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Abstract

This article presents the development process of a consumer-oriented, illustrative benchmarking tool enabling consumers to use the results of environmental life cycle assessment (LCA) to make informed decisions. Active and environmentally conscious consumers and environmental communicators were identified as key target groups for this type of information. A brochure presenting the benchmarking tool was developed as an participatory, iterative process involving consumer focus groups, stakeholder workshops and questionnaire-based feedback. In addition to learning what works and what does not, detailed suggestions on improved wording and figures were obtained, as well as a wealth of ideas for future applications.

Keywords
LCA, communication, sustainable consumption, user participation

1. Introduction

Life cycle assessment (LCA) is a systematic method for assessing the environmental impacts of a product from cradle to grave, i.e., from the extraction of raw materials from nature to the final deposition of waste substances to nature [1]. Besides being the most comprehensive available analytical method for assessing products, endorsed by e.g. the World Summit [2] and the EU Commission [3], it also has the potential to reshape relations in the supply chain. Small choices made by customers can have far-reaching impacts throughout the product life cycle. For example, selecting an energy-efficient appliance influences carbon dioxide emissions for years to come. By placing pressure on suppliers, customers can indirectly influence environmental impacts in distant places, such as the effluents from factories in

China [4]. LCA thus has the potential to reveal the “world behind the product” [5] and empower consumers to make more responsible decisions.

There are also sound arguments for not saddling consumers with too much responsibility for the environmental impacts of products, such as information asymmetry [6] and the limited impact of individual decisions [7,8]. Collective solutions are needed to protect the environmental commons. Yet – while waiting for better forms of global environmental governance to emerge – there are many choices in which consumers can make a difference and catalyze positive developments [9]. Unfortunately, many suggestions for greener consumption swiftly become controversial. As the amount of advice provided proliferates, it is also difficult for consumers to distinguish which decisions are really important.

Environmental LCA holds the potential to help environmentally-conscious consumers to sort out the available advice and find suitable and relevant environmental improvement options for their own lives. With time, it may also help consumers to assume a more powerful role in influencing global supply chains. More and more LCA results are becoming available, but the reports are extremely technical, featuring long lists of environmental pollutants and unfamiliar terms. They are not directed at lay people who need to get a quick overview and make decisions on a day-to-day basis. There have been some efforts to develop illustrative presentation formats in the LCA community. It is common to benchmark the various effects against the total effects in an area or country; e.g., in the Eco-indicator method the environmental effects are normalized by the effects caused by the average European during a year [10]. The normalized results can also be weighted according to the assumed seriousness of each effect: in Eco-indicator, these weights are determined by a panel method. After normalization and weighting, the resulting 'ecopoints' can be shown in illustrative forms, e.g., using the common column format. In addition, quite sophisticated presentation methods, using e.g. spheroids and addressing both the values and uncertainty of the various impacts, have also been used to increase the effectiveness of visualization [11].

Despite previous efforts there still is an obvious need to develop methods to interpret and present LCA results to consumers. Surveys indicate that ordinary consumers’ environmental literacy is relatively low: for example, the main causes and effects of climate change are not well known [6,12]. In this situation, one starting point for developing usable information could be the concept of “anchoring” suggested by social representation theory [13,14].

"Anchoring" means that new concepts are adopted by constructing continuities to familiar things from the past. Thus, we assume that LCA results would be easier to understand if they were linked to a familiar frame of reference. Everyday consumer products and activities may offer benchmarks which bring the frame of reference close to one's own life. This paper presents a Finnish effort to develop an illustrative benchmarking tool enabling consumers to use LCA results and make informed decisions on everyday consumer issues.

The benchmarking tool was developed as an iterative process involving LCA experts from several Finnish research institutes, as well as consumer researchers and consumers from the National Consumer Research Centre's Consumer Panel, and also feedback gained from other stakeholders such as professional environmental communicators [15]. This paper describes the development process applied in the project. We analyse how the "benchmark tool" evolved during this iterative process, and how users and experts interacted to create the current format of the benchmarks and to identify future development tasks.

2. Benchmark tool project: creating the benchmarks and developing the communication format

The aim of the project was (a) to develop benchmarks allowing consumers to make sense of and utilize LCA-based information (b) to find suitable applications, presentation formats and information channels for such benchmarks and (c) to develop an information brochure launching the benchmark idea to consumers and other stakeholders. The project was conducted as an iterative process involving a group of researchers with different backgrounds, two rounds of feedback from ordinary consumers, as well as feedback seminars for professional users such as environmental communicators (Figure 1). This section first presents the arguments for user involvement and the specific type of user involvement process applied. Next, the development of the first versions of the benchmarks is described in detail.

figure 1 here

2.1 The role of users and experts in the iterative development of the benchmarks

From the start, the project aimed to create an LCA-based tool for ordinary consumers – who represent a diverse public with varying views and interpretations of environmental issues.

While lay people often lack knowledge on “scientific facts” about the environment, they have their own local understandings and interpretation frames [16,17]. In order to integrate these lay understandings into the communications development process, recent studies have adopted a participatory approach to developing environmental communications [18, 19, 20, 21]. Interaction with information users has enabled the designers to identify the users’ beliefs, knowledge and concerns, as well as their perceived information needs. It has also helped to customize the language used to accommodate the users’ own concepts and images, and to develop useful examples and analogies. When successful, such co-design approaches allow communicators to combine research on target audiences’ perceptions with more specific input into the communication design itself.

At the start of the process, the idea of creating “benchmarks” was fairly diffuse. It was informed by research in, e.g., social representation theory [13, 14], which suggests that new concepts are adopted through "anchoring", i.e., understanding new information by constructing continuities to familiar things from the past. Thus, we assumed that LCA results would be easier to understand if they were linked to a familiar everyday object. You could, for example, state the environmental impact of a new product using a familiar product (such as a loaf of bread or a 10-mile drive) as a reference: “the damage is equivalent to that of two loaves of bread”. Yet it was not clear at this phase what products would be best as benchmarks, what would be appropriate presentation formats, and where and how consumers might like to receive this information. We thus opted for starting with a relatively open-ended form of user involvement, which is described below.

2.2 Creating benchmarks for sustainable consumption: the first phase

In the first phase of the project, two different kinds of benchmark alternatives were first developed. In addition, six different presentation types (both figures and verbal) were developed, in which comparisons were demonstrated between the environmental impacts of a product and the benchmarks. The benchmarks and presentation types were described in a “draft brochure”, which aimed to both serve as the first stage of a brochure about this methodology and to provide material for the evaluation by the consumer panel. This 20-page information package also included an illustration of how the benchmarks could be applied to a consumer decision, as well as provided a brief account of the LCA studies and other data sources referenced as well as on the calculation rules and the various environmental impacts

(both those involved and those not accounted for at this stage). Feedback on the first versions of benchmarks and presentation formats was obtained from potential users of the information, including both ordinary consumers and other stakeholders such as professionals providing environmental advice and counselling. After this, the presentation formats were refined, and more feedback was obtained on the revised presentation formats.

Alternative benchmarks

In order to develop a benchmark that could serve as a proxy measure of a person's "total daily impact", we calculated the average daily per capita environmental impacts of the whole Finnish economy. This benchmark was based on three factors, namely 1) the environmental effects of the whole economy of Finland in a year, including industry, agriculture, silviculture and communities (Table 1), 2) the population of Finland which was 5.206 million at the end of 2002 [22] and 3) the number of days per year (365).

table 1 here

The second type of benchmark was based on a number of common products. We thought they would serve as a useful comparison point and allow consumer to "anchor" the novel information to a familiar context. Two conditions were set for these products: 1) there must be an existing LCA of the product which is of good quality, and can be updated and modified (if needed) to be relevant to the conditions of Finnish consumers, and 2) the product must be a familiar everyday product for Finnish consumers. In order to screen suitable LCA-studies, a survey was conducted of existing studies, using literature databases (e.g., Cambridge Scientific Abstracts). Tens of LCA-studies were pre-evaluated, and more than ten studies were thoroughly assessed. The assessments focused on the re-applicability of the study, so that the results of the selected LCA studies could serve as reliable benchmarks. It was important that the results should correspond to the environmental impacts of similar products in current Finnish conditions, or that the study could be modified to provide relevant results for Finnish consumers. Finally, five LCA-studies were selected for further development (Table 2). Rye bread and cheese were the food products selected as benchmarks, largely due to the importance of food in everyday consumption and data availability considerations. Both make up only a small part of the daily food intake, but they serve to illustrate the

environmental loads of commonly used products. Other benchmark products included were a wash of laundry, a two-bedroom apartment and a car trip.

table 2 here

All of the selected LCA-studies required some modifications and updating (Table 2). A typical modification was to use new data for the environmental effects of electricity and district heating, representing the year 2003 and average values for whole Finland, also taking into account imported electricity on the basis of country-specific values. The products are described briefly below and in more detail in Nissinen et al.[15], and the new inventory results are shown in Table 3.

Rye bread is a staple food in Finland. The benchmark was calculated for the average daily consumption of rye bread (83 g) among regular users of this food (80% of the population). This amount corresponds to approximately two slices of bread. The benchmark for rye bread is based on a Finnish LCA-study [23,24,25] of bread made of rye grown in Finland.

Cheese represents an animal-based product with a high nutritional energy content. The benchmark was calculated for the average daily consumption of cheese (30 g) among regular cheese users (80% of the population). This amount corresponds to approximately four thin slices of cheese. The LCA was made for Emmental cheese [26], which is popular in Finland. The results pertain to conditions in 2000-2001, and represent one-third of the total production of Emmental cheese in Finland.

Laundry was selected to represent an everyday, familiar activity at home. A two-person family was assumed to do one wash of laundry per day. Finnish families currently wash their laundry almost on a daily basis: 25 washing machine cycles are run every month, on an average. Of these washes, 55 % are cold (40°C) and 35 % warm (60°C), while the remaining 10 % are either hotter or colder. The LCA data are based on a European study [27], case Sweden 1998. We updated the data pertaining to energy consumption at the use stage and to waste water treatment to correspond to Finnish conditions [28], and based our calculations on a washing temperature of 40°C. The washing machine performance data represent a relatively new and energy-efficient appliance with an energy-label class A.

A two-bedroom apartment was selected to represent housing, and the benchmark for housing is "one day of living in a warm apartment" per person. Many Finnish households (44%) live in apartment houses (blocks of flats), and the average living space per person is 36 m^2. Thus the benchmark apartment of 83 m^2 was selected as a fairly common housing type for 2 persons, with a living space per person of 41 m^2. The apartment benchmark is based on an LCA of a three-floor prefabricated apartment building [29,30], with supplementary data gained through personal communication from Koskela. The useful life of the building was calculated as 100 years. The energy consumption of the building includes space heating using district heating (combined heat and power production) and the electricity use of the facility (i.e., electricity used in common spaces of the house). Thus, the housing benchmark does not include electricity used at home for lighting, laundering, kitchen or other appliances.

A car trip represents mobility, and the benchmark corresponds driving 20 km alone. The average daily travel by car in the metropolitan area is 21 km (which is also close to the national average 19 km), the average number of persons in the car being close to 1 (i.e. 1.2). The data for fuel use and emissions in Finland of a typical car fulfilling EURO3 standards are based on the Liisa database maintained by the VTT Technical Research Centre of Finland (www.lipasto.fi). In addition, the environmental impacts of fuel production [31] were included in the calculation. The data on car manufacturing and maintenance were calculated on the basis of a relatively new LCA on the VW Golf A4 [32], with the most recent data dating from summer 2000.

table 3 here

Life cycle impact assessment

In the study, the impact assessment methodology is based on the general phases of life cycle impact assessment (LCIA): selection of impact categories, classification, characterization, normalization and weighting [33]. The selected impact categories and contributing emissions were:

1) climate change (CO_2, N_2O, CH_4),
2) acidification (SO_2, NO_x, NH_3)
3) tropospheric ozone formation (NO_x, VOC/HC, CH_4)
4) terrestrial eutrophication (NO_x, NH_3)

5) aquatic eutrophication (NO_x, NH_3, N(w), P(w)).

The other impact categories such as human toxicity, ecotoxicity, particulate matter and effects of land use were not modeled or shown in the presentation formats at this stage of the project.

Characterisation factors for Finland were used for acidification [34], tropospheric ozone formation [35] and aquatic eutrophication [36] (thus the impacts were calculated as if all the emissions had occurred in Finland) (Table 4). For normalization (and at the same time for the first benchmark), the reference values for each impact category were calculated on the basis of the total Finnish emissions and energy use (Table 1). Finland-specific weighting factors were available from an earlier study [37], following the principles presented by [38].

table 4 here

2.3 Presentation formats

Six different presentation formats were developed, as well as a background information package explaining what LCA is and explaining the environmental impacts considered in the benchmarks (climate change, acidification, eutrophication, tropospheric ozone formation and primary energy use) as well as those not considered (e.g., impacts on biodiversity, ecotoxicity). The presentation formats focused on different levels of aggregation of the data, as well as on visual vs. verbal presentation [15]. The “draft brochure”, a 20-page information package, also included an illustration of how the benchmarks could be applied to a consumer decision (Figure 2), and provided a brief account of the studies and data sources referenced as well as on the calculation rules. This “draft brochure” was used as the first version on which feedback was solicited.

Figure 2 here

3. User feedback on the first versions

Active and environmentally conscious consumers and environmental communicators were identified as key target groups for this type of information. We thus considered volunteer members of the Consumer Panel of the National Consumer Research Centre [39] an

appropriate user group to involve as user representatives. We solicited help from 300 members of this panel, and obtained 57 volunteers for the co-design process consisting of (1) inspecting the information package, (2) participating in a focus group interview, and (3) participating in a second questionnaire-based round of feedback on the improved brochure.

3.1 Gaining user feedback

As expected, those who volunteered to provide us feedback on the benchmarks were, on average, somewhat more environmentally concerned than the general population, and they were more attentive to environmental media communications. Most were middle-aged, many with a professional education and an active interest in consumer issues. The participants could also be identified as central sources of advice in their own social networks, cf. [40], who would be the first to use and diffuse this kind of information. The first round of consumer input was gained using focus group interviews [41]. Consumers were sent out the "draft brochure" in advance, and invited to discuss the following issues at the focus group sessions: (a) comments on the overall idea of using LCA-based benchmarks, (b) comments on presentation formats and (c) ideas on useful applications and future prospects of the benchmark tool. Altogether, 10 focus groups were conducted, resulting in a wide range of viewpoints – but also some clear indications for further development.

The consumers, in general, welcomed the development of reliable and unbiased environmental information. The "draft brochure" had provided them with a new perspective on the environmental impacts of consumption: for example, many were surprised about the significance of housing compared with, e.g., a car-trip, which was a more familiar cause of environmental concern. They were apprehensive, however, that the information was too complex for ordinary consumers to understand – and the single application demonstrated did not fully convince the consumers about its usability in everyday life. The consumers also doubted the potential of this type of information to alter consumer behavior on a large scale. Many discussants argued that the information should be provided to policy makers, who could then develop regulations or economic instruments to alter the behavior of companies producing the products. Even though consumers were sceptical about the impact of the information as an environmental policy measure, they did welcome it as *consumer policy* measure, helping environmentally conscious consumers to make informed choices.

The presentation format of the "draft brochure", however, evoked a lot of criticism. The research group's idea of where and how the benchmarks would actually be applied was vague – and this was evident in the draft brochure. "You're just presenting a bunch of statistics – a kind of 'nice-to-know' thing", one consumer summarized. These discussions helped us understand that we need to think more about the kind of questions that the benchmark can be used to answer, and also need to explain the figures in more detail. Visual and verbal presentation formats were given as alternatives in the "draft brochure", but it was evident that they need to be combined. The focus group feedback alerted the research group to the consumers' need for guidance and "spelling things out"– even informed consumers who like to draw their own conclusions. We were encouraged to seek for a new balance between "presenting data for consumer empowerment" and "providing advice".

As to future applications, a number of different suggestions were obtained. Comparisons between products within the same product group were the first application that came to mind, but during the discussions, many problems in this kind of application were identified. LCA information is too data-intensive for making quick comparisons in shops, and the figures developed are not easy to print on packages. Some consumers also questioned whether LCA can really discriminate between the environmental impacts of different brands of cheese, for example. A more feasible application could be of the type demonstrated in Figure 2: comparing alternative consumption patterns. Some participants felt that the information provided in the "draft brochure" was more in the category of "general education" – which would be useful for policy makers and product designers, as well. Finally, some consumers greeted the benchmark tool as a step toward a personal environmental profile, and suggested developing an Internet site allowing consumers to calculate their own environmental impact.

We also sought feedback from professional environmental communicators from the public administration (e.g., waste prevention counselors), from business (e.g., environmental managers) and from NGOS (e.g., counselors, campaigners) by organizing two seminars: the first to introduce the project, and the second to obtain systematic feedback. This was done by organizing groupwork sessions asking the participants to identify ways in which they could use the benchmarks in their work and suggest future application that they might find useful.

3.2 Lessons gleaned from the user feedback

We gained a wealth of input from the different consultations– some encouraging, some discouraging, some clear-cut and some confusing. As opinions differed on many issues (not the least, the alternative presentation formats), there was seldom a clear majority view to follow. All suggestions could not be integrated in a single development project, but the research group picked out some that suggested the following lines of development:

- Many potential users of the benchmarks preferred aggregated and weighted results, as they considered them most usable in actual decision situations. Yet some users were not prepared to leave the weighting of environmental impacts to anonymous experts, so there is reason to retain the unweighted data (i.e., separately for each environmental problem) alongside the weighted results in public communications. Even with aggregated data, many of the users considered the information too complex and undiscriminating to be used as a "proxy ecolabel" on product packaging. Moreover, there are existing eco-labeling schemes to serve this purpose.
- In contrast, many users considered the information might be extremely useful in comparing broader alternative behavioral patterns such as alternative forms of transportation – or "make-or-buy" decisions such as home cooking vs. ready meals. One of the most important strengths of the benchmarks was their quantitative nature, enabling consumers to identify large and important decision, such as housing and space heating.
- Many alternative suggestions for presentation formats were received – ranging from color-coding to awarding points similar to those used by Weight Watchers. The most useful suggestion, however, was obtained from a professional communicator at one of the workshops. She suggested using a "ruler" as a scale on which different products could be placed according to their environmental impacts.
- All the different benchmarks were considered useful, and users were not prepared to select a single product as a suitable "anchor" for understanding the environmental impacts of other products. Thus, we were encouraged to develop a benchmark format combining the weighted environmental impacts into a single meta-benchmark, and integrating this with the "ruler" idea.

4. Second version of the benchmarks and presentation format

Inspired by the feedback gained, the basic benchmark was given the form of a ruler, which aims to serve as a yardstick for the environmental impacts of different products, services or activities (Figure 3). The backbone of the benchmark-ruler is based on the average daily per capita environmental impacts of the whole Finnish economy. This ruler also integrates the different benchmark products, which serve as additional – more down-to-earth – benchmarks.

In addition to the aggregated presentation, it can be worthwhile to show the values for each environmental impact class. When using ordinary A4 paper, the first page could present the aggregated results and the second page show the results for each impact class. This combination of presentation types would cater to the needs of both those who prefer aggregated data, and those who prefer to draw their own conclusions on the importance of different environmental impacts.

We also reduced the brochure to eight pages, with more focus on questions and answers and practical applications – including verbal explanations of the figures (Figure 3). The second feedback round, conducted using questionnaires (N= 39), provided encouraging results. Even though we were unable to accommodate all the (partly conflicting) suggestions into the new version of the brochure, most respondents were pleased with the new benchmark format. Almost all agreed that the overall appearance and language of the brochure had improved significantly. Typical suggestions for further improvements included more examples and more opportunities to personalize the information. The next foreseen task of the research group will thus be the construction of an interactive website enabling consumers to use the benchmark to make their own calculations (see Figure 1).

5. Evaluation: project evolution and the users' role

The process of developing the benchmarks was highly iterative, and some original assumptions and plans were revised during the course of the process. In the end, we decided to use the environmental effects of the whole economy of Finland as the basis of the scale in the benchmark. This 'economy-based approach' has often been used in the normalising of the various environmental effects [42]. Feedback obtained in the user consultation processes, however, helped to turn this normalization factor into a new presentation format and visualisation tool for LCA results.

The benchmark developed here has benefits that were welcomed by the consumers and other stakeholders consulted. The ability to address multiple environmental impacts in a quantitative form provides users with much-sought information on priorities and the relative importance of various decisions. Thus, it may help to move discussions on sustainable consumption away from marginal issues such as recycling discarded packaging or choosing eco-product variants. The feedback obtained, however, identified many challenges in the utilization of this information: who will use it, where, and how? One of the challenges is that most individual decisions are fairly small on this kind of a scale. Thus, one of the future directions for improving the benchmark is to develop it into an interactive website allowing consumers to model, e.g., the combined effects of multiple environmental improvements of their choice. We will also work toward obtaining more product benchmarks from different product groups, and look forward to applications of the method in other countries, see [15].

One of the obvious benefits of involving consumers was that the research group obtained feedback on the language and presentation format – what people understand and what they don't. What was specific to the interactive and iterative nature of the process, however, was the possibility to get detailed suggestions on improved wording and figures – as well as a wealth of ideas for future applications. The participants naturally represent a small vanguard of future "lead users" of the LCA-based benchmark tool, and other efforts are needed to provide straightforward environmental advice to the general population.

We were not able to integrate all the innovative suggestions and all the divergent viewpoints into the final version of the benchmark brochure. This experience echoes those of Magnusson [43]: the suggestions obtained from ordinary users are highly divergent and often not directly implementable. They are an input and a source of inspiration for the development process, and need further processing by the developers themselves. As such, however, both the users' suggestions and the process through which they are obtained are an invaluable way for designers to get closer to their users. In the present study, the interaction with users helped the LCA experts to gradually focus more and more on the usability on the information, and develop new conceptualizations and visualizations for communicating LCA to non-expert users.

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ILLUSTRATIONS

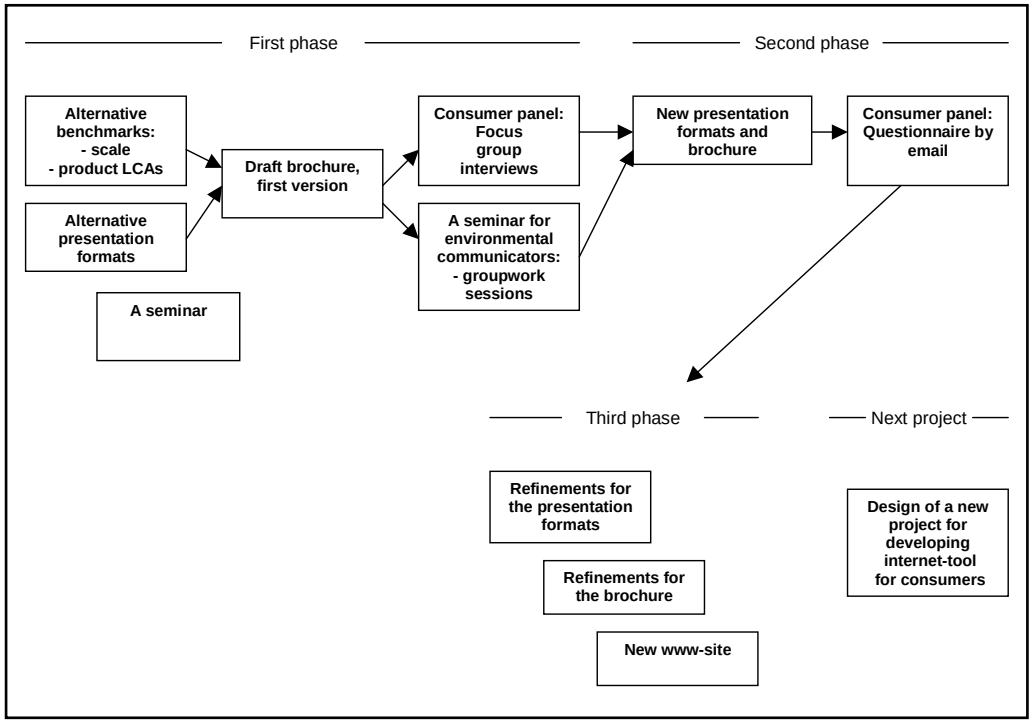

Figure 1. The iterative process of developing the benchmarks and the presentation types for consumer communications.

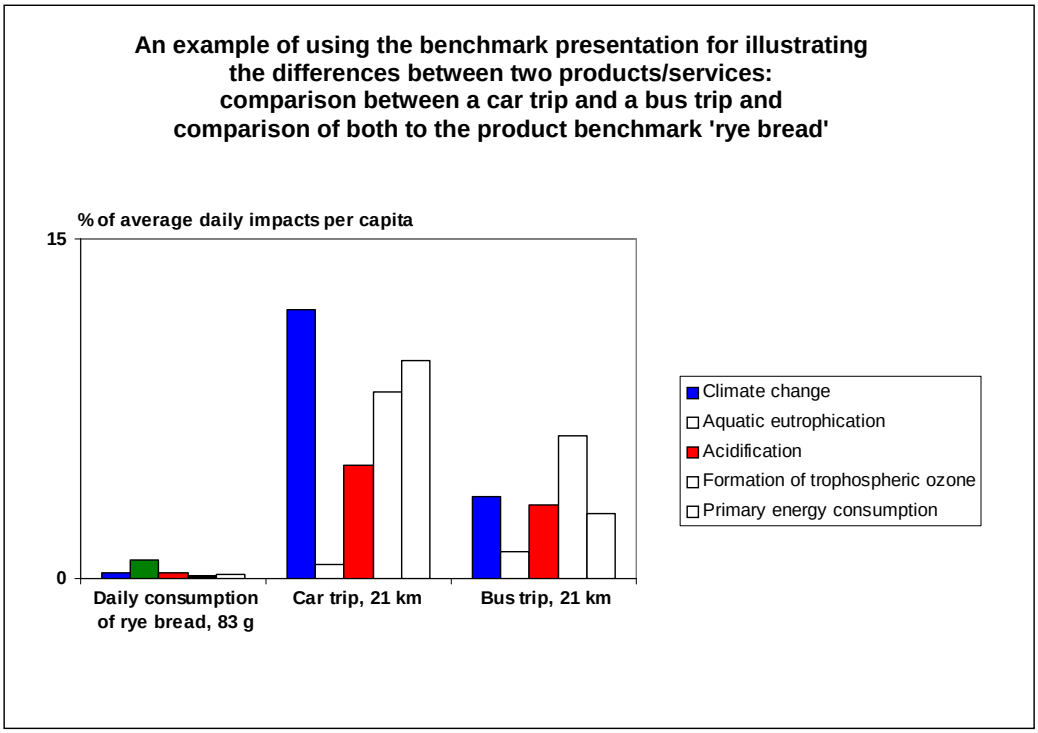

Figure 2. Excerpt from the first version of the brochure: illustration of how the benchmark can be applied.

How can the Benchmark be used?

An example of comparing two products or services

Does it matter how one makes one's daily trips?
– How large is the difference between using a car and going by bus?

One can see from the figure that a typical car trip and a typical bus trip are 'services' that have relatively high impacts compared with other products and services.

In addition, the differences in the environmental impacts between the two kinds of ways to make the trip are large.

Conclusion: This choice is something worth considering if one wants to decrease one's environmental impacts.

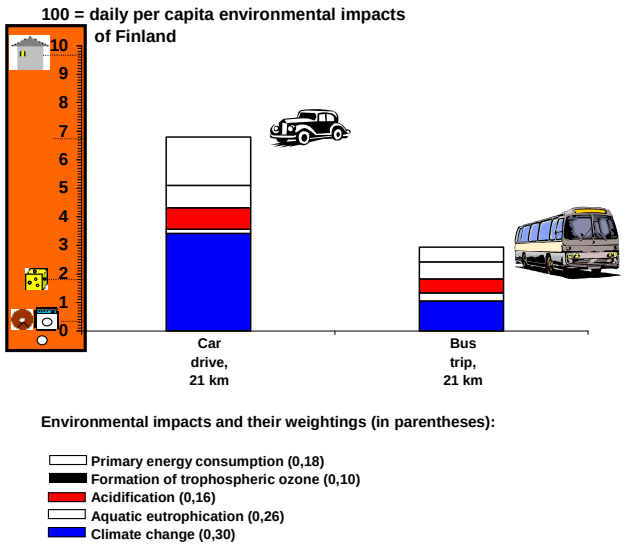

Figure 3. Excerpt from the revised brochure: illustration of how the benchmark can be applied.

TABLES

Table 1. Environmental loads of the Finnish Economy in 2002. Data source: Finnish Environment Institute 2004.

Environmental load	Value	Unit
Primary energy use	1443	10^9 MJ
Emissions to air:		
CH_4	243	10^9 g
CO	600	10^9 g
CO_2	69270	10^9 g
N_2O	21.9	10^9 g
NH_3	33.3	10^9 g
NOx [a]	208	10^9 g
SOx [b]	82.4	10^9 g
VOC/HC [c]	150	10^9 g
Emissions to water:		
N(w) [d]	78.2	10^9 g
P(w) [e]	4.21	10^9 g

[a] calculated as NO_2
[b] calculated as SO_2
[c] calculated as non-methane C
[d] calculated as total N
[e] calculated as total P

Table 2. Product-benchmarks and their main LCA-information sources

Product/service	Main LCA and other main references	Modifications and updating to Finnish conditions
Rye bread	Grönroos and Seppälä 2000. Agricultural production systems and the environment. The Finnish Environment 431. (Only abstract in English).	Updated nutrient leaching & eutrophication of waters, electricity in Finland.
Emmental cheese	Voutilainen et al. 2003. Environmental impacts and improvement possibilities of Emmental blue-label cheese. Maa ja elintarviketalous 35. (Only abstract in English).	Updated nutrient leaching & eutrophication of waters, electricity in Finland.
Laundry	Saouter, van Hoof, Feijtel, Owens 2002. The effect of compact formulations on the environmental profile of northern European granular laundry detergents. Part II: LCA Int J LCA 7 (1) 27-38.	Consumption of electricity and water of typical washing machine, 40 C, Electricity and wastewater treatment in Finland.
Apartment	Koskela et al. 2002. Environmental impacts in assessing the ecoefficiency of buildings. The Finnish Environment 585. (Only abstract in English).	Updated electricity and district heating in Finland, electricity of appliances in the appartment not included.
Car drive	Schweimer and Levin, Life cycle inventory for the Golf A4. downloaded from www.volkswagen.-environment.de	Energy consumption and emissions of vehicles from a national model (www.lipasto.fi, made by VTT Technical Research Centre of Finland), EURO 3 norm. Fuel production (gasoline in Finland).

Table 3. Inventory results of the benchmark products

		Rye bread	Laundry	Cheese	Car drive	Apartment
Functional unit:		*83 g*	*0,5 wash*	*30 g*	*20 km*	*41 m^2*
	Unit:					
Primary energy	*MJ*	1.25	1.97	a	69.6	87.3
CH_4	*g*	0.080	0.419	6.09	0.400	15.1
CO	*g*	0.055	0.135	0.090	33.2	9.24
CO_2	*g*	62.1	130	112	4684	5686
N_2O	*g*	0.140	0.016	0.48	0.6	0.75
NH_3	*g*	0.092	b	1.86	b	b
NOx	*g*	0.163	0.398	0.480	4.67	10.2
SOx	*g*	0.078	0.356	0.210	3.07	10.5
VOC/HC	*g*	0.006	0.206	0.030	10.8	0.375
N(w)	*g*	0.181	0.005	1.11	0.004	c
P(w)	*g*	0.016	0.008	0.063	0.001	c

[a] Value so far confidential.

[b] No data for NH_3 emission in the original inventories of laundry, car drive and appartment.

[c] No data for water emissions for apartment (including electricity and heat production and construction), and values generally assumed to be low.

Table 4. Characterisation factors. See text for references.

Emission	Coefficient value	Unit
Climate change		
CO_2	1	g CO_2 eq g^{-1}
N_2O	296	g CO_2 eq g^{-1}
CH_4	23	g CO_2 eq g^{-1}
Tropospheric ozone formation[a]		
NO_2	0.35	pers*ppb*hours g^{-1}
VOC/HC	0.27	pers*ppb*hours g^{-1}
CH_4	0.33	pers*ppb*hours g^{-1}
Acidification		
SO_2	0.463	AE meq g^{-1}
NO_2	0.186	AE meq g^{-1}
NH_3	0.535	AE meq g^{-1}
Aquatic eutrophication [b]		
NO_2	0.015	g PO4 eq g^{-1}
NH_3	0.038	g PO4 eq g^{-1}
Tot P (w)	1.192	g PO4 eq g^{-1}
PO_4 as P(w)	3.060	g PO4 eq g^{-1}
Tot N (w)	0.215	g PO4 eq g^{-1}
NH_4, NH_3 as N(w)	0.420	g PO4 eq g^{-1}
NO_2, NO_3 as N(w)	0.420	g PO4 eq g^{-1}

[a] Effects on vegetation (AOT 40).

[b] These are average values for Finnish emissions. However, in the calculations sector-specific values have been used, derived from Seppälä et al. 2004.