When carbon is not enough: Comprehensive Ecological Rucksack Indicators for Products

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Abstract

Consumers increasingly demand more transparent information about the sustainability performance of products and services. Thus companies aim at measuring and communicating the environmental performance of products. But which indicators enable a consistent measurement of the environmental sustainability of a product? Some major European initiatives have been launched, focusing in most cases on the indicator Carbon Footprint. But the Carbon Footprint does not take into account resource scarcity and trade-offs between different environmental categories, including the use of raw materials, water and land. In this paper, we present a pilot study assessing a more comprehensive set of indicators, which was conducted in 2008 with a number of Austrian companies. In contrast to the single indicator approach, a set of five indicators was selected and tested for the assessment of the environmental sustainability performance of products: Abiotic Material Rucksack, Biotic Material Rucksack, Water Rucksack, Actual Land Use and Carbon Footprint. In an ongoing Austrian research project, we currently explore, whether this indicator set can be further developed into an integrated and Web-based Business Resource Intensity Index (BRIX).

Keywords: Carbon Footprint, MIPS, resource efficiency, sustainable production

1 Introduction

Many of today's most urgent environmental problems arise from ever increasing volumes of worldwide production and consumption and the associated resource flows (UNEP, 2007). The supply of goods and services is always linked to the use of natural resources, including raw materials (renewable and non-renewable), energy, water and land. Economic growth, and the related increase in production and consumption, has thus led to a strong growth in resource use.

World-wide resource use is rising due to growth of world population, continued high per capita resource consumption in the industrialized countries and rapidly increasing per capita resource consumption in emerging economies. Global extraction of natural resources (fossil fuels, metals, minerals and biomass) increased from around 40 billion tons in 1980 to almost 60 billion tons in 2006 (Behrens et al., 2007). Scenario calculations illustrate that this number could further grow to around 100 billion tons if no policy measures for increasing resource productivity and reducing resource consumption are introduced (Giljum et al., 2009a).

This worldwide overuse of several significant resources accelerates the depletion of resource stocks and causes negative environmental impacts on ecosystems and related ecosystem services (OECD, 2007a; WWF et al., 2008). The consumption of raw materials leads to resource scarcity, for abiotic material as well as for biotic materials, since a switch to renewable (raw) materials can only happen sustainably if the total material demand is reduced. It also leads to rising amounts of waste and greenhouse gas emissions (Giljum et al., 2009b). Land area is one of the core inputs to production, and sustainability issues related to land use include the rising intensity of land use, increased sealing and deforestation as well as destruction of habitats for wildlife. The environmental issues related to the resource category water, namely water scarcity and water pollution, will be key issues of the 21st century (Giljum et al., 2009b).

Thus, the core sustainability challenge is to diminish resource use in absolute terms, rather than just reducing the harmful effects of specific substances (Schmidt-Bleek, 1992). In order to reduce resource use, including energy use, an increase in resource efficiency is necessary to provide and use the required natural resources in a more environmentally and socially sustainable way (Irrek and Kristof, 2008). The concept of resource efficiency aims at minimizing the consumption of natural resources by reducing the inputs of raw materials, energy and water and at increasing the number of services of goods, and, at the same time reducing procurement costs of materials and waste management costs. Thus, an increase of resource efficiency due to eco-innovations may lead to a reduction of production costs and consequently to enhanced competitiveness (Bleischwitz et al., 2009). Proper measurement of resource use and related environmental effects is a prerequisite for effectively monitoring progress towards sustainability objectives.

In the last decade, the topics of natural resource use and resource productivity have gained importance in European and international policy agendas. Examples are the OECD programme on “Material Flows and Resource Productivity” (OECD, 2008), the EU Thematic Strategy on the Sustainable Use of Natural Resources (European Commission, 2005) or the EU Action Plan on Sustainable Production and Consumption and Sustainable Industrial Policy (European Commission, 2008). For the implementation of these policy initiatives, aiming for improving resource productivity, applicable and affordable measurement concepts for industry and entrepreneurship are required (Kögler et al. 2004).

In this paper we present an indicator set which measures environmental sustainability in the main environmental categories of resource use. Section 2 headlines the necessity of a life-cycle wide measurement of product’s resource use and related environmental issues. Section 3 describes the criteria according to which the indicator set was chosen as well as the resulting indicator set. The analytical framework of the three case studies, the data requirements and the case study results are presented in section 4. The overall conclusions, drawn from applying the indicator set on different products, are presented in section 5.

2 Importance of life-cycle-wide resource indicators

The evaluation of a product’s environmental sustainability requires the measurement of resource use and related environmental impacts along the whole product’s life-cycle. Most producers so far tend to focus on “on-site” or “direct” resource use rather than taking life-cycle-wide environmental impacts into account. This perspective, however, may justify the outsourcing of services or organisational entities in order to improve the producer’s environmental performance and only shifts the environmental burden elsewhere in the production chain instead of reducing it. Partial life cycle assessments which focus e.g. only on transport related environmental effects of a product, might lead to suboptimal decision making.

Life-cycle wide environmental impacts of products can be discussed from two different views: consumer responsibility or producer responsibility. An increasing number of companies admit their producer responsibility for sustainable production and at the same time more and more consumers demand sustainable products and services (Frey, 2009). . Producers so far tend to focus on “on-site” or “direct” resource use rather than taking life-cycle-wide environmental impacts into account. This perspective might allow burden shifts by outsourcing services or organisational entities. If companies are implementing the concept of resource-efficiency, they should recognize their responsibility for the whole supply chain, since it is scientifically proved, that an overall analysis of the environmental pressures related to a product has to cover the whole product’s life cycle. Lenzen et al. (2006) defined this specific life-cycle perspective for producers as extended producer responsibility (Lenzen et al., 2006).

Product-oriented environmental assessment methods, which focus on the direct and indirect resource inputs and/or emissions along product’s life cycle, are called life cycle assessment (LCA) methods (Huijbregts et al., 2007). In an LCA resource use and the related environmental impacts along products life cycle from cradle to grave/cradle are compared and assessed, which includes extraction of resources, production, distribution, retail, use phase and disposal/recycling (Baldo et al., 2008). The LCA approach is standardized by the International Organization for Standardization in the ISO 14040 LCA (Principles and Framework) und ISO 14044 LCA (Requirements and Guidelines) (Finkbeiner et al. 2006). A Life Cycle Assessment according to ISO 14040/44 involves the following phases: goal and scope definition, inventory analyses, impact assessment and interpretation. Currently the ISO Technical Committee TC 207 is developing a Water Footprint Standard and a Carbon Footprint Standard on product level. Even though overall standards are required LCA-based approaches should always be linked to the specific requirements of the system under investigation (Baldo et al., 2008). In practice producers and consumers share the responsibility for the resource use associated with the production of goods and services and both use LCA-based environmental indicators.

This paper focuses on resource use indicators and Carbon Footprint, not on an output-oriented LCA, but the accounting methods are oriented towards the general guidelines of LCA.

3 A set of comprehensive Ecological Rucksack indicators for products

In the past 15 years, a number of methodological approaches were developed which measure resource use and related environmental impacts caused by production and consumption. Among them are input-oriented approaches which quantify resource use, such as Material Flow Analyses or Material Input per Unit of Service (MIPS) (Schmidt-Bleek et al. 1998; Ritthoff et al. 2002; OECD 2007a), or water use indicators such as Water Rucksack, Water Footprint, and Virtual Water) (Chapagain & Hoekstra 2004). There are also output-oriented methods such as Life Cycle Assessment (LCA), which measure environmental impacts, for example climate change, depletion of abiotic resources, land use, climate change, toxicity, acidification, and eutrophication (Brentrup et al., 2004). A more specific output-sided indicator is the Carbon Footprint, which measures greenhouse gas emissions along the life cycle of products or services (Wiedmann & Minx 2007, BSI, 2008). Other methods combine different environmental categories in a single indictor such as the Ecological Footprint, which involves land use aspects with resource use and greenhouse gas emissions (Wackernagel et al., 2004). In recent years these indicators have been standardized at the level of nations (see, for example the Eurostat and OECD guidebooks for Material Flow Analyses (OECD 2007b), Ecological Footprint Standards by the GFN Standards Committees (GNF, 2006), or the various Guidelines for National Greenhouse Gas Inventories (IPCC/OECD/ IEA, 1997; IPCC, 2000; IPCC, 2003)). At the product level a harmonisation and standardisation of several measurement methods mentioned above is required. The life cycle assessment (LCA) of products is already standardized by the International Organization for Standardization in ISO 14040/44. The overall standards set in ISO 14040/44 are valid for other measurement methods, for example Carbon Footprint or Water Footprint, for which an ISO standard is already under development. A Standardisation of the Ecological Footprint calculation method for products and services is currently under development and is due to be released in summer 2009. First ideas have been discussed for similar development in the context of water footprint. A standard method for the calculation of the Ecological Rucksack (MIPS), which assesses the material inputs along the whole product life cycle, already exists (see Ritthoff et al., 2002).

For the selection of the indicator set proposed a set of criteria was chosen. An indicator or set of indicators for measuring environmental sustainability of products or services should fulfill a number of criteria (Giljum et al., 2006; Schmidt-Bleek, 2009):

- A comprehensive indicator set should cover main environmental categories and present these categories in a disaggregated manner.
- It has to provide information on the sustainability performance of a product or service, which can be relied upon and used as guidance, even though it may not always provide full accuracy but only a rough estimation.
- It has to be objectively verifiable by using transparent accounting schemes, system boundaries and data sources.
- It should enable a life cycle wide assessment of the environmental effects of a product or service.
- It should enable the practical application of the indicator or indicator set for a large range of products, be appropriate for a variety of different product categories and feasible within an adequate effort in terms of time and costs, once an environmental data system has been introduced in the company.
- The compatibility with national accounts should to the extent possible be established so the results can be put in relation to national and international environmental targets.
- The resource use caused by the production and consumption of a product or service should be quantified in absolute numbers and in relation to the scarcity of all natural resources.
- Starting points for improving the resource-efficiency of a product and reducing its environmental effects should be allowed to be identified.
- The ability to be understandable and easy to communicate to the general public is key in order to provide relevant information not only to a small group of experts.

Single indicators are not able to illustrate the full environmental impact of a product or service. Climate change is the most pressing environmental challenge of the 21st century, therefore the measurement and reduction of greenhouse gas emissions is of great importance. While the indicator Carbon Footprint applies the concept of life-cycle wide measurement in accordance with the standards of the International Organization for Standardization in the ISO 14040/44 (BSI, 2008), it does not consider other environmental categories than carbon emissions and cannot measure trade-offs with environmental categories, such as materials or water. Thus, a more comprehensive measurement method has to be found, such as Life Cycle Assessment (LCA). The LCA method, however, focuses only on the negative environmental impacts of resource use, such as climate change, ozone, over-fertilisation and eutrophication, rather than on resource use per se. Furthermore LCA requires substantial investments in terms of monetary resources and time it is difficult to apply to entire product portfolios of large companies.

The indicator set should help mitigate environmental problems, thus an input-oriented approach has to be integrated, measuring resource use and land use in different categories. The best known approaches on product level are the Ecological Rucksack (MIPS) and the Ecological Footprint. Since the Ecological Rucksack (MIPS) covers a set of the main environmental input categories and is able to measure trade-offs between them, it is suitable for the analysis of case studies. Resource efficiency of a product can be quantified and reduced by means of this indicator set, to contribute to a total reduction of global resource use and related negative environmental effects. But the Ecological Rucksack indicator does not take the land use perspective into account, one of the most limited resources since humanity only has one planet for the production of food, raw materials and renewable energies; preservation of biodiversity; areas for settlement and transportation (Giljum et al., 2009b). The Ecological Footprint is a tool for measuring how much biologically productive land area is required to provide the resources consumed and absorb the wastes generated by a population for a certain period of time (GFN 2006). It addresses the issues of land use and includes climate change impacts by measuring the forest area that would be needed for the sequestration of CO_2-emissions from fossil fuel use. But the major methodological drawback of the Ecological Footprint is that it does not take into account greenhouse gases other than carbon dioxide and that it does account greenhouse gas emissions in units of hypothetical forest area for sequestration of carbon dioxide instead of using a weight unit of CO_2-equivalents. Furthermore, in order to analyse local and regional impacts on land, land use should be measured as Actual Land Use with real units of area, rather than using the weighted hypothetical unit of global hectares.

The indicator selection for the case studies in 2008 was aiming for a comprehensive indicator set, which covers all resource categories listed below and can be assessed with a limited degree of effort. The prioritised environmentally related topics of the business representatives were greenhouse gas emissions from transport and energy use, resource use and waste.

In a first step, we selected the Ecological Footprint and MIPS as two existing environmental indicators to measure a product’s environmental sustainability performance:. However, since those two approaches are not free of overlaps and the Ecological Footprint shows some methodological drawbacks, the Sustainable Europe Research Institute (SERI) and the Factor 10 Institute continued developing the indicator set towards a coherent measurement system for resource use, which can be consistently applied from the micro to the macro level (see Giljum et al., 2009b). This new set consisting of the indicators Abiotic Material Rucksack, Biotic Material Rucksack, Water Rucksack, Actual Land Use and Carbon Footprint covers main resource use categories and is shown in table 1.

Environmental categories	Indicator set
Non-renewable resources	Abiotic Material Rucksack
Renewable-resources	Bioric Material Rucksack
Water	Water Rucksack
Land	Actual Land Use
Greenhouse gas emissions	Carbon Footprint

Table 1: Main resource categories set of resource use indicators and Carbon Footprint

This comprehensive multi-dimensional indicator set covers all main environmental input categories: abiotic materials, biotic materials, water and land area. Additionally the output category of carbon dioxide emissions was included in the indicator set, since climate change is an environmental issue of top priority.

4 Case studies for assessing product's environmental sustainability

The first case studies to test the suitability and applicability of the selected indicator set were conducted in 2008 on behalf of the Working Group on Sustainability of Efficient Consumer Response (ECR)[1] Austria. ECR is a joint trade and industry body which aims to improve and optimise aspects of supply chain and demand management to create benefits for the consumer. The main objective of the ECR Austria Working Group on Sustainability is to develop a comprehensive assessment methodology for the environmental sustainability of products based on existing methods. The case studies were an important step of the ECR group towards achieving this overall objective.

Regarding applications at the level of products and companies, the indicator set is currently being further applied to other product groups and industries in 2009 in cooperation with ECR (Austria) and in the framework of the research in the project Business Resource Intensity Index (BRIX)[2].

4.1 Selection of case studies

The selected indicator set was applied for the measurement of the environmental aspects of three different pairs of products – two types of light bulbs, two types of spinach and two types of packaging for mineral water. In a first step, the goal and scope of the case study was defined, including the service unit for the comparison of a pair of products. For an in-depth understanding of the production chain and processes, the input and outputs of the production chain were analysed in detail. Therefore all steps in the supply chain and input data for all resource and energy inputs along the product's life cycle were analysed.

[1] www.ecrnet.org

2 The project BRIX (aims at developing an index to measure and assess the resource intensity of products and companies. The scientific project consortia is cooperating closely with three Austrian companies from different industrial sectors (construction industry, furniture industry and pulp industry) and applies a set of indicators, which builds on the main resource use categories as discussed above. www.seri.at/brix

Case studies were chosen which enabled a comparison of two products with a similar benefit for the consumer. To enable a comparison of the case study results the service unit of the Ecological Rucksack (MIPS) was applied to all indicators. The service unit enables comparability of results of different products.

For the two different types of spinach – deep-frozen spinach of Iglo Austria GmbH[1] and fresh spinach baby-leaf salad of the Horticultural College and Research Institutes Schönbrunn[2] – the service unit of 1 kg of spinach was chosen. For Vöslauer Mineralwasser AG[3] two different ways of packaging for natural mineral water were compared, using the service unit 1 litre of mineral water. Since the comparison of a low-energy light bulb with a light bulb has to consider the different durability of the bulbs, of 8.000 operating hours with the same luminance were chosen as a service unit.

Even though, in theory, the whole life cycle should be assessed, each case study had to focus on a specific stage of the product's life cycle, due to limited data availability. The spinach case study focused on differences in the agricultural production, the light bulb case study on the usage phase, and the mineral water case study on the recycling paths of packaging. At the time the case studies were conducted, an overall and consistent analysis framework for the Carbon Footprint on product level was missing, thus the general LCA framework was applied for the Carbon Footprint as well as for the indicator of actual land use. The MIPS framework was applied according to the guidelines of Ritthoff et al. for the categories of materials and water (2002).

4.2 Data

For calculating the selected indicator set, material input data, energy input data including the underlying energy mix as well as land and water input data (e.g. process water) were collected for the different stages of the products' life-cycles. Data on indirect (embodied) resource inputs, which are not directly used at the production site, but are necessary for the production and transport of used raw materials and other production inputs, were retrieved from specific LCA data bases.

The case studies for spinach and mineral water were calculated based on company-specific primary data. The primary data for the two types of spinach were provided by the company Iglo Austria GmbH and the while the primary data for the natural mineral water with different packaging were provided by Vöslauer Mineralwasser AG. In the case of the light bulbs, where no primary data were available, secondary data of a life cycle inventory were used for the production chain assessment (Pfeifer, 1994). The main data sources for the Ecological Rucksack (MIPS) factors were the MIPS data base from the Wuppertal Institute for Climate, Environment and Energy "MIPS Online", the Factor 10 Institute Austria and information from literature like Schmidt-Bleek (1998) and others.

The greenhouse gas emissions can be calculated by multiplying the fossil and energy related material inputs with compatible CO2-equivalent-factors. Those secondary data were provided by the data base ecoinvent (econivent centre), ProBas (German Federal Environment Agency (UBA), GEMIS (Öko-Institut e.V.) or International Reference Life Cycle Data System (ILCD) (European Commission JRC). Since no data on the indirect (embodied)

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[1] http://www.iglo.at/

[2] www.hblagart.bmlf.gv.at

[3] www.voeslauer.com

land area required for the extraction and processing of raw materials and preliminary products were available, only the direct land area used for the production of the product was accounted for the Actual Land Use.

5 Discussion of Results

The results of the case studies are presented in absolute terms for the selected functional unit, demonstrating on some examples that the comprehensive indicator set provide comprehensive information on environmental sustainability of a product, whereas applying single indicators could lead to shifts of the environmental burden between different environmental categories.

It shall be noted that the results for the different products are unfortunately not directly comparable, since different analytical frameworks were used due to limited time and effort as well as due to limited data for the life cycle phases of retail, usage and disposal.

The results for the comparison of low-energy light bulb and light bulbs are mainly driven by the usage phase (see Table 2). The results contain the following steps of the products life cycle: Raw-material extraction, production process, packaging, transport to Austria (by ship from China or by truck from Poland) and the usage phase for 8,000 operating hours. Retailing and disposal are not included.

Results per 8,000 operating hours	Low-energy light bulb	Light bulb
Abiotic Material Rucksack	110 g	576 g
Biotic Material Rucksack	19 g	44 g
Water Rucksack	2,971 g	16,023 g
Actual Land Use	31 mm^2	250 mm^2
Carbon Footprint	34 g	182 g

Table 2: Case study results for light bulbs, functional unit: 8,000 operating hours

The resource use and related environmental effects of light bulbs are driven by the energy use in the usage phase of the product's life cycle. This is shown by the Abiotic Material Rucksack of the low-energy light bulb is about five times higher than for light bulbs. Carbon Footprint, which in this case only accounts only for carbon dioxide emissions due to lack of data at the time this first case study was conducted, is mainly driven by the usage phase. Therefore the Carbon Footprint for the low-energy light bulbs is, in accordance with the Abiotic Material Rucksack about four times lower than for light bulbs. If only the production phase is compared, the Carbon Footprint of the production phase of a low-energy light bulb is about 1.2 times lower higher than for the light bulbs, considering the service unit of 8,000 operating hours, which sets one low-energy light bulb into relation with approximately eight light bulbs. The Carbon Footprint of producing a single low-energy light bulb is higher than for a single light bulb. The Actual Land Use for this energy using equipment does not have any significant influence on the results. The results for Biotic Material Rucksack are negligibly small, which is typical for this specific product category. The Water Rucksack for low-energy light bulbs is 4.4 times lower than for conventional light bulbs, and is caused by the energy use in the usage phase. The total values of water input are influenced by the Austrian electricity mix. Therefore the most efficient measure to improve environmental sustainability would be the use of green electricity in the usage phase. A discussion of the results with renewable energy scenarios will not automatically lead to a similar interpretation in the different resource categories, since e.g. the Water Rucksack or the Actual Land Use might increase, depending of the kind of renewable energy carriers used. The case study results provide information for more ecological production, too. A reduction of aluminium and glass as well as energy efficient production (e. g. using renewable energy) could improve the Abiotic Material Rucksack and Carbon Footprint values of the light bulbs in the production phase. Even though in this case study the results of the different indicators are pointing in the same direction, the indicators do not always provide the same indication, as the results of the other two case studies demonstrate.

The results of the comparison between deep-frozen spinach and baby-leaf spinach are illustrated in Table 2. They demonstrate that the influence of the Actual Land Use is greater for agricultural products than for other product categories. In this case study the focus of the assessment was put on the agricultural production, thus the product was assessed according to the cradle-to-gate approach, which includes raw material extraction, agricultural production, processing, packaging and transport to the retailer. The retailer, the usage phase and the disposal was excluded from the assessment due to a lack of data. The carbon footprint for these agricultural products includes besides carbon dioxide emissions from the combustion of fossil fuels, other greenhouse gas emissions such as methane and nitrous oxide.

Results per 1 kg spinach	Deep-frozen spinach	baby-leaf spinach
Abiotic Material Rucksack	722 g	750 g
Biotic Material Rucksack	1,165 g	1,020 g
Water Rucksack	50 g	99 g
Actual Land Use	6 mm^2	8 mm^2
Carbon Footprint	266 g	456 g

Table 3: Case study results spinach, functional unit: 1 kg of spinach

Comparing the two agricultural products reveals that the small scale baby-leaf spinach production requires more Actual Land Use per kg of final product due to smaller yields per hectare of agricultural production. The Carbon Footprint of the baby-leaf spinach exceeds the value of deep-frozen spinach by about 71 per cent. Even though the deep-frozen spinach requires a lot of energy in subsequent processing and storage, the Carbon Footprint for the fresh baby-leaf spinach is higher due to extremely inefficient transport by passenger car and the polypropylene packaging material. The Water Rucksack indicators provide different results: the deep-frozen spinach only half as much water as the baby-leaf spinach, since the water use of irrigation and cleaning the baby-leaf spinach is much higher than for deep-frozen spinach. A small advantage of baby-leaf spinach in the Biotic Material Rucksack is caused by the smaller production loss due to manual labour in harvest, cleaning and packaging. The Abiotic Material Rucksack of the baby-leaf spinach is only slightly higher than the Abiotic Material Rucksack of the deep frozen spinach. The reason, why the Carbon Footprint of the baby-leaf spinach is about 40 per cent higher than the Carbon Footprint of the deep frozen spinach is due to the fact, that methane and nitrous oxide emissions are havening a much higher global warming potential than carbon dioxide. The indicators suggest that the baby-leaf spinach could be produced more ecologically, if a different packing material was used (e.g. cardboard) and if the transport would be organized in a more efficient way.

The results for the case study on two different types of packaging of mineral water (see Table 4) are based on the assessment of the raw material extraction respectively the recycling of secondary raw material, production, packaging and transport to retailer. The usage phase was not integrated in the evaluation, but the recycling process and related transports were assessed. The Actual Land Use is negligible small, since only the direct land use has been taken into account, and not the embodied land use.

Results per 1 l mineral water	mineral water in recycled PET-bottle	mineral water in PET-bottle
Abiotic Material Rucksack	159 g	199 g
Biotic Material Rucksack	40 g	29 g
Water Rucksack	7 g	10 g
Actual Land Use	0,5 mm²	4 mm²
Carbon Footprint	103 g	109 g

Table 4: Case study results mineral water, service unit for comparison: 1 litre of mineral water

The mineral water in the bottle-to-bottle recycled PET-bottle has a slightly smaller Carbon Footprint than the mineral water bottle made of primary PET granulate, even if the possible substitution of the raw material with recycled PET is taken into account. In contrast to the Carbon Footprint results, the Abiotic Material Rucksack allows measuring the substitution of primary PET with recycled PET in a more appropriate way. With the bottle to bottle recycling the Abiotic Material Rucksack can be reduced by 25 per cent compared to the primary PET bottle. Due to different bottle sizes the Biotic Material Rucksack for 1 litre of mineral water in a recycled-1-litre-PET-bottle exceeds the Biotic Material Rucksack for 1 litre mineral water in 1.5-litre-PET-bottle, since it needs more space on the wooden transport pallet. If the PET-bottle is not recycled, 44 per cent more water input is needed to provide one litre of mineral water. From an ecological point of view a very interesting result of this case study is that the production of one litre of bottled mineral water requires a life-cycle wide consumption of seven litres of water if it is packaged in a recycled PET-bottle or ten litres of water if the mineral water is packaged in a primary PET bottle! In the assessment the hot-spot of the whole mineral water life cycle is the raw-material for PET-granulate. A reduction of the primary raw material should be aspired. This can be achieved through a higher recycling quota, which now is limited to 30 per cent because of technical requirements, or a reduction of the bottle weight. The bottle weight reduction is a perfect example of resource efficiency since it facilitates economic savings and environmental benefits.

6 Conclusions

The main objective of the case studies presented in this paper was to examine the suitability and comprehensiveness of the developed set of indicators for resource use and climate impacts of products.

Measuring direct and indirect (embodied) environmental effects of products is of key interest for consumers, producers and policy makers. Companies use environmental sustainability indicators for optimizing processes, products and services, monitoring progress towards higher resource efficiency, as well as for communication purposes. Case study experiences are an important input to the current discussion on product labelling and improvement of resource-productivity since they demonstrate the potential benefits and obstacles of a product assessment based on ecological sustainability indicators. The use of resource input indicators as target indicators on the micro level of products and enterprises also facilitates eco-innovations, which per definition satisfy human needs with a life-cycle-wide minimal use of natural resources per unit service unit (Reid and Miedzinski, 2008).

Our main conclusion from the case studies is that the selected indicator set is suitable for comprehensively quantifying environmental pressures, as the five indicators cover all central environmental categories related to resource use. This conclusion was supported by the group of companies at ECR Austria, for which the work has been carried out. The results of the case studies raised awareness among the participating companies about the environmental impacts of their products. The assessment led to the identification of priority action fields in the improvement of the environmental efficiency of products and to the development of a performance measurement system.

The conclusions from a single indicator assessment such as the Carbon Footprint might not be correct for all resource categories. If one phase of the product life cycle is dominating, e.g. the usage phase in the case of light bulbs, the most suitable indicator could lead to an adequate result. But if different resource categories and more than one phase of the product life cycle significantly influence the result, e.g. packaging and transport in the spinach case study, a more comprehensive indicator set, as selected for the case studies, is required.

For certain product categories, such as electronic devices, the inclusion of the usage phase in the assessment is essential for providing appropriate information about the resource use and environmental impacts related to the product, e.g. the results for the light bulbs case study are mainly driven by the usage phase. The energy use is one of the central influence factors for the results. A discussion of different energy scenarios will not automatically lead to a similar interpretation in the different resource categories, since e.g. the Water Rucksack or the Actual Land Use might increase, depending of the kind of renewable energy carriers used. A more comprehensive indicator set is more suitable to show the environmental burden shifts, caused by a change of energy mix, than a single indicator.

The influence of different resource categories might vary between different product categories and different production methods. For instance agriculture products or final technical products are influenced in a totally different by the selected resource categories. The influence of environmental category Actual Land Use is generally higher for agricultural or harvesting products than for electronic devices. The substitution of primary raw materials by recycled materials can be measured more adequately by the selected indicator set than by carbon footprint, since the reduction of abiotic and biotic material input is measured directly.

Furthermore the case studies show that the selected resource indicators can be influenced very differently by single life cycle phases of the product. For instance there is no direct correlation between material consumption (abiotic or biotic) and energy consumption (as part of carbon footprint) for the production phase in most of the cases. One reason is that the extraction of natural resources in most of the cases needs only a small amount of energy (for instance in mining). Correlations or no correlations between the different indicators are also often due to technical circumstances (for instance the consumption of water) and not because of the "nature" of the indicators itself.

During the project the demand for a validated international database on resource indicators, in order to enable the assessment of hundreds of products, which should be updated and administrated by an independent third party, was expressed by the involved companies. In addition generally accepted methodological guidelines and a common life cycle database are required to provide verifiable and accurate results (Bierter et al., 2000). The Data Centre on Natural Resources and Products, which is currently set up at Eurostat could be one key step for increasing the availability of data to regularly calculate indicators on resource use on the national and the product level. This would be the basis for monitoring the effectiveness of national and EU resource policies aiming at increased resource productivity and reduced environmental impacts related to resource use.

Further research work is necessary for different branches and product categories. Based on the results of the case studies presented above, the indicator set is currently further developed and applied to other product groups and industries in 2009 in cooperation with ECR (Austria) and the research project Business Resource Intensity Index (BRIX)[1]. The project BRIX aims at developing an index to measure and assess the resource intensity of products and companies (integration of different resource indicators into one single business index) and at developing a better data situation for all indicators (including no research to make macro and meso data available also for the micro/product level). The scientific project consortia is cooperating closely with three Austrian companies from different industrial sectors (construction industry, furniture industry and pulp industry) and applies a set of indicators, which builds on the main resource use categories as discussed above. As part of the BRIX project, a first version of an online tool will be developed, which shall allow users to calculate the various indicators as well as the aggregated BRIX index.

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[1] www.seri.at/brix and, from September 2009, www.brix-index.net

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