full picture for the environmental impacts caused. Different modes of transportation need to be distinguished.

2.3. Life cycle impact assessment and indicators

Several methods for the characterisation of environmental impacts and the calculation of single score indicators are analysed and compared in this chapter. The pre-selection of LCIA methods has been made including only methods that provide an individual indicator (single-score), that are known in Switzerland and that cover a range of environmental impacts:

- Ecological scarcity method 2006 (Frischknecht et al. 2009): The development of this method has been commissioned by the Swiss FOEN. This method reflects best the goals of environmental policy in Switzerland and thus might be applied also for countries with similar environmental policy.

- Eco-indicator 99 (H,A) (Goedkoop et al. 1998; Goedkoop & Spriensma 2000): Developed in a Dutch – Swiss cooperation and based on natural and social sciences. This method allows three social perspectives for the weighting of environmental impacts.

- Impact 2002+ (Jolliet et al. 2003): Developed by a Swiss research group especially for assessment of toxic substances. Other mid-point indicators are based on Eco-indicator 99. No weighting scheme.

- ReCiPe (Goedkoop et al. 2009), successor of Eco-indicator 99 (H,A): The development of this method has been commissioned by the Dutch Ministry of Housing, Spatial Planning and Environment. The method allows using different assumptions for normalisation[1] and weighting[2].

The following methods cover only one or two relevant environmental aspects:

- Ecological footprint: The ecological footprint has been applied according to the new guidelines, it does not include nuclear energy (Global Footprint Network 2009).

- Carbon Footprint, CO_2-emissions, Global Warming Potentials, etc. (only climate change) (Solomon et al. 2007)

- Cumulative energy demand: This indicator describes the use of fossil, nuclear and renewable resources (Frischknecht et al. 2007).

- Material intensity per service unit: Aggregated mass flows. All masses are added non-weighted in 5 categories (e.g. kg/kg product) (Schmidt-Bleek et. al. 1996).

- Water Footprint: All water consumption is summed up over the life cycle with a differentiation of different types of water quality (e.g. Pfister et al. 2009).

Tab. 4 shows a summary of the coverage of environmental problems in different LCIA methods for assessing aggregated environmental impacts. It has to be noted that these methods have different features and underlying assumptions. Thus, they cannot be ranked absolutely, but only in view of goals set by the decision-maker.

The methods on energy (CED), resources (MIPS), climate change (CF), water (WF) and ecological footprint (EF) can cover only a very limited list of environmental problems. Thus, according to the criteria C1 in Tab. 1, we cannot recommend to use them.

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

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[1] Division by total emissions in one region e.g. Europe or World.

[2] Stages where different types of environmental impacts are summarized and that cannot be based on natural science alone. E.g. weighting human health effects versus ecological damages.

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

We recommend using the ecological scarcity 2006 method in EPI applied in Switzerland. The method is specifically designed to represent the assessment of environmental problems from the national perspective. It covers many environmental problems and the method can be adapted to cover further environmental topics (e.g. more regionalized assessment of water use, noise, and other environmental issues which are decided on the political agenda).[3] The method is suitable for all types of products and can be used on a regional or national level.

[3] A project for updating and extending the method for the reference year 2011 has been launched.

Tab. 4 Impact categories covered by different life cycle impact assessment methods (based and extended from Frischknecht 2009)

		One environmental issue			Aggregation of several environmental issues				
	LCIA method: Impact category	Cumulative Energy Demand	MIPS	Carbon footprint	Ecological footprint	Ecological scarcity 2006	Impact 2002+	Eco-indicator 99	ReCiPe 2009
Resources	Energy, fossil	√	√ 2)	∅	∅	√	√	√	√
	Energy, nuclear	√	√ 2)	∅	∅10)	√	√	∅	∅
	Energy, renewable	∅	√ 2)	∅	∅	√	∅	∅	∅
	Ore and minerals	∅	√ 2)	∅	∅	√ 7)	√	√	√ 4)
	Water	∅	√ 2)	∅	∅	√	∅ 12)	∅ 14)	√ 1)
	Biotic resources	∅	√	∅	∅	∅	∅	∅	∅
	Land occupation	∅	∅	∅	√	√	√	√	√
	Land transformation	∅	∅	∅	∅	∅	∅	√	√ 11)
Emissions	CO_2	∅	∅	∅	√	∅	∅	∅	∅
	Climate change	∅	∅	√	∅	√	√	√	√
	Ozone depletion	∅	∅	∅	∅	√	√	√	√
	Human toxicity	∅	∅	∅	∅	√	√	√	√
	Particulate matter formation	∅	∅	∅	∅	√	√	√	√
	Photochemical ozone formation	∅	∅	∅	∅	√	∅	√	√
	Ecotoxicity	∅	∅	∅	∅	√	√	√	√
	Acidification	∅	∅	∅	∅	√	√	√	√ 3)
	Eutrophication	∅	∅	∅	∅	√	√	√	√
	Odours	∅	∅	∅	∅	∅	∅	∅	∅
	Noise	∅	∅	∅	∅	∅9)	∅	∅ 13)	∅
	Ionizing radiation	∅	∅	∅	∅	√	√	√	√
	Endocrine disruptors	∅	∅	∅	∅	√	∅	∅	∅
Others	Accidents	∅	∅	∅	∅	∅	∅	∅	∅
	Wastes	∅	∅	∅	∅	√ 5)	∅	∅	∅
	Littering	∅	∅	∅	∅	∅	∅	∅	∅
	Salinisation	∅	∅	∅	∅	∅	∅	∅	∅
	Erosion	∅	∅	∅	∅	∅	∅	∅	∅

√: Impact category included
∅: Impact category not included
1): Only summation of all water uses
2): Quantified according to moved masses for extraction
3): Only terrestrial acidification
4): Including uranium as a mineral resource
5): Includes radioactive wastes and hazardous wastes stored underground
7): Eco-factor for gravel
9): Supplementing proposal made by Doka (2009) for road traffic
10): Nuclear electricity was included in the original version (Wackernagel et al. 1996), but is according to revised guidelines published in 2009 not included anymore (Global Footprint Network 2009)
11): Only transformation of forests
12): Under development
13) Supplementing proposal made by Müller-Wenk (1999) for road traffic
14) Supplementing proposal made by Pfister et al. (2009)

Nevertheless, also other LCIA methods might be used. ReCiPe is considered as the second best option, but so far, there is not much experience with this method. The evaluation of nuclear energy might be seen as shortcoming from a Swiss perspective because relevant aspects of final disposal of nuclear wastes are not considered within ReCiPe. The weighting in ReCiPe leads in many cases to similar results as in a carbon footprint analysis.

Impact 2002+ and Eco-indicator 99 (H,A) can be considered as somewhat obsolete because basic assessment steps have been revised within the ReCiPe method. Impact 2002+ does not provide factors for the weighting step. Thus it cannot be used in environmental product information as long as there is no commonly agreed procedure for weighting.

2.4. Inclusion of the use phase

A special issue of environmental product information is the consideration of the use and end-of-life phase. Thus, one has to decide if the EPI shows the environmental impacts from cradle to the shop or if it includes the use and disposal of the product. Different approaches are applied today in the different initiatives.

The problem of considering the use phase is elaborated in Fig. 1 for different degrees of influence using the example of washing cloth, clothing and playing tennis. Grey boxes stand for products, which are bought by the consumer. Black boxes describe consumer behaviour in the use phase.

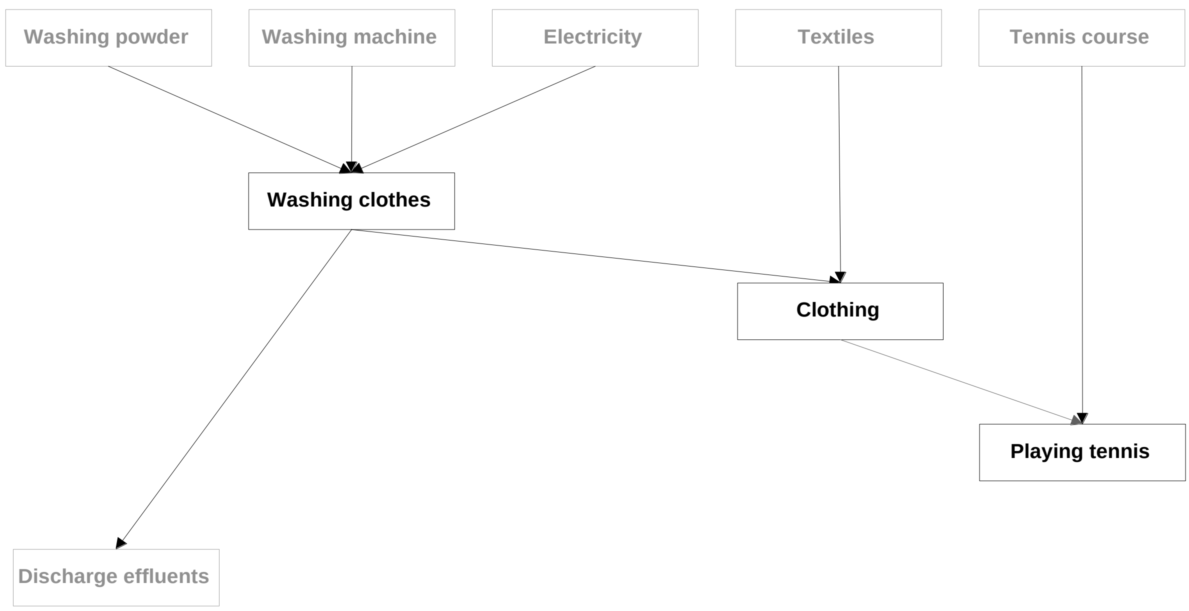
Now the question is: “What to include in the use phase of a certain product?” It seems to be necessary to include for washing powder and washing machine also the direct inputs of electricity and the discharge of effluents in a life cycle evaluation (inputs of first-degree). On the other side, it does not seem necessary to include washing in the use phase of electricity, as electricity can be used in quite different ways and the individual electricity product does not have a direct influence on this.

Washing is an important aspect in the life cycle of clothing. Thus also indirect inputs such as the buying of washing powder, washing machine and the electricity used during washing have to be considered if one wants to show and compare the environmental impacts of different types of textiles over the full life cycle (second-degree inputs).

If one has to decide between different types of sport courses, clothing might have some importance in the use phase of this service again. Thus, diving and playing tennis can only be compared if the necessary equipment is included in an analysis. Therefore, the influence of washing powder has also to be taken into consideration (inputs of third-degree).

Consequently, it can be said that if the use phase of a product involves in parallel a second product there will be double counting of environmental impacts because they are considered within the EPI of both products. Thus it is not clear anymore for which product such information really has to be taken into account.

Fig. 1 Different degrees of influence in the use phase (grey – products, black – use phase with household activities)



The question of system boundaries for these phases which occur downstream of the point where the EPI is calculated will be difficult to solve and there is no perfect solution. We see two principle options: “at shop” or “at grave”, which both have also severe disadvantages. The main aspects of both approaches are summarized in Tab. 5.

The authors of this paper recommend restricting EPI to these impacts associated with its production to the point of sale. With the approach “at the shop” it is possible to provide information directly for the amount of product purchased (e.g. one car, one train ticket, one cup of yoghurt). We came to the conclusion that it is not feasible to provide EPI for the full life cycle for all products where the use or disposal might be relevant if one considers all disadvantages identified in Tab. 5. The environmental product information should at least provide recommendations on important aspects of consumer behaviour if it only deals with the life cycle until the shop. The full life cycle impacts of a consumer activity such as washing or driving a car can then be analysed e.g. by consumer organisations as soon as information for all relevant products used by the consumer to fulfil a specific need are available.

As a deviation from this principle, direct emissions in the use phase must be considered for such products that are combusted or used up. This is mainly important for fuels, solvents, detergents and pharmaceutical products that are emitted into air or water.

In order to fulfil the request C1 in Tab. 1 too, we recommend showing second information for products where the use phase is relevant. While the first information e.g. for a car is provided for the product as it is bought (production of one car), the second information shows the environmental impacts over the full life cycle. This would include for a car the environmental impacts per kilometre driven accounting for the fuel production, associated emissions, production and disposal of the car. The details such as a functional unit have to be defined in so-called product category rules (PCR) and thus the workload would be considerable higher than for products which are investigated only for the life cycle until the shop (conflict with C4). Often it will not be possible to clearly identify which aspects belong to the use phase and which not.

In some cases an EPI only for the product at the shop might be misleading for direct comparisons with products with a similar function. Therefore the review process in the organization should have the possibility to withhold such information and search for a solution.

Tab. 5 Main options for general system boundaries

Criteria	Cradle to point of sale	Full life cycle
Principle	Analogous to price. Environmental impacts are considered until the point where the product is sold to the customer. The price of the product and environmental impacts follow the same principle. EPI is shown for the packaging size.	The full life cycle is considered. This might include secondary products which are needed in the use phase (e.g. electricity for the washing machine) and direct emissions. EPI must be shown for a functional unit that allows a comparison with other products on a functional basis.
Advantages	Principle is quite clear and does not leave much room for interpretation, thus also low workload for guidelines. Allows add-up total impacts of consumption. Useful for all DML and good guidance on higher levels of decision-making. Directly related to reduced environmental impacts achieved in the production chain. Less uncertain because no prediction of consumer behaviour necessary. The information can be used for comparison with all other products and many possible decision situations. Consistent with e.g. organic or fair trade label, other product information (e.g. nutritional value) and price information. Second information still could be provided in case the use phase is relevant. It is necessary really to investigate all consumer products in order to show full life cycle impacts.	Good guidance for the comparison of single similar products in a predefined setting for the decision-making (DML 3-4). Possibility to integrate aspects of the use phase which might be more important than the production. Highlights the importance of full life-cycle thinking. Consistent with traditional LCA thinking according to ISO 14040.
Disadvantages	For comparison of single products one might derive wrong conclusions if parts of the life cycle are neglected. Consumers have to think themselves about further aspects in the life cycle e.g. the washing machine that had low impacts during production, but higher electricity consumption during use. Not accepted by traditional LCA community who prefers to investigate the full life cycle in one study.	Several difficult questions how to handle distribution, use phase, end-of-life. Often it is not clear which product really determines the impacts in the use phase. Variation in consumer behaviour can have a large influence that cannot be fully considered. Functional unit must be clearly defined and thus the result is only valid for a very limited scope of decisions. Not possible to add-up impacts of different products to one total figure because of double counting of inputs. Not appropriate for higher levels of decision making (5-9) as several double counting will occur and functional unit will be difficult to define. Product design or clear description must ensure forecasted benefits. Aspects influenced directly by the producer get less important which limits the influence of EPI on the reduction of environmental impacts during production. High workload for elaboration and discussion of product category rules (PCR). High influence of decisions in the development of PCR for product comparisons and thus difficult discussion with pressure groups and stakeholders. It does not seem feasible to develop clear guidelines and rules that can be easily applied.

2.5. Estimating threshold limits for environmental impacts caused by Swiss consumption

The communication on environmental impacts is easier if actual values can be compared with a reference value. Ideally this reference would describe the environmental impacts allowed to be caused by a sustainable life-style. Such a understandable reference is e.g. the basic idea of the “ecological footprint” concept (Wackernagel et al. 1996), which relates environmental impacts to the size of our planet.

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

Targets for the (worldwide) environmental impacts caused per person in a sustainable world are so far not available despite proposals for a set of so-called Global Environmental Goals (see Perrez & Ziegerer 2008). But we can estimate the level of environmental impacts that should be achieved according to the goals of Swiss politics, reflected in the method of the ecological scarcity.

Starting point is the environmental impact of the current final consumption in Switzerland (*total consumption* in Fig. 2). In total 20 million eco-points are caused per capita in Switzerland in 2005. This result has been calculated with the total impacts of Swiss consumption divided by the Swiss population (Jungbluth et al. 2011b).

For calculating the *critical burden* in Fig. 2 the same reduction targets as found for the *critical flow*[4] have been applied to the seven categories of emissions and resource uses. This results in a target environmental impact to be caused per capita and year and amounts to about 12 million eco-points (Fig. 2). However this approach is defendable only for countries with a similar environmental quality as the world average. For countries with a relatively high environmental quality and a relatively high level of environmental impacts caused abroad through imported products, this approach leads to an underestimation of the reduction needed.

From an even stricter point of view one could thus argue that Switzerland should aim at a neutral trade balance with respect to environmental impacts. Assuming that the total environmental burden caused by Swiss consumption and production should not exceed the total environmental impact per capita acceptable in Switzerland, environmental impacts caused through net imports must be compensated by even further domestic emission reductions. With this point of view total environmental impacts would be limited to the critical flow defined by the Swiss politics (Frischknecht et al. 2009). Thus, a reduction by more than 60% would be necessary.

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

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

A critical point is the time frame of achieving the critical burden. We consider 20 years to be a reasonable time frame within which the critical burden should be achieved. This is in the time frame covered by the legislation that builds the underlying framework for the development of this LCIA method. Thus, one might develop an annual reduction target. A linear calculation would set the target each year 400’000 eco-points lower. Thus in 2011 it is 19.6 million eco-points, in 2012 it is 19.2 million eco-points and so on. This would allow a step by step attainment to the target and it would mean

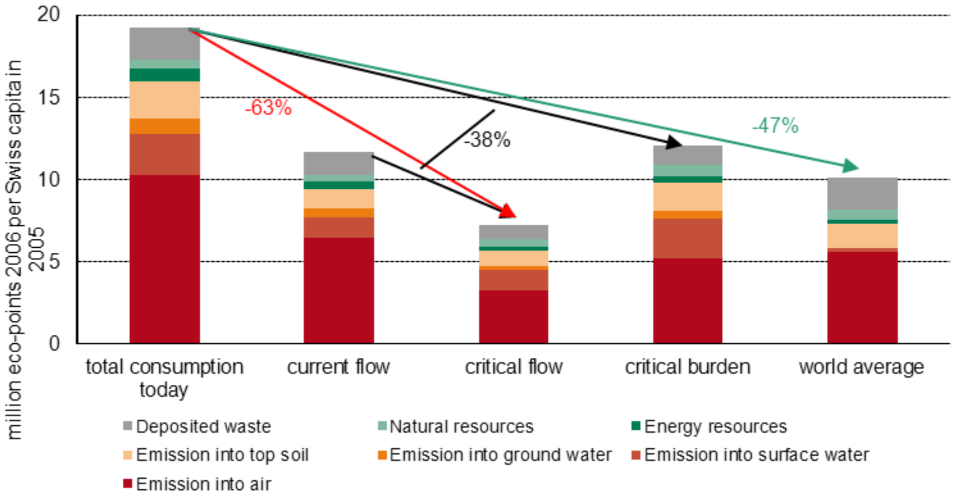
[4] The calculation of the *current flow* in Switzerland includes domestic emissions and resource uses accounted for with the ecological scarcity method. A part of e.g. the energy resource extraction takes place outside Switzerland. The critical flow defines the target according to the Swiss politics for domestic emissions and resource uses of Switzerland (including energy resources extracted abroad). The difference between the two columns ‘current flow’ and ‘critical flow’ defines the total reduction target for direct emissions and resource uses in Switzerland of about 40%. The current flow amounts to about 7 million eco-points per capita. But, reduction targets for single emissions and resource uses are not identical. For instance, the reduction targets concerning air emissions are set at about 50% while for natural resources the reduction targets would even allow a slight increase (Frischknecht et al. 2009).

that the eco-time of one product increases every year if the targets for improvements in the live cycle have not been met.

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

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

Fig. 2 Estimation for the target value or critical burden of total environmental impacts caused by Swiss consumption



2.6. Communication of results with an Environmental Time Unit (ETU)

Communication of LCA results in a very simplified form is another issue of consideration. For consumers it is quite difficult to understand the units of environmental indicators such as eco-points or kg CO_2-eq. Therefore we propose in our study a new type of indicator that is easier to understand.

Time is one of the few things that everyone is experienced with and of which all people have the same annual budget of 365 days, regardless of their income or any other social differences. Thus we aim to express environmental impacts in a time unit further elaborating the idea and concept proposed by Kaenzig and Hauser (2009). We normalise the environmental threshold limit per year (40% reduction compared to present environmental impacts as developed in the previous chapter) with the time in one year (365 days, 8’760 hours, 526 thousand minutes, 32 MM seconds). We call the units eco-years, eco-hours, eco-minutes, etc. This allows the consumer to easily assess the burden of a product in relation to his or her annual budget.

Tab. 6 shows the environmental impacts of some product examples. A return flight to New York takes about 28 eco-days of the annual budget against real time duration of half a day. The manufacture of a T-Shirt is equivalent to about nine eco-hours. Buying a new car takes 4’700 eco-hours, but these can be written off by the consumer over 8-10 years of usage. Car driving of 10’000 km costs 1'700 eco-hours, but with an average speed of 50 km/h only 200 hours of real time. With this method every consumer can assess the importance of single product purchases in relation to the annual budget of 365 days.

This approach could also be used if the ecological scarcity method is developed with a regional focus larger than Switzerland. The idea can also be applied for other indicators with clear defined targets, e.g. global warming potential and one tonne of CO_2-eq per capita and year (Stulz 2010).

Tab. 6 Conceptual example of ETU of consumer products calculated from cradle to shop in Switzerland

Product	Real time duration	Ecological scarcity	Ecological Time
	hours	eco-points	eco-hours
Annual budget	365d 0h 0` 0``	12'000'000	365d 0h 0` 0``
Spinach, deep frozen, 1 kg	0d 0h 30` 0``	3'000	0d 2h 11` 24``
T-Shirt, cotton	66d 16h 0` 0``	12'400	0d 9h 3` 7``
Car, VW Golf	83d 8h 0` 0``	6'370'000	193d 18h 6` 0``
Car driving, 10'000 km	8d 7h 59` 60``	2'320'000	70d 13h 36` 0``
Mineral water, 1 litre	0d 0h 10` 0``	200	0d 0h 8` 46``
Flight, New York, 12'600 km	0d 13h 0` 0``	920'696	28d 0h 6` 28``
Electricity, 1 kWh	0d 10h 0` 0``	340	0d 0h 14` 54``

time provided in days, hours, minutes, seconds

3. Conclusions

Within this paper, we investigated the key aspects and the feasibility of developing environmental product information. The focus of research was on recommending an approach for Switzerland. Ongoing developments in several other countries are considered too.

An EPI may help consumers consider the environmental impacts of products in their buying decisions. Many methodological restrictions have to be considered while developing a comprehensive approach. The approach needs to be simplified, as all possible goals cannot be met at the very beginning.

Consumers can make environmentally relevant purchasing choices on different levels of decision making. The approach for EPI has to be developed depending on the level that should be addressed. Here we recommend to start developing EPI for the higher levels of decision making and thus highlight the most relevant purchasing decisions from the consumers' point of view. Later on this approach can be refined step by step.

We consider the method of process chain analysis as used in LCA for the investigation of life cycle inventory data as a good starting point for EPI.

We recommend choosing a comprehensive environmental indicator that already considers several relevant environmental aspects (emissions and resource uses) and which can be further developed with increasing scientific knowledge. This helps to avoid burden shifting and reducing one environmental impact at the expense of others. Therefore we propose to use the Swiss ecological scarcity method for calculating an indicator for products sold in Switzerland.

We recommend showing EPI for the product that as it is provided to the consumer. This includes all environmental impacts from cradle to the shop (and direct emissions from using the product). Environmental impacts from use and disposal should not be included in the EPI of the product. They are covered in the EPI of the disposal process or the EPI of additional products as e.g. electricity which is necessary for the activity within this product is used.

In all cases where the use of the product is important from a life cycle perspective, this should be supplemented with information on the full life cycle and for a predefined functional unit.

A target for the reduction of environmental impacts has to be defined as a reference. Here we suggest 40% reduction of present environmental impacts. In order to make EPI understandable we recommend using a well-known unit that can be related to personal behaviour. Time seems to be the unit most easy to understand and to bear upon it. The target for the maximum environmental burden in one year can be set equal to one year of eco-time. Thus it is possible to quantify the environmental impacts of each product in the unit of time and make it comparable.

After all these thoughts and prerequisites, the question is now what is good environmental product information?

In short, a good statement should be (see e.g. Schwegler et al. 2011):

- Truthful, accurate and verifiable
- Provided by an organisation independent from the producer and in a clearly defined procedure
- Relevant
- Clear about the environmental issue the claim refers to
- Easily understandable for the target group (i.e. consumers)
- Explicit about the meaning of any indicator

The discussion in this report of several methodological and conceptual issues has revealed that it would be impossible to develop an approach that can fulfil all goals from the very outset. The following Table 7.1 summarises the main conflicts in the development of EPI.

The left column describes the criteria that should be fulfilled by environmental product information according to the goals set at the beginning (Tab. 1). Thus the approach should allow good guidance for sustainable consumption. The different columns stand for certain methodological choices that have to be made while developing the approach (e.g. system boundary set as cradle to shop). Red fields (-) highlight conflicts between a criterion and a methodological choice.

One choice is for example the system boundary for the information "at shop" or "full life cycle". The first allows a summation of several purchases to a total figure, while the second allows a fair comparison of individual products with a given function.

Tab. 7 Overview of conflicting decisions to be made in the development of environmental product information. Recommended choices marked in blue

		Goal and Scope										LCI		Reference				Indicator				Communication	
Criterion demanded for good EPI	Choices to be made	DML 1	DML 2	DML 3	DML 4	DML 5	DML 6	DML 7	DML 8	DML 9	Develop PCR	at shop	full life cycle	Impacts per unit	Impacts per function	Quantitative results	Qualitative results	carbon footprint	ecological footprint	ecological scarcity 2006	ReCiPe	Indicator result	Ecological time
Allows a fair comparison of single products (C4)		.	.	+	+	+	+	.	-	-	+	-	+	-	+	+	-	.	.	+	+	.	.
Allows a good guidance for sustainable consumption (C1)		-	-	-	.	.	+	+	+	+	.	+	+	+	-	.	+	+	+	+	-	.	+
Includes all relevant aspects in the full life cycle (C1)		-	-	+	+	+	.	-	-	-	+	-	+	-	+	+	.	+	+	+	+	.	.
Low uncertainties of judgements		+	+	.	.	.	.	+	+	+	+	+	-	+	-	-	-	+	-	+	+	-	+
Inclusion of several environmental impacts (C1)		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-	.	+	+	+	+
Approach is transparent for consumer (C2)		.	.	.	.	+	+	+	+	+	.	+	-	+	-	+	-	+	-	+	+	.	+
Low workload (C4)		-	-	-	-	-	.	.	+	+	+	+	.	+	.	-	+	+	+	-	-	.	.
Add up of impacts is possible (life cycle, household, national) (C5)		-	-	+	+	+	+	+	+	+	-	+	-	+	-	+	-	+	+	+	+	+	+
One approach is possible for all products (C3)		-	-	-	-	-	-	+	+	+	-	+	-	+	-	+	-	+	+	.	.	-	+
Worldwide accepted as a method (C6)		-	-	.	+	+	.	.	.	.	.	.	.	+	+	.	.	+	+	-	-	+	-
Information on traded products is valid (C7)		.	.	+	+	+	-	-	-	-	.	+	-	+	-	+	.	+	+	-	+	+	.
Communication is understandable (C7)		-	-	+	+	+	+	+	+	+	+	+	-	+	+	.	+	+	+	+	.	-	+
Value judgements are separated (C8)		.	.	.	.	.	.	.	.	.	+	+	.	+	-	+	.	-	-	+	-	.	-
Criterion can be fulfilled	+																						
Criterion difficult to be fulfilled	-																						
Neutral concerning criterion or unsure	.																						

4. Outlook and open research questions

Clear procedures and guidelines are necessary as a first step when developing the EPI approach further. They should be based on the approach proposed in our report. The development process should be led by a national authority. In a second step, pilot LCA studies should be carried out for selected types of consumer products. The generic data should be published and collected in one central database. As long as more specific information is not available these generic results should be used for the EPI. The pilot LCA studies should also identify hot-spots in the life cycle and develop product specific rules that have to be followed by later LCA studies for products by specific producers. The pilot LCA and investigated data would need to be peer-reviewed independently. In a third step, case specific LCA could be calculated following the overall generic guidelines and the specific recommendations of the pilot LCA. This feasibility study revealed several issues that need more investigation and development in the future. We see for example the following:

The ecological scarcity method should be further developed (e.g. foreign land transformation, pesticides). Furthermore, overall environmental goals (including product imports) should be discussed with stakeholders and be fixed in time-bound steps (e.g. emission reductions until 2020, 2030, etc.).

Authorities could support initiatives for international agreement on single-score LCIA methods and weighting. Therefore collaboration with single countries or interested institutions seems to be a promising way in order to establish a better international acceptance in the first step. After that, a joint effort of those member countries to implement an European version could be envisaged.

A further focus might be to investigate consumer acceptance and understanding of initial ideas for the design of EPI.

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References

AFNOR 2008 AFNOR (2008) Principes généraux pour l'affichage environnemental des produits de grande consommation. BP X30-323. AFNOR et ADEME.

Carbon Trust & DEFRA 2008 Carbon Trust and DEFRA (2008) PAS 2050:2008: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. British Standard, BSi, London, retrieved from: www.bsi-global.com/en/Standards-and-Publications/Industry-Sectors/Energy/PAS-2050.

Doka 2009 Doka G. (2009) Estimates of road, rail and airplane noise damages for Life Cycle Assessment. Doka Life Cycle Assessments, Zurich, retrieved from: www.doka.ch.

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

Frischknecht et al. 2007 Frischknecht R., Jungbluth N., Althaus H.-J., Bauer C., Doka G., Dones R., Hellweg S., Hischier R., Humbert S., Margni M. and Nemecek T. (2007) Implementation of Life Cycle Impact Assessment Methods. ecoinvent report No. 3, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Frischknecht et al. 2009 Frischknecht R., Steiner R. and Jungbluth N. (2009) The Ecological Scarcity Method - Eco-Factors 2006: A method for impact assessment in LCA. Federal Office for the Environment FOEN, Zürich und Bern, retrieved from: www.bafu.admin.ch/publikationen/publikation/01031/index.html?lang=en.

Frischknecht 2009 Frischknecht R. (2009) Teil 2: Ökobilanzen (Life cycle assessment, LCA). ETH Zürich Studiengang Umweltnaturwissenschaften, retrieved from: www.esu-services.ch.

Global Footprint Network 2009 Global Footprint Network (2009) Ecological Footprint Standards 2009. Global Footprint Network, Oakland, retrieved from: www.footprintstandards.org.

Goedkoop et al. 1998 Goedkoop M., Hofstetter P., Müller-Wenk R. and Spriensma R. (1998) The Eco-Indicator 98 Explained. *In: Int J LCA*, **3**(6), pp. 352-360, retrieved from: www.scientificjournals.com/sj/lca/welcome.htm.

Goedkoop & Spriensma 2000 Goedkoop M. and Spriensma R. (2000) The Eco-indicator 99: A damage oriented method for life cycle impact assessment. PRé Consultants, Amersfoort, The Netherlands, retrieved from: www.pre.nl/eco-indicator99/.

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

Jolliet et al. 2003 Jolliet O., Margni M., Charles R., Humbert S., Payet J., Rebitzer G. and Rosenbaum R. (2003) IMPACT 2002+: A New Life Cycle Impact Assessment Methodology. *In: Int J LCA*, **8**(6), pp. 324-330.

Jungbluth 2000 Jungbluth N. (2000) Environmental Consequences of Food Consumption: A Modular Life Cycle Assessment to Evaluate Product Characteristics. *In: Int J LCA*, **5**(3), pp. 143-144, retrieved from: www.esu-services.ch.

Jungbluth et al. 2011a Jungbluth N., Büsser S., Frischknecht R., Leuenberger M. and Stucki M. (2011a) Feasibility study for environmental product information based on life cycle approaches. ESU-services GmbH, im Auftrag des Bundesamtes für Umwelt (BAFU), Uster, CH, retrieved from: www.esu-services.ch/publications/methodology/.

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

Känzig & Hauser 2009 Känzig J. and Hauser A. (2009) Darlegung der Umweltbelastung - True and Fair View und Umweltbelastungszeiten. Präsentation 29. Juni 2009, BAFU, Bern.

Müller-Wenk 1999 Müller-Wenk R. (1999) Life-Cycle Impact Assessment of Road Transport Noise. 77, ISBN Nr. 3-906502-80-5. Hochschule St. Gallen, Switzerland, retrieved from: www.iwoe.unisg.ch.

Perrez & Ziegerer 2008 Perrez F. and Ziegerer D. (2008) A Non-institutional Proposal to Strenghten International Environmental Governance. *In: Environmental Policy and Law*, **28**(5), pp. 253-261.

Pfister et al. 2009 Pfister S., Koehler A. and Hellweg S. (2009) Assessing the environmental impacts of freshwater consumption in LCA. *In: Environ. Sci. Technol.*, **43**(11), pp. 4098–4104, retrieved from: http://pubs.acs.org/doi/abs/10.1021/es802423e.

PRé Consultants 2011 PRé Consultants (2011) SimaPro 7.3, Amersfoort, NL, retrieved from: www.esu-services.ch/simapro/.

Schmidt-Bleek et. al. 1996 Schmidt-Bleek et. al. F. (1996) MAIA (Einführung in die Material Intensitäts-Analyse nach dem MIPS - Konzept). Wuppertal Institut, Wuppertal.

Schwegler et al. 2011 Schwegler R., Itten R., Grünig M., Boteler B., Känzig J. and Hauser A. (2011) Anforderungen an Umweltinformationen für eine True and Fair View - Anwendung auf die Berichterstattung zur Umweltbelastung von Konsum und Produktion einer Volkswirtschaft. Bericht für das Bundesamt für Umwelt, Bern, CH.

Solomon et al. 2007 Solomon S., Qin D., Manning M., Alley R. B., Berntsen T., Bindoff N. L., Chen Z., Chidthaisong A., Gregory J. M., Hegerl G. C., Heimann M., Hewitson B., Hoskins B. J., Joos F., Jouzel J., Kattsov V., Lohmann U., Matsuno T., Molina M., Nicholls N., Overpeck J., Raga G., Ramaswamy V., Ren J., Rusticucci M., Somerville R., Stocker T. F., Whetton P., Wood R. A. and Wratt D. (2007) Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernemental Panel on Climate Change (IPCC)*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Stulz 2010 Stulz R. (2010) Leichter Leben: Auf dem Weg zu einer nachhaltigen Energiezukunft — am Beispiel der 2000-Watt-Gesellschaft. novatlantis – Nachhhaltigkeit im ETH-Bereich, mit Unterstützung Bundesamt für Energie BFE und SIA, Schweizerischer Ingenieur- und Architektenverein, retrieved from: http://www.2000watt.ch/data/downloads/LeichterLeben.pdf.

Wackernagel et al. 1996 Wackernagel M., Rees W. and Testemale P. (1996) Our Ecological Footprint - Reducing Human Impact on the Earth. New Society Publishers, Philadelphia, PA, and Gabriola Island, BC, Canada.