COMPREHENSIVE ECOLOGICAL INDICATORS FOR PRODUCTS: THREE CASE STUDIES APPLYING ECOLOGICAL RUCKSACK (MIPS) AND ECOLOGICAL FOOTPRINT

Eva BURGER [a], Stefan GILJUM [a], Christopher MANSTEIN [b] and Friedrich HINTERBERGER [a]

[a] Sustainable Europe Research Institute (SERI), 1090 Vienna, Garnisongasse 7-21, Austria

[b] Factor 10 Institute (Austria), 1070 Vienna, Lindengasse 2/14, Austria

Paper presented at ESEE 2009 in Ljubljana. Not to be quoted. Comments are very welcome.

1. 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, and some major European initiatives have been launched, focusing on the indicator "Carbon Footprint". A more comprehensive set of indicators, based on the Ecological Footprint (including the Carbon Footprint) and the Ecological Rucksack (MIPS – Material Input per unit of Service), is presented in this paper. The results of case studies, conducted in 2008 for three different pairs of products, confirm that the selected indicator set is suitable for comprehensively quantifying environmental aspects along the whole life cycle.

Key words: resource efficiency, sustainable production, Ecological Footprint, Ecological Rucksack (MIPS), Carbon Footprint

2. INTRODUCTION

Today's most urgent environmental problems arise from ever increasing volumes of worldwide production and consumption and the associated material 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 and increasing per capita resource consumption in the industrialized countries as well as in emerging economies. Global extraction of natural resources (fossil fuels, minerals and biomass) increased from around 40 billion tons in 1980 to almost 60 billion tons in 2006. 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 materials 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, and 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 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 still required (Kögler et al. 2004). One of the most important approaches for the evaluation of the resource use and its related environmental impacts of products or services is life-cycle-wide measurement.

Life-cycle-wide assessments of the resource use of a product or service provide useful information for both producers and consumers. On the micro level of companies and products, an increasing number of companies admit their producer responsibility for sustainable production. At the same time, more and more consumers demand sustainable products and services (Frey, 2009). 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 instead of reducing it. Partial life cycle assessments which focus e.g. only on the transport related environmental effects of a product, might lead to suboptimal decision making.

In order to reduce resource use, including energy use, an increase of resource efficiency is necessary to provide the required natural resources in an environmentally and socially sustainable way (Irrek and Kristof, 2008). The concept of resource efficiency, including energy efficiency, aims at minimizing waste by reducing the inputs of raw materials, energy and water and at the same time reducing procurement costs of materials and waste management costs. Thus, an increase of resource effiency thanks to eco-innovations may lead to a reduction of procurements costs and consequently to enhanced competitiveness (Bleischwitz et al., 2009). Measurement of resource use and related environmental effects is prerequisite for monitoring progress towards sustainability objectives.

In this paper we present an indicator set which measures environmental sustainability in the main environmental categories focussing on resource use. 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.

3. THE SET OF INDICATORS

A more comprehensive set of indicators for the measurement of the environmental performance of a product than a single indicator such as Carbon Footprint should cover the main environmental categories and the most pressing environmental problems. The indicator selection for the case studies on the environmental sustainability of products presented in this paper was guided by the demand for a comprehensive indicator set, which covers the main resource categories and can be assessed with a limited degree of effort. In the 6th Environmental Action Programme of the EU, the environmental issues Natural Resources, Waste, Soil, Forestry, Air, Climate Change, Water, Biodiversity, and Land Use are listed as policy priority areas. The five main input categories, which should be covered by a comprehensive indicator set for products, are biotic (renewable) and abiotic (non-renewable) materials, water, land area and air (OECD, 2007b). The main output category besides waste and waste water, which are implicitly accounted for in material use und water use, is greenhouse gas emissions. Although greenhouse gas emissions are caused by the use of fossil energy carriers and biogenic sources, this output category is of such great importance on the environmental policy agenda that it should be mentioned separately. These five categories cover the main environmental topics: scarcity of natural resources (non-renewable materials, renewable materials and water), land use change and deforestation, extensive energy use, waste and climate change (greenhouse gas emissions).

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. 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 proposed set of indicators a set of criteria was chosen. An indicator or set of indicators for measuring environmental sustainability of products or services should fulfil 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 be given so that 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 the 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 and it is difficult to apply to entire product portfolios of large companies.

The set of indicators 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, which is 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 climate change by measuring the hypothetical forest area needed for the sequestration of CO_2-emissions from fossil fuel use.

Given the criteria listed above, the headline indicators Ecological Footprint and Ecological Rucksack (MIPS) are useful and comprehensive assessment tools for the environmental performance of goods and services. Figure 1 illustrates which resource use categories are covered by which indicator of the selected indicator set consisting of Ecological Rucksack (MIPS) and Ecological Footprint. The environmental categories abiotic material input, biotic material input and water input are covered by the Ecological Rucksack (MIPS). The land area required for producing all renewable resources is measured by the Ecological Footprint. Additionally, the Ecological Footprint assesses the output category carbon dioxide emissions by measuring the hypothetical forest area for CO_2 sequestration. A set of indicators consisting of Ecological Rucksack (MIPS) and Ecological Footprint provides reliable information on the life-cycle wide sustainability performance of a product or service and is feasible with a limited effort if all data on embodied resource inputs and emissions are taken from an LCA database.

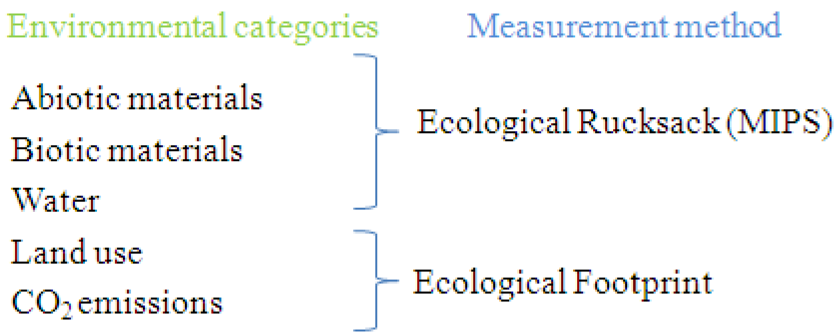

Figure 1: Main resource categories and corresponding measurement methods

Furthermore the Ecological Rucksack (MIPS) as well as the Ecological Footprint can be applied to a great variety of products, and both indicators can be applied on a national level as well. If the accounting scheme, system boundaries and data sources used are transparently documented, the results of the Ecological Footprint and the Ecological Rucksack (MIPS) assessment are verifiable. While the Ecological Footprint concept provides the advantage of communicability, the Ecological Rucksack (MIPS) is useful for identifying resource-efficiency improvements. For these reasons the selected indicator set tested through case studies in 2008 consisted of the headline indicators Ecological Footprint and Ecological Rucksack (MIPS).The indicator Ecological Footprint covers the issues of land use, biotic material use, CO_2-emissions and biodiversity aspects (Wackernagel et al., 2004). The Ecological Footprint is a resource use indicator developed in the 1990s by Wackernagel und Rees (Wackernagel et al., 1999) which measures how much biologically productive land and water areas are required to produce a certain amount of resources and to assimilate the waste and emissions generated by the consumption of these resources. The Ecological Footprint concept can be applied to products, organizations, households and at the level of cities, regions, nations and the globe as a whole (GNF; 2009). The indicator Ecological Footprint covers the issues of land use, biotic material use, CO_2-emissions and biodiversity aspects (Wackernagel et al., 2004). A standard for the calculation of the Ecological Footprint on product and company level is currently in development, but at the time the first case studies were conducted no specific standard was available (GNF; 2009).

There are different definitions of the Carbon Footprint, of which some are more appropriate than others for certain types of products. The Carbon Footprint, as defined by the Global Footprint Network (GFN) as a part of the Ecological Footprint, involves only carbon dioxide emissions caused by the combustion of fossil fuels and the use of fossil energy carriers, while other greenhouse gases are not included (Wiedmann and Minx, 2007, GFN 2006). This omission of other greenhouse gas emission sources (e.g. biogenic sources) and greenhouse gases other than carbon dioxide, such as methane and nitrous oxide is a major draw-back of the GNF's Carbon Footprint definition as carbon dioxide emissions from the use of fossil fuels accounted for only 56.6% of the total global greenhouse gas emissions in 2004 (IPCC, 2007). The definition of the British Standards Institution (BSI), might be more appropriate as a method to assess the life-cycle wide greenhouse gas inventory at the product level, in particular for agricultural and forestry products.

MIPS (material input per unit of service) is the underlying method applied to estimate the Ecological Rucksack of goods and services. It was developed by Friedrich Schmidt-Bleek (Schmidt-Bleek, 1994) at the German Wuppertal Institute. The five resource categories assessed by MIPS are: abiotic resources, biotic resources, water consumption, air consumption and movement of soil (Ritthoff et al., 2002). Used and unused material inputs (measured in metric tons) along the whole production chain of a product are assessed by the Ecological Rucksack (Schmidt-Bleek, 2009). The Ecological Rucksack concept is related to material flow analyses but the object for analysis is a product or service instead of countries (Giljum et al., 2008). While LCA traditionally focus on negative environmental impacts, MIPS measures the resource use along product's life cycle, assuming that every resource use causes material flows causing environmental pressures (Schmidt-Bleek et al., 1998, Ritthoff et al., 2002). MIPS shows the trade-off between the use of biotic and abiotic materials, since those two resource categories are reported separately. Furthermore MIPS measures the direct and indirect water use along the product's life cycle. Thus MIPS is an ideal tool for evaluating eco-innovations which facilitates the use of renewable resources. The Water Input assessment focuses on the withdrawal of surface and ground water used for agriculture, industry and domestic purposes. The Water Input calculated with the MIPS approach considers only the so-called blue water, while green water (water from rainfall and stored by plants) is excluded from the assessment (Mauser, 2007). A drawback of this assessment method is that it does not consider regional water scarcity aspects, for which the virtual water concept is more useful (Chapagain and Hoekstra, 2004).

The selected indicator set, based on the existing methods MIPS and Ecological Footprint, covers the main environmental categories to provide holistic information on a product's environmental performance. It does not claim to be free of overlaps, as the Carbon Footprint and the MIPS categories abiotic material input and air, as well as biotic material input and the Ecological Footprint's land types cropland and forest are related to each other. Comprehensiveness and applicability were of greater importance for the case studies.

4. CASE STUDIES

The case studies to test the suitability and applicability of the selected indicator set were conducted in 2008 on behalf of the Efficient Consumer Response (ECR)[1] Austria Working Group on Sustainability. 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 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 towards achieving this overall objective.

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 inputs 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.

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 Ecological Rucksack (MIPS) was applied for the Ecological Footprint Calculations, too. The service unit enables comparability of results of different products. For the two different types of spinach – deep-frozen spinach of Iglo Austria GmbH[2] and fresh spinach baby-leaf salad of the Horticultural College and Research Institutes Schönbrunn[3] – the service unit of 1 kg of spinach was chosen. For Vöslauer Mineralwasser AG[4] 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, 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 Ecological Footprint on product level was missing, thus the MIPS framework was applied according to the guidelines of Ritthoff et al. (2002).

---

[1] www.ecrnet.org

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

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

[4] www.voeslauer.com

4.2. Data

For calculating the selected indicator set material input data, energy input data including the underlying energy mix as well as the 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 kinds 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 CO_2-factors, not including non-carbon greenhouse gas emissions. 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) 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 equivalence factors for the Ecological Footprint area types were taken from the National Footprint Accounts - Austria 2003 and the Carbon Sequestration factor per hectare of forest area was taken from Austria's National Inventory Report 2006 (Anderl et al., 2007).

4.3. Results and Discussion

The results of the case studies are presented in absolute terms for the selected service unit. The results for the total Ecological Rucksack (MIPS) and the total Ecological Footprint are subdivided, for a more detailed interpretation. The carbon emissions assessed for calculating the carbon land of the Ecological Footprint, the (forest) area required for the absorption of the CO_2-emissions, were reported separately in the case study results in terms of g CO_2/service unit and as a part of the total Ecological Footprint in terms of global square meters (the ten-thousandth part of a global hectare).

The results for the comparison of low-energy light bulbs and light bulbs are mainly driven by the usage phase (see Table 1). 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 service unit [su = 8,000 operating hours]	**low-energy light bulb**	**light bulb**
Carbon Footprint [g/su]	34,225	181,695
Carbon Footprint [gm²/su]	11.59	61.55
land use based part of the Ecological Footprint [gm²/su]	0.00	0.00
Ecological Footprint [gm²/su]	**11.59**	**61.55**
Abiotic Material [g/su]	109,822	576,042
Biotic Material [g/su]	19	44
Water[g/su]	2,970,680	16,022,617
Air [g/su]	29,643	159,312
MIPS [g/su]	**3,110,164**	**16,758,016**

Table 1: Case study results for light bulbs, service unit for comparison: 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. The Ecological Rucksack (MIPS) of the low-energy light bulb is about four times higher than for light bulbs. The Carbon Footprint, which only accounts for carbon dioxide emissions according to the definition of the Global Footprint Network, is mainly driven by the usage phase. Therefore the Carbon Footprint for the low-energy light bulbs is, in accordance with the abiotic material input, about 4.3 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 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 build-up land requirements for this energy using equipment do not have any significant influence on the total Ecological Footprint results, since the energy consumption in the usage phase made up 95 per cent of the total Ecological Footprint. The results for Biotic Material Input are negligibly small, which is typical for this specific product category. The water input 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. Even thought the usage phase is the dominating influence factor in the light bulbs life cycle, 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 Ecological Rucksack (MIPS) and Ecological Footprint values of the light bulbs in the production phase. A discussion of the results with renewable energy scenarios will not automatically lead to a similar interpretation in the different resource categories. The results for the light bulb case study are pointing in the same direction for Ecological Rucksack (Abiotic Material, Water and Air) and Ecological Footprint / Carbon Footprint. This is due to dominant electricity use in the usage phase and seems to be a general tendency for such products which are dominated by the electricity consumption in their usage phase. But the two 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 demonstrate that the influence of the land use based part of the ecological footprint (crop land and build-up land) is greater for agricultural products than for other products (see Table 2). In this case study the focus of the assessment was 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. In this case the carbon footprint only causes about 85-87% of the total Ecological Footprint. Comparing the two agricultural products reveals that the small scale baby-leaf spinach production requires more crop land per kg of final product due to smaller yields per hectare of agricultural production, thus the land use based part of the Ecological Footprint of baby leaf spinach is 41 per cent bigger than that of the deep-frozen spinach. 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 Ecological Rucksack (MIPS) assessment provides different results: the baby-leaf spinach exceeds the value of deep-frozen spinach about 94 per cent. The total Ecological Rucksack (MIPS) is mainly driven by the input category water, 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 input is caused by the smaller production loss due to manual labour in harvest, cleaning and packaging. It is unclear why the input air is smaller for baby-leaf spinach than for deep-frozen spinach, since it should be similar to the category CO_2. First explanations are indirect CO_2 effects and different data sources of the life cycle data. 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.

results per service unit [su = 1kg spinach]	**deep-frozen spinach**	**baby-leaf spinach**
Carbon Footprint [g/su]	266	456
Carbon Footprint [gm²/su]	0.72	1.23
land use based part of the Ecological Footprint [gm²/su]	0.13	0.18
Ecological Footprint [gm²/su]	**0.85**	**1.42**
Abiotic Material [g/su]	722	750
Biotic Material [g/su]	1,165	1,020
Water[g/su]	49,914	99,255
Air [g/su]	477	366
MIPS [g/su]	**52,279**	**101,391**

Table 2: Case study results spinach, service unit for comparison: 1 kg of spinach

The results for the case study on two different types of packaging of mineral water 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. In the comparison, the land use based part of the Ecological Footprint (build-up land) amounts only three-tenth of a per cent of the total Ecological Footprint (see

Table 3). Thus, nearly 100 per cent of the total Ecological Footprint is based on the Carbon Footprint and the land use based part of the Ecological Footprint is, once again, negligibly small.

results per service unit [su = 1 l mineral water]	**mineral water in recycled PET-bottle**	**mineral water in PET-bottle**
Carbon Footprint [g/su]	103	109
Carbon Footprint [gm²/su]	0.28	0.30
land use based part of the Ecological Footprint [gm²/su]	0.00	0.00
Ecological Footprint [gm²/su]	**0.28**	**0.30**
Abiotic Material [g/su]	159	199
Biotic Material [g/su]	40	29
Water[g/su]	6,887	9,938
Air [g/su]	64	99
MIPS [g/su]	**7,150**	**10,265**

Table 3: 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 Ecological 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 Ecological Footprint results, the Ecological Rucksack (MIPS) allows measuring the substitution of primary PET with recycled PET in a more appropriate way. With the bottle to bottle recycling the abiotic material input can be reduced by 25 per cent compared to the primary PET bottle. Due to different bottle sizes the biotic material input for 1 litre of mineral water in a recycled-1-litre-PET-bottle exceeds the biotic material input 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.

The results for the different products are not 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 use of material input indicators as target indicators on micro level 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). The results of the case studies raised awareness among the participating companies about the environmental impacts of their products and identified potentials for resource efficiency improvements. The proposed indicator set can help companies to internally evaluate measurements that improve resource productivity. Consequently measures for reducing the Ecological Footprint and the Ecological Rucksack (MIPS) contribute to reaching global resource use objectives, if rebound effects could be avoided. In addition, comprehensive quantitative results were generated which form the basis for credible communication of the product's sustainability performance to consumers.

5. CONCLUSIONS

Measuring direct and indirect (embodied) environmental effects of products are 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.

When companies are implementing the concept of resource-efficiency, they should recognize their responsibility along the whole supply chain. Our main conclusion is that the selected indicator set consisting of Ecological Footprint and Ecological Rucksack (MIPS) is suitable for comprehensively quantifying and mitigating environmental pressures as the two indicators Ecological Rucksack (MIPS) and Ecological Footprint cover all central environmental categories related to resource use. The conclusions from a single indicator assessment such as the Carbon Footprint might not be right for all environmental 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 environmental 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.

The assessment led to the identification of priority action fields in the improvement of ecological efficiency of products and to the creation of a characteristic performance measurement system. Results of the case studies show that difference within the selected indicator set can be expected in general in the case of agriculture products and in cases where different energy or electricity scenarios play a role. Further research should also focus on the sectoral level.

In order to provide verifiable and accurate results, generally accepted methodological guidelines and a common life cycle database are required (Bierter et al., 2000). 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. The Data Center 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.

The selected indicator set based on Ecological Rucksack (MIPS) and Ecological Footprint, are not free of overlaps. Based on the experiences obtained in this pilot project, the Sustainable Europe Research Institute (SERI) and the Factor 10 Institute continue 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). Regarding applications at the level of products and companies, the indicator set is 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)[5]. 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. SERI is also working with civil society organizations such as Friends of the Earth in order to demand the application of a measurement system for resource use at the national and European level. Further results will be presented at the World Resources Forum in Davos (Switzerland) and at a forthcoming conference in cooperation with the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management.

ACKNOWLEDGMENTS

We thank the company representatives participating in the case studies with their knowledge and data about their products: Barbara Schausberger (Iglo Austria GmbH), Johann Zahrl (FoodEffect) and Wolfgang Palme (Horticultural College and Research Institutes Schönbrunn) as well as Herbert Schlossnikl (Vöslauer Mineralwasser AG) and Martina Schöbl (Vöslauer Mineralwasser AG). In addition we offer our thanks to all members of the ECR Austria working group on sustainability for their valuable comments on the selection of the indicator set and on the interpretation of the results, in particular Nikolaus Hartig.

REFERENCES

Anderl, M., Kampel, E., Köther T. et al. 2007. Austria's annual greenhouse gas inventory 1990-2006. Submission under Decision 280/2004/EC (Short-NIR), Vienna.

Baldo, G.L. et al. 2008. Study for the EU Ecolabel Carbon Footprint Measurement Toolkit - Background Manual. Brussels : European Commission, 2008b. B-1049.

Bierter, W. Irgang, G., Manstein, C.,Schmidt-Bleek, F. 2000. PROREGIS - Productivity Registry - Center for Resource Productivity Factors for Wealth Creation. Machbarkeitsstudie des Factor 10 Innovation Networks im Auftrag des deutschen Bundesministeriums für Bildung und Forschung sowie des österreichischen Bundesministeriums für Verkehr, Innovation und Technologie, Giebenach, Altach, Klagenfurt, Carnoules.

Bleischwitz, R., Giljum, S., Kuhndt, M.,Schmidt-Bleek F., et al. 2009. Eco-innovation - Putting the EU on the path to a resource and energy efficient economy. Wuppertal Spezial 38, Wuppertal Institut, Wuppertal.

Brentrup, Küster, Kuhlmann and Lammel, 2004. Environmental impact assessment of agricultural production systems using the life cycle assessment methodology: I. Theoretical concept of a LCA method tailored to crop production .European Journal of Agronomy, Volume 20, Issue 3, 247-264.

BSI British Standards. 2008. PAS 2050:2008 - Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. London : Selbstverlag, 2008a. ISBN 987 0 580 50978 0.

Chapagain, A. K. and A. Y. Hoekstra (2004). Water Footprints of Nations. Delft, the Netherlands, UNESCO-IHE.

European Commission. 2005. Thematic Strategy on the Sustainable Use of Natural Resources. COM(2005) 670 final, European Commission, Brussels.

[5] www.seri.at/brix

European Commission. 2008. Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan. COM(2008) 397 final, European Commission, Brussels.

Finkbeiner, Matthias, et al. 2006. The New International Standards for Life Cycle Assessment: ISO 14040 and ISO 14044. The International Journal of Life Cycle Assessment. 1, 2006, Bd. Volume 11, Number 2, S. 80-85.

Frey, B. and Mühlbach, D.-S.. 2009. Betriebliche Klimastrategie und Carbon Footprint. [Buchverf.] Michael Aßländer und Konstanze Senge. Corporate Social Responsability im Einzelhandel. Marburg : Metropolis-Verlag, 2009.

GFN (2006). Ecological Footprint and Biocapacity. Oakland, CA, Global Footprint Network.

GFN (2009): Ecological Footprint Standards 2009 - Draft Version 3.2. Oakland: Global Footprint Network. Available at www.footprintstandards.org

Giljum, S., Hinterberger, F., Wackernagl, M. and J. Kitzes. 2006. Resource use indicators in the European Union. Policy processes, indicator sets and criteria for a headline indicator. Aachen Foundation Kathy Beys: Aachen, Germany.

Giljum, S., Hinterberger, F. and S. Lutter (2008). Measuring natural resource use. Context, indicators and EU policy processes. SERI Background Paper 14, SERI, Vienna

Giljum, S., Polzin, C., Lutz, C. 2009a. Global implications of a European environmental tax reform. petrE Working Paper (available at www.petre.org.uk), SERI & GWS, Vienna & Osnabrück.

Giljum, S., Eva Burger, Friedrich Hinterberger, Lutter, S. 2009b. A comprehensive set of resource use indicators from the micro to the macro level. SERI Working Paper 9, Sustainable Europe Research Institute, Vienna.

Kögler, K., Allen, C., Speight, P., Vollenbroek, F.A. (2004), 'European policy initiatives on natural resources, products and waste: Reconciling resource with environmental protection', in Glueckauf Mining Reporter (2), pp. 45-48.

IPCC/OECD/IEA. 1997. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. UK Meteorological Office, Bracknell.

IPCC. 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Institute for Global Environmental Strategies, Japan.

IPCC. 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Institute for Global Environmental Strategies (IGES) for the IPCC, Geneva.

IPCC. 2007. Climate Change 2007: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland. pp 104. www.ipcc.chIrrek, W. and Kristof K. 2008. Ressourceneffizienz: Warum sie verdient, viel schneller umgesetzt zu werden Wuppertal Spezial 176, Wuppertal Institut, Wuppertal.

Mauser, W. 2007. "Wie lange reicht die Ressource Wasser?", Fischer, Frankfurt.

Reid, A., Miedzinski, M. (2008): SYSTEMATIC Innovation Panel on eco-innovation. Final report for sectoral innovation watch. www.europe-innova.org

Ritthoff, M., Rohn, H., Liedtke, C. 2002. MIPS berechnen. Ressourcenproduktivität von Produkten und Dienstleistungen. Wuppertal Spezial 27, Wuppertal Institut, Wuppertal.Rodrigues, J., Domingos, T., Giljum, S., Schneider, F. 2006. Designing an indicator of environmental responsibility. Ecological Economics 59, 256-266.

Schmidt-Bleek, F. 1992. Material flows and eco-restructuring, Fresenius Envir. Bull. 1:529-534.

Schmidt-Bleek, F. 1994. Wie viel Umwelt braucht der Mensch? MIPS – das Maß für ökologisches Wirtschaften. Birkhauser, Berlin, Basel.

Schmidt-Bleek, F., Bringezu, S., Hinterberger, F., Liedtke, C., Spangenberg, J., Stiller, H., Welfens, M. 1998. MAIA. Einführung in die Materialintensitätsanalyse nach dem MIPS-Konzept. Birkhauser, Berlin, Basel.

Schmidt-Bleek, F. (Ed.). 2004. Der ökologische Rucksack. Wirtschaft für eine Zukunft mit Zukunft. Hirzel, Stuttgart.

Schmidt-Bleek, F. 2009. The Earth: Natural Resources and Human Intervention. Haus Publishing London

OECD. 2007a. Measuring material flows and resource productivity. The accounting framework. ENV/EPOC/SE(2006)4/REV1, Environment Directorate. Organisation for Economic Co-operation and Development, Paris.

OECD. 2007b. Measuring Material Flows and Resource Productivity. The OECD guide. ENV/EPOC/SE(2006)1/REV3, Environment Directorate. Organisation for Economic Co-operation and Development, Paris.

OECD. 2008. Measuring material flows and resource productivity. Synthesis report. Organisation for Economic Cooperation and Development, Paris.

UNEP. 2007. Global Environmental Outlook 4. United Nations Environment Programme, Nairobi.

Wackernagel, M., Onisto, L., Bello, P., Linares, A.C., Falfan, I.S.L., Garcia, J.M., Guerrero, A.I.S., Guerrero, M.G.S. 1999. National Natural Capital Accounting with the Ecological Footprint Concept. Ecological Economics 29, 375-390.

Wackernagel, M., Monfreda, C., Schulz, N., Erb, K., Haberl, H., Krausmann, F. 2004. Calculating national and global ecological footprint time series; resolving conceptual challenges. Land Use Policy 21, 271-278.

Wiedmann, T., Minx, J. 2007. A Definition of ‘Carbon Footprint’. ISA/UK Research & Consulting, Durham.

WWF, Zoological Society of London, Global Footprint Network. 2008. Living Planet Report 2008. WWF, Gland, Switzerland.