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**Interim Report** **IR-02-073**

# Life-cycle Approaches to Sustainable Consumption Workshop Proceedings, 22 November 2002

Edgar Hertwich (ed.)

**Approved by**

Prof. Leen Hordijk
Director, IIASA

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# “Life Cycle Approaches to Sustainable Consumption”

This workshop has been organized as a collaboration of three institutions, the Research Center for Life Cycle Assessment, AIST in Japan, the United Nations Environment Programme, and the International Institute for Applied Systems Analysis. It serves to promote international cooperation on sustainable consumption research. UNEP is interested in this because it is responsible to follow up the Johannesburg Plan of Implementation, which calls for a "10-year framework of programmes to support sustainable consumption and production". For IIASA, this is part of an exploratory research project on the industrial ecology of consumption, and the first opportunity to bring together a consortium of researchers which put together a proposal to the European Union on "Policies and Tools for Sustainable Consumption" (part of the 6th framework programme for research). For the Research Center for Life Cycle Assessment, AIST this is an opportunity to collaborate on an important Japanese project. Please allow me to elaborate.

In November 2002, the Ministry of Economy, Trade and Industry (METI) of Japan has started a new project named “The promotion project in international research collaboration on global climate change”. As a part of the program, the Society of Non-Traditional Technology (SNTT) has been promoting a new project, “Life Cycle Approaches to Sustainable Consumption”. This project is fully supported by METI through SNTT.

The aim of this project is to find new ways to reduce the CO2 emissions from the viewpoint of consumers. It might include Product Service Systems, Change of the patterns of household consumption etc.

To accomplish this project successfully, a steering committee was organized with the members from academia, research institutes, and industry. The head of the steering committee is Dr.Atsushi Inaba of Research Center for Life Cycle Assessment of the National Institute for Advance Industrial Science and Technology (AIST) and it was decided that the Research Center of Life Cycle Assessment was responsible to execute and conduct this project under the steering committee.

On behalf of the steering committee, I would like to ask you kindly to support our activities. It would be our great pleasure to have your collaboration.

Dr. Atsushi Inaba
Director, Research Center for Life Cycle Assessment
The National Institute for Advance Industrial Science and Technology (AIST)

## Introduction

"Sustainable consumption" is an easily misunderstood term, which the "environment & development" policy community uses to point to the possibility of reducing environmental pressures, improving social conditions, and furthering international equity through changes in consumer choices. In the general public, but also among environmental NGOs such as Greenpeace and World Wildlife Fund, the "ecological footprint" is an idea that is often used to communicate the connection between personal consumption and the environment. The ecological footprint is an indicator for resources needed to produce the goods consumed and absorb or neutralize the emissions produced. "Clean cloth" and "fair trade" (and the civic campaigns associated with these terms) similarly indicate the connection between social issues (sweatshop labor and terms of trade) and consumer choice.

"Life-cycle approaches to sustainable consumption" are those approaches based on the consideration of life cycles. We primarily refer to the life cycle of products. Life-cycle assessment (LCA) is a method to account for and evaluate the environmental impacts of products, from the extraction of the raw materials through manufacturing, distribution, use, to disposal. LCA takes into account many types of environmental stressors, allowing for an identification and evaluation of tradeoffs. There are other life-cycle concepts whose relevance to sustainable consumption remains to be explored: the life-cycle of individuals and the life-cycle of innovations. The life-cycle of individuals is important because a position in the life-cycle, e.g. being a student or having a family with small kids, has important implications for the lifestyle one leads. Innovations and their diffusion are relevant because cleaner products or new production methods are some of the things that social activists would like to push.

The World Summit for Sustainable Development, held 26 Aug - 4 Sept 2002 in Johannesburg, put "sustainable consumption" on the global policy agenda of the next ten years. Under the heading of "changing unsustainable patterns of consumption and production," the world leaders call for "fundamental changes in the way societies produce and consume" (§13 of the Johannesburg Plan of Implementation). They resolve to "encourage and promote the development of a 10-year framework of programmes in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, delinking economic growth and environmental degradation …" (§14).

Sustainable consumption has two distinct but related aspects, products and lifestyles. Improved products & services are those that require less resources, cause less emissions, and avoid unhealthy labor conditions during their production, those that use less energy or other inputs during their use and are more easily recycled or harmless when disposed. Product-services systems can focus the attention on the cost of service provision, emphasizing operating costs, durability and repair. Innovative, improved products and services, however, are also often cheaper, causing a rebound effect in form of increased consumption of this or other products & services. Sustainable lifestyles are characterized by consumption patterns that put less strain on the environment and that depend less on social disparities. This means that more money is spent on things that cause relatively little emissions (e.g. personal services) compared to those that cause significant emissions (e.g. personal transportation). The assessment of lifestyles also guarantees that rebound effects are properly addressed.

"Sustainable consumption" is a topic where civic organizations and policy makers seem to be far ahead of the scientific community. While sustainable consumption research has been going on for some years, the research efforts have been fragmented, hampered by disciplinary boundaries and language barriers, in lack of scientific conferences and meetings at which to exchange ideas and report on research progress. This workshop was a start for the "life cycle" community to organize itself, to address sustainable consumption, and to start talking to some of those social scientists working in the field.

More workshops will be organized by my co-organizers, as part of a Japanese research effort headed by Atsushi Inaba of *National Institute for Advanced Industrial Science and Technology* (AIST) and as part of the WSSD-follow up activities organized by Bas de Leeuw of the *United Nations Environment Programme* (UNEP).

I would like to thank the workshop participants for their interesting contributions and hope for a fruitful and lasting cooperation. I would also like to thank the IIASA staff, especially Sanja Drinkovic. Last but not least, I would like to thank Atsushi Inaba and Bas de Leeuw for their support and advice in organizing this workshop.

Edgar Hertwich                                        Laxenburg, 16 December 2002

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# Values as determinants of environmental behaviour

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## Abstract

In experimental studies we have compared the effect of positive and negative labelling on choice of ecological products. By and large, the effect of negative labels is stronger than the effect of positive labels. People avoid products that are worse than average when it comes to environmental consequences rather than choosing products that are better than average in terms of environmental consequences. However, this is not true for all consumers and the differentiated affect can be accounted for by differences in how strongly one adheres to environmental values.

The importance of values is followed up in a new set of studies, but this time in relation to policy measures. The basic idea is that policy measures frame the decision situation and guide evaluations of the policy at hand. Hence, financial measures could draw attention to wealth and individual interests, what's in it for me, while measures such as voluntary agreements could invoke a social institutional perspective. Preliminary data support this basic idea.

## Introduction

In contrast to attitudes, values are always assumed to be trans-situational and rather abstract in nature. Schwartz (1994, p. 21) defined values as *desirable trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or other social entity*. Schwartz assumes that ten motivational types of values can be distinguished. The structure of values adheres to a continuum that takes a circumplex form. The more closely organised values are, the more compatible they are. This circumplex can be described or captured by two dimensions, see Figure 1 below.

The first dimension, self-transcendence versus self-enhancement, opposes values such as universalism and benevolence to those that pursue personal interests, e.g., power and achievement. The second dimension, openness to change versus conservation opposes values that stress independence, such as self-direction and stimulation, against values that emphasise tradition and conformity. In this structure of values, environmental values are assumed to be located close to self-transcendence.

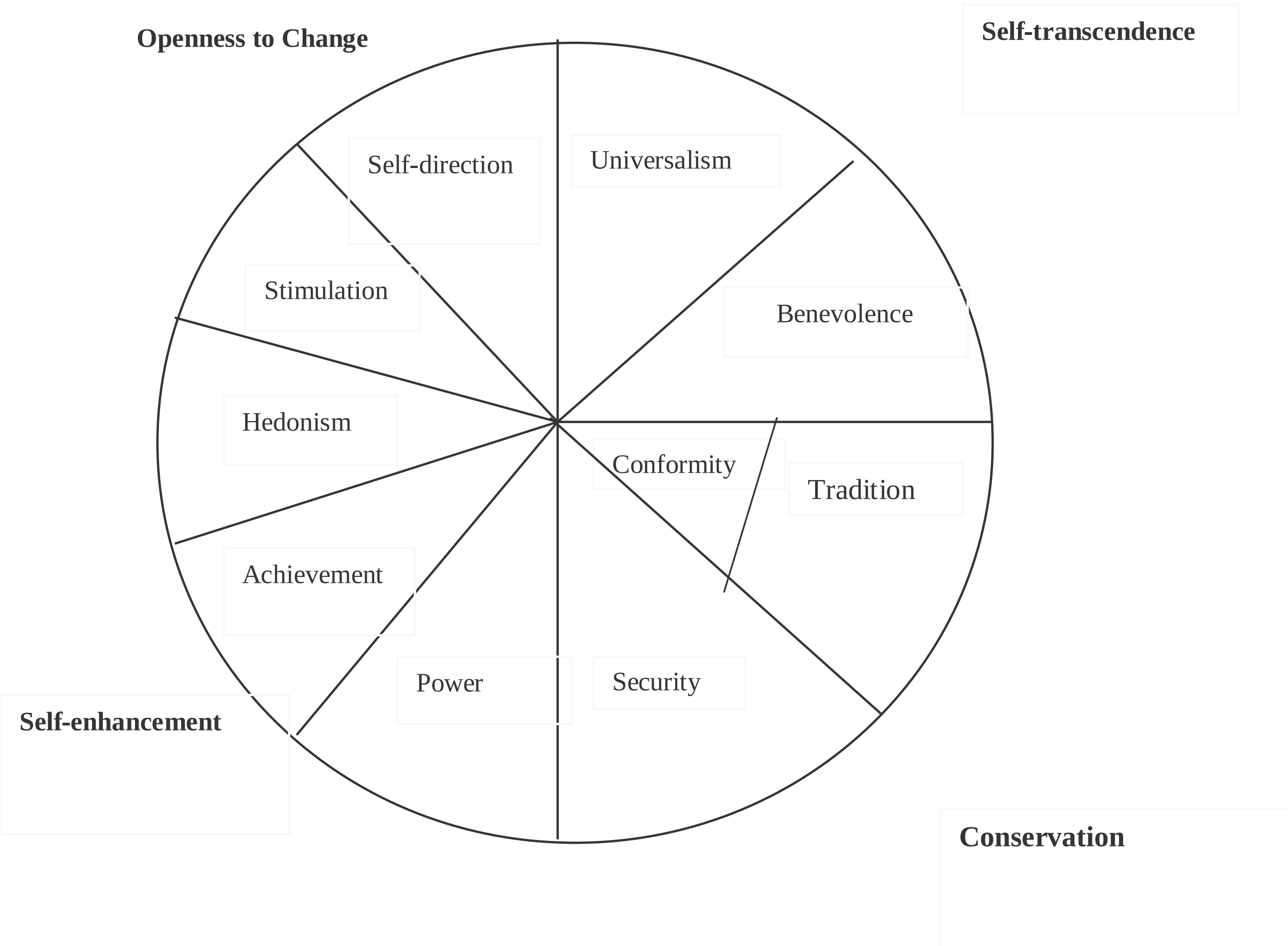


Figure 1: Theoretical model of structure of relations among ten value constructs (after Schwartz et al., 2001).

Likewise, in stressing the general nature of values, Feather (1995, p. 1135) proposed that values can be conceived as abstract structures that involve the beliefs that people hold about desirable ways of behaving or about desirable end states, a description that is very similar to an earlier definition provided by Rokeach (1973). One important aspect of values is their motivational nature. In accord with their priorities, values may drive people to seek the "best possible living" (Rohan, 2000). Some may strive to be successful in life, while others may be guided by security. Most researchers regard values as stable personality variables. Although changes in value priority may occur, such changes come about slowly across the life span.

However, the stable nature of values has been discussed. Seligman and Katz (1996) proposed that value systems are dynamic, that is, value priorities may change across contexts. In one study, they compared the rank order of the importance of values when subjects were given traditional instructions (general) to the order when the same subjects were asked to rank the values with regard to a particular issue (abortion). The correlation between the two rank orders was rather low, around .50, indicating that there is a substantial reordering of values according to context. Since people subscribe to a range of values, captured by the circumplex model in Figure 1, this should come as no surprise. Some values are endorsed more strongly and others more weakly. Most of the time values echo the sound of silence and need to be activated (Feather, 1995) in order to be influential. Activation (Verplanken & Holland, 2002) may occur:

(1) on a more or less chronic basis. A value may be particularly strongly incorporated as part of someone's self-concept, and might thus be activated in a large range of situations. Dedicated environmentalists, for example, might use an environmental value perspective to interpret and analyse most issues they encounter.

(2) by the context. It could make a difference whether plans for building a waste disposal installation in a residential area is presented as an economic issue versus a health issue versus an environmental issue. Context can take many forms including the ‘source’ of information (e.g., some people don't trust the government and project values on their assumed intentions), or the task (e.g., CVM) itself.

(3) by irrelevant contexts. Values may be activated in the context of interest, but linger on in an irrelevant context.

Our present research addresses the first two propositions. Environmental value strength has been investigated in experimental studies where the effect of positive and negative labelling on choice of ecological products were compared. By and large, the effect of negative labels was stronger than the effect of positive labels. Respondents avoided products that were worse than average when it came to environmental consequences rather than choosing products that were better than average in terms of environmental consequences. However, this was not true for all consumers and the differentiated affect could be accounted for by differences in how strongly one adhered to environmental values.

## Environmental values and effects of negative and positive eco-labels

Initially participants were informed that a number of pairs of products would be presented on a computer screen and that their task would be to indicate product preference within each pair. Next, a three level eco-label system was introduced. This system was adopted from the design of a traffic light. Accordingly, the colour of the top signal or label was red and defined as: “Compared to other products of the same category, environmental consequences of this product are much worse than average”. Environmental consequences associated with the yellow signal were described as “average”, while environmental consequences defined by the green label were “much better than the average product”.

Sixteen pairs of products, eight food (bread, potatoes, milk, meat, apple, tomato, coffee, and pasta) and eight non-food commodities (washing-up detergent, soap, washing powder, toilet paper, battery, T-shirt, a light bulb, and writing paper), were selected as target stimuli. Two pictures of each pair were presented simultaneously and described on three to four attributes such as price, quality, country of origin, expiry date. In addition, each commodity was portrayed with an eco-label. Two versions of each pair were created. In one version, the control condition, each alternative was labeled with a yellow label[1]. In the experimental condition, one of the alternatives was depicted with a yellow label while the other product carried either a red or a green label, equally divided between food and non-food commodities. All pairs were presented in two trials. Half of the pairs in each trial were controls. Order of experimental and control condition between trials was counterbalanced between subjects. Order of presentation within trials was individually randomized. The second trial was preceded by a one-minute pause to avoid that subjects would remember, and adjust to, previously made ratings.

For each pair of products, one alternative designated A and the other B, respondents were asked to indicate their product preference on a 21-point scale anchored on “I would definitely choose product A” (1)/ “I would definitely choose product B” (21). The midpoint of the scale (11) was defined as “I could just as well choose product A as product B”. Subjects were further asked to rate “importance attached to environmental consequences then purchasing everyday commodities”. Ratings were made on a 7-point scale anchored on “Not at all important” (1)/ “very important” (7). Finally, subjects were asked about their age and gender.

For each participant and pair of products the difference in preference ratings between the control (that is, both alternatives had a yellow label) and the experimental condition (that is, one product had a yellow label and the other product a red or a green label) was calculated. Next, for each participant one mean preference change score was calculated across the sixteen pairs of products.

In Figure 2, the effect of the positive and the negative label, respectively, is presented as a function of environmental concern. While individuals with low or no environmental concern were uneffected by environmental information, negative or positive, those with a strong environmental concern were affected the most, and equally much, by both kinds of information. As shown, individuals with a semi-strong concern displayed a differentiated pattern in that they were affected more by negative than by positive information.

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[1] As judged by an independent sample, when both products of a pair were portrayed with a yellow (neutral) eco-label, the two alternatives were perceived as equally attractive.

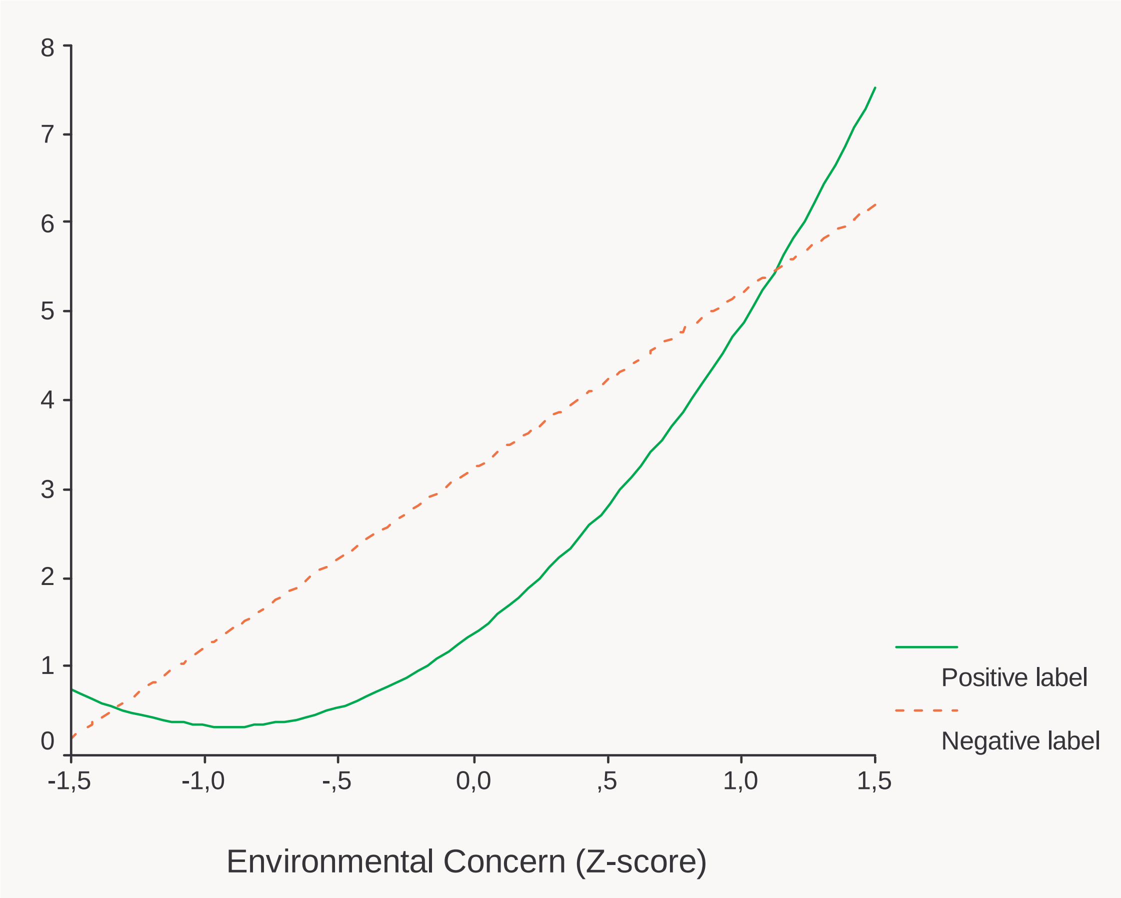


Figure 2: Mean change in product preference due to positive and negative eco-labels, respectively, as a function of environmental concern.

The importance of values is followed up in a new set of studies, but this time in relation to policy measures. The basic idea is that policy measures frame the decision situation and guide evaluations of the policy at hand. Hence, financial measures could draw attention to wealth and individual interests, what's in it for me, while measures such as voluntary agreements could invoke a social institutional perspective. Preliminary data support this basic idea.

One group of subjects was presented with six different vignettes, three concerning car use and three related to recycling. One vignette in each domain included a tax policy measure, another law and the third voluntary agreement; see below for examples in the car domain. The order was counterbalanced between subjects. Another group of subjects, control, was presented a more neutral suggestion. The vignettes were as follows:

As a car owner you regularly commute by car. In order to reduce negative impacts from car traffic, the Parliament:

- Is proposing to raise the $CO_2$ taxes. This will impose an extra cost for you of SEK 2 per liter of petrol.
- Is proposing a law that bans driving in inner parts of cities. This implies that you have to choose other transport means.

- Is proposing a system for car-pooling. This implies that you can declare how you use your car to your municipality and the local traffic board develops a car-pooling schedule.

Has set up a committee to come up with proposals how to reduce car use (CONTROL)

For each vignette, participants rated how important certain life values, Wealth and Environment (index of Protecting environment and Unity with nature), were to them in this particular situation and whether they should object or accept the proposal. Wealth was rated as significantly more important when a tax was suggested than in the other three conditions. The environmental value was seen as somewhat more important in the control condition than when policy measures were proposed. As for attitudes towards the policy instruments, Law and Voluntary agreement were rated more favorably than a tax.

Finally, six regression analyses were performed with attitude towards each policy measure as dependent variable (three for each domain) and the values Wealth and Environment as independent variables. The results are summerised in Table 1 below. The general picture that emerges is that when Tax is the suggested policy measure, only the importance of Wealth accounts for variation in attitude. However, when Law or Voluntary agreements are proposed it is mainly the value Environment that affects the attitude.

Table 1: Wealth and Environment as predictors of attitudes towards policy measures. Values are standardized regression coefficients (β) and significance level (*p*).

| Policy Measure | Wealth | | Environment | |
|---|---|---|---|---|
| | β | *p* | β | *p* |
| Car | | | | |
| Tax | -.38 | .000 | .26 | .02 |
| Law | -.10 | .24 | .49 | .00 |
| Vol agree | -.04 | .67 | .47 | .00 |
| Recycling | | | | |
| Tax | -.25 | .01 | .18 | .06 |
| Law | -.08 | .38 | .44 | .00 |
| Vol agree | -.15 | .13 | .20 | .04 |

In line with Seligman and Katz (1996) our results suggest that value systems are dynamic and indeed affected by context. Furthermore, economic incentives could draw attention to self-enhancement values rather than collective matters (see also Frey, 1997 especially chapter 8). Whether such attentional shifts alter our concern for long-term environmental consequences or not should be investigated.

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# Durable consumption: reflections on product life cycles and the throwaway society

*Dr. Tim Cooper*

Tim is Head of the Centre for Sustainable Consumption, which specialises in research on the life span of household products. Its current projects relate to waste from electrical and electronic appliances, product-service systems, and consumer behaviour influences upon product life. He was previously a Researcher at the New Economics Foundation, prior to which he worked in industry as an economist and environmental consultant.

## Abstract

This paper assesses the potential of increased household product life cycles to accelerate progress towards sustainable consumption. It will identify current knowledge of product life spans and consider how this is applied in life cycle assessment and assessed in recent debate on resource productivity and waste reduction. In reviewing current understanding of issues relating to product life, the results of recent research on household appliances in the United Kingdom, the E-SCOPE study, will be examined. This demonstrated that many discarded appliances are reparable or still functional. At the same time, the study revealed that a substantial proportion of householders desire longer lasting appliances. The implications of this apparent paradox will be discussed. The paper concludes by evaluating the acceptability of longer lasting appliances and considers how these might be successfully promoted, with particular reference to product information and product-service systems.

## 1. Sustainable consumption and resource throughput

### *1.1 Introduction*

Sustainable consumption is interpreted in many different ways but there is a general consensus that for industrialised countries, at least, it demands a reduction in the throughput of resources. Progress requires a shift from a linear economy to a circular economy in order to reduce demand for virgin material and energy inputs and cut the amount of waste in need of disposal (Cooper, 1994). McLaren et al (1998) calculate that in order to make satisfactory progress towards a fair use of 'environmental space' (the earth's capacity to support human activities) Britain should aim to cut its consumption of steel, aluminum and energy by over 80% by 2050, implying cuts of at least 20% by 2010. For timber the figures are 73% and 65% respectively, a particularly dramatic short-term reduction. Such calculations have prompted the current interest in increased 'resource productivity'.

Much recent literature relating to sustainability utilises this contextual framework. Some of it touches, though too often lightly, upon the implications for product life spans. Increased product life, whether by greater intrinsic durability or 'product life extension' through repair, reuse and upgrading, is one way to slow the throughput of resources. Significantly, product durability was a key theme in an early contribution to the debate on sustainable production and consumption by the World Business Council for Sustainable Development (Falkman, 1996). von Weizsäcker et al (1997, p 70), in developing the 'Factor Four' concept, argued that "durability is one of the most obvious strategies for reducing waste and increasing material productivity." Likewise, McLaren et al (1999, p 53) describe durability, alongside reuse and recycling, as "critical in increasing overall efficiency." Yet the twin themes of product durability and product life extension have attracted relatively little in-depth research and whether the academic research community regards them as central or peripheral to sustainability discourse remains somewhat unclear.

Inadequate understanding of issues relating to product life has a practical significance. In a project co-ordinated by Consumers International (1998), consumer organisations explored how to promote sustainable consumption by improving their ability to provide environmental information to consumers. Their report noted that they focused mainly on the use phase of appliances when giving buying advice and concluded that they have not adequately stressed the importance of considering all aspects of a product's life cycle, including reparability and the timing of replacements. It recommended that, in order to give consumers reasonable advice, they should in future analyse the optimal life cycle of appliances, explore the potential for upgrading and pay greater attention to after-sales services.

In this paper I shall expand upon this argument that greater attention must be paid to product life spans if satisfactory progress is to be made towards sustainable consumption. Firstly, I shall address product durability in the context of recent developments in 'life cycle thinking', with particular reference to consumer behaviour. I shall then briefly survey past research on product life spans and summarise the recent empirical findings from a project undertaken in the United Kingdom. Finally, I shall consider some policy implications. Although the focus is on consumer durables, there are important messages for public procurement, industry goods and (perhaps above all) once-durable products that have been redesigned as 'disposables'.

### *1.2 The throwaway society and disinterest in waste*

Municipal waste in industrialised countries has generally increased at the same rate as economic growth, approximately 40% over the past thirty years, and, so far, "the delinking of effluence from affluence remains elusive" (OECD, 2001). Today's 'throwaway society' is tolerated, if not accepted. The concept has a history that can be traced back at least 40 years to publication of *The Waste Makers* (Packard, 1960). It is a term used frequently in popular debate and is well known to the general public and yet remarkably little attention has been paid to it by the research community.

Such inadequacy reflects a general dearth of research on waste, particularly among social scientists. Waste research in recent years has tended to focus on packaging and recycling. These are important themes but this limited approach is indicative of a wider socio-political failing. Modern politicians, operating in a liberal culture and woefully failing to distinguish improved human well-being from a growth in affluence, are invariably positive towards consumption in general and consumer sovereignty in particular. They thereby render themselves powerless to challenge the throwaway mentality. To choose to be irresponsible has somehow become one of the consumers' 'rights'.

Within the academic community there are a few noteworthy exceptions. There is a fairly substantial body of literature on consumer culture that seeks to explain why people consume (e.g. Featherstone 1991; Cross, 1993; Lury, 1996). A small body of research on 'disposition behaviour' seeks to explain why people sense a need to replace products (Jacoby et al, 1977; Hanson, 1980; Box, 1983; Bayus, 1988; Antonides, 1990; Harrell and McConocha, 1992). In general, however, the forces that drive our throwaway culture are poorly understood.

### *1.3 Resource prolonging*

Reference to resource productivity in previous environmental debates would have been interpreted in the context of depleting finite resources (e.g. Conn, 1977). By contrast, there now appears to be a consensus that resource scarcity does not pose a threat in the short term (or even medium term), although it would be unwise to ignore the possibility of this threat re-emerging (Frosch and Gallopolous, 1989). Instead, today's debate on resource productivity has been prompted by concern that the level of consumption in most industrialised countries threatens to reduce the well-being of people in other continents and future generations.

The British Government's Performance and Innovation Unit (PIU, latterly renamed the Strategy Unit) recently produced a report on resource productivity (Cabinet Office, 2001). In the original Scoping Note, the PIU (2001) highlighted five ways of increasing resource productivity, the first of which was 'resource prolonging' by increasing durability, decreasing turnover rates (presumably less frequent replacement), and redesigning products (or components) for longer use. Another was reuse of products or components, alongside recycling. It was significant (if not surprising, given the political climate) that the final document excluded any reference to this call for resource prolonging. Evidently the challenge to economic convention were too dramatic to contemplate for the Treasury officials consulted. Thus the final report addressed the need for resource productivity and how it might be measured, but excluded any reference to durability, instead highlighting general strategic tools (the role of market based instruments, 'resource productive innovation', public procurement, cultural change) rather than precise mechanisms.

## 2. Life cycle thinking

### *2.1 Life in totality*

The case for increased product durability needs to be understood in the context of a trend associated with sustainable development towards 'life cycle thinking' in product development and public policy analysis, sometimes described as a 'cradle to grave' approach. This may be traced to four developments.

First, during the 1990s, LCA (Life Cycle Assessment) became increasingly popular as a tool to estimate the environmental impact of products, in part because of a need to substantiate claims relating to eco-labelling (Ayres, 1995; Lee, Callaghan and Allen, 1995). LCA quantifies the environmental impacts of a product across successive phases from initial resource extraction to final disposal. Second, concern about waste has led to the development of legislation based on the principle of 'producer responsibility' (Lifset, 1993; Mayers and France, 1999). This requires companies that might previously have had little knowledge about their products after the initial guarantee period to take a greater interest throughout their life spans because they are made responsible for end-of-life disposal.

Third, the need to reduce environmental impacts in affluent nations without reducing the quality of life led researchers to contemplate the possibility of increasing the 'service' provided by a particular product during its life. Manufacturers began to review the potential for leasing products rather than selling them (Stahel and Jackson, 1993; Oosterhuis et al 1996; White, Stoughton and Feng, 1999; Cooper and Evans, 2000). Finally, evidence that many consumers are unaware of the proportion of costs accounted for during the use phase of appliances (Kollman, 1992), coupled with criticism of the cost of extended warranties (Office of Fair Trading, 2002), raised interest in costs incurred throughout the product life cycle additional to the purchase price.

Life cycle thinking is essential in confronting the throwaway society because it deepens understanding of products beyond the point of purchase. This is particularly important in a marketing context. Significantly, the need to address the whole life cycle of products is now being recognised by consumer behaviour specialists. Antonides and van Raaj (1998) illustrate the distinction between the product life-cycle and the consumption life-cycle. The former, an essential part of marketing theory, is concerned with the introduction of a product into the market, the development of sales, the process of product improvement, and the stage at which the product is removed from the market. By contrast, the consumption life-cycle is concerned with pre-purchase activities such as problem recognition and information search, followed by purchase, use and disposal. Understanding the life span of products demands awareness of a complex range of influences upon the product life-cycle and the consumption life-cycle.

### *2.2 Life Cycle Assessment*

Life cycle thinking does not of itself imply a need for increased product life spans. Indeed, one of the earliest, most widely publicised examples of life cycle assessment, a study of washing machines for the UK Ecolabelling Board, implicitly challenged the case for increased durability by suggesting that most of the environmental impact of the product was in its use rather than production and disposal (Jackson, 1996). Similar research on refrigeration equipment resulted in public subsidies for low income householders who replace old, inefficient appliances. Thus reduced energy use was prioritised over cutting waste. LCA measures environmental impacts such as energy consumption and waste volumes but political decisions remain to prioritise one or the other.

Life cycle assessment is complex and fraught with potential difficulties and many life cycle assessments undertaken by industry are never published (for a critique see Ayres, 1995; Lee, O'Callaghan and Allen, 1995). Although LCA has its critics, most recognise its potential value. Consumers International (1998) has called for improved LCA in order to provide consumers with reliable information on when to dispose of an appliance. Heiskanen (1996) indicates that only one published LCA has been concentrated directly with product life extension and this confirmed the environmental benefits for household appliances, clothing and furniture (though not for lighting and heating devices).

Two general problems with LCA relating to life spans are worth noting here. The first concerns system boundaries. The washing machine example cited above was subject to criticism because it did not include the impact of raw materials extraction (Cooper, 1994). Sustainability demands a global perspective, which requires environmental impacts in countries where resource extraction takes place to be as significant as impacts closer to home. The second concerns the assumption about life spans. There has long been concern about inadequate data on how long products last and the aforementioned study assumed the average life of washing machine to be 14 years, well above other estimates. Organisations undertaking LCA use internal data, the accuracy of which is disputable unless open to scrutiny, and there is considerable potential for confusion over variations in life spans because of different measures (e.g. the replacement life of a product differs from its service life depending on whether it is passed on to the second hand market).

LCA is not only used by industry but also government. For example, the British Government, preparing its response to the proposed EU Directive on Waste Electrical and Electronic Waste, commissioned an LCA (and also a life cycle financial assessment) of eight products, though limited this to a comparison of alternative end-of-life options (i.e. the current situation and various landfill, reuse and recycling permutations). Using multi-sourced data in an established software tool, the study revealed that the Directive would provide clear environmental benefits for six out of the eight products (Ecobalance UK, 1999).

### *2.3 Ecodesign and product policy*

Until the middle of the 20th century consumer durables were considered as investments and it was assumed that they were designed to last as long as possible. Since then, planned obsolescence, a term popularised by Packard (1960) as the deliberate curtailment of a product's life span, has become commonplace.

Design trends, whether design for environment (DfE), ecodesign or sustainable product design, indicate a growing concern that durability be considered alongside other objectives (Fiksel, 1996). At present, however, other environmental impacts appear to be getting more attention. In the report cited above Consumers International (1998) observed that although manufacturers have reduced water-use and energy-use and increased the proportion of recycled materials in their products, many more improvements are still possible, particularly in relation to durability.

One of the aims of integrated product policy is to achieve a coherent approach to product development. Promoting durability, it could argued, might increase energy consumption. There may well be unavoidable trade-offs, but it should be stressed that concern is largely limited to a few types of product, notably refrigeration equipment and vehicles. Moreover, Heiskanen (1996) has exposed a weakness in the argument for replacing functional products for reasons of energy efficiency. She notes that as long as there is a constant rate of energy saving innovation to delay replacement allows for the purchase of even more energy-efficient models.

### *2.4 Slower consumption*

Increasing resource productivity is attractive to industry and government because of its association with eco-efficiency, using energy and material efficiently in order to reduce costs while reducing environmental impacts. Technical efficiency in product design, however, is not enough. It is also important to slow down the rate at which raw materials are transformed into products and subsequently thrown away as waste, a process has been described as 'slow consumption' (Ax, 2001).

In broadening interest in products beyond the period from development and sale, life cycle thinking demands an understanding of 'product biographies': how they are used - how carefully, how intensively, how intimately. Slow consumption is a response to concern that 'life in the fast lane' is transient, unsatisfying and ultimately counterproductive and that many people feel trapped in the 'make, take and throwaway' and 'work hard/play hard' culture. Alternative lifestyles are possible. Ever since the consumer boom in the 1960s there has been a counterculture of people seeking 'simpler' lifestyles, while in the 1990s such thinking was repackaged as 'downshifting'. Nonetheless the consumer culture prevailed. The following three examples may suggest that more substantial change is afoot.

In the United States the Long Now Foundation addresses attitudes to time and is seeking to develop tools that will help people in thinking, understanding and acting responsibly over long periods. According to Stewart Brand, one of its directors, "Civilization is revving itself into a pathologically short attention span. The trend might be coming from the acceleration of technology, the short-horizon perspective of market-driven economics, the next-election perspective of democracies, or the distractions of personal multi-tasking. All are on the increase. Some sort of balancing corrective to the short-sightedness is needed - some mechanism or myth which encourages the long view and the taking of long-term responsibility, where 'long-term' is measured at least in centuries" (Long Now, 2002).

Long Now was sparked off by a idea from computer scientist Daniel Hillis: "I think it is time for us to start a long-term project that gets people thinking past the mental barrier of an ever-shortening future. I would like to propose a large (think Stonehenge) mechanical clock, powered by seasonal temperature changes. It ticks once a year, bongs once a century, and the cuckoo comes out every millennium" (Long Now, ibid). The organisation plans to create a well-engineered clock that will be charismatic to visit, interesting to think about, and famous enough to become iconic in the public discourse. The aim is to reframe the way people think about time in the same way that photographs of Earth from outer space altered how many people thought about the environment.

Another important initiative is Eternally Yours, a Netherlands-based network of designers with a specialist interest in the socio-cultural and psychological influences upon product life spans. Eternally Yours was formed almost a decade ago in response to awareness that many consumer products are discarded not because they are worn out but because people become fed up with them. It aims to address the relevance of 'time in design', seeking to divert attention away from exclusive focus on the moment of product realization or purchase to product 'careers' and the wider cultural implications of consumption. Recognising the impact that consumers have on product life, Eternally Yours advocates 'extensive design', which involves not only the creation of a product but also its entire 'career of use'. This requires the development of services and concepts for future communication tactics that will support products already sold.

Operating in a rather different context but with clear parallels is Slow Food, a movement of critics of the fast food culture and those people "who are too impatient to feel and taste, too greedy to remember what they had just devoured" (Slow Food, 2002). Slow Food, which boasts 65,000 members in 45 countries, has adopted a snail as its symbol. Citing the 17th century writings of Italian Francesco Angelita, who believed all creatures to be God-sent bearers of the divine message and considered slowness an essential virtue, it suggests that the snail is "of slow motion, to educate us that being fast makes man inconsiderate and foolish."

## 3. Product durability and product life extension

### *3.1 Research context*

Research into household consumption has grown as governments have sought to discover how to promote sustainable development most effectively (Noorman and Uiterkamp, 1998; Sushouse, 2002; OECD, 2002). By contrast, there has been no comprehensive study of product life in an environmental context since an OECD report twenty years ago (OECD, 1982). There has been a policy review of durability as a waste strategy (Cooper, 1994), a report on options to encourage product life extension (Heiskanen, 1996), and a book on the marketing potential of longer lasting products (Kostecki, 1998) but, overall, the research base remains surprisingly weak.

More specifically, data on product life spans has long been regarded as inadequate (Conn, 1977). According to Bayus (1998, p.764), "Empirically, it is very difficult to rigorously examine product lifetimes, since detailed data for the entire product life-cycle and at all the various product market levels are generally difficult to acquire." In the United Kingdom, however, the E-SCOPE project has recently generated some comprehensive data relating to household appliances through a quantitative survey of over 800 UK households and a series of focus groups. Data was collected on the age of the current stock of appliances, opinions about appropriate life spans, attitudes and behaviour relating to repair, the means by which items are discarded, and reasons why people might be deterred from purchasing longer lasting appliances. Statistics cited in the following section, unless otherwise specified, are from the report of this project (Cooper and Mayers, 2000).

Figure 1: Age of discarded appliances

| **Product category** | **Age of all discarded appliances (mean)** |
|---|---|
| Electric cookers | 12 |
| Refrigerators and freezers | 11 |
| Televisions | 10 |
| Washing machines, dishwashers and tumble dryers | 9 |
| Hi-fi and stereo | 9 |
| Vacuum cleaners and carpet cleaners | 8 |
| Video equipment | 7 |
| Home and garden tools | 7 |
| Microwave ovens | 7 |
| Computers and peripherals | 6 |
| Telephones, faxes and answer machines | 6 |
| Radio and personal radio, stereo and CD | 6 |
| Small work or personal care appliances | 4 |
| Mobile phones and pagers | 4 |
| Toys | 4 |

Source: Cooper and Mayers (2000)

### *3.2 Longevity*

Some academics claim that product life spans have declined (Kostecki, 1998), whereas others are sceptical (Bayus, 1998). A lack of comparable historical data for the United Kingdom has led to reliance upon anecdotal evidence. In focus group discussions participants were inclined to argue that appliances, particularly small items, do not last as long as in the past (Cooper and Mayers, 2000).

The E-SCOPE survey revealed that 88% of the current stock of appliances are under 10 years old and 57% less than 5 years old. As shown in Figure 1, the average life span of discarded appliances ranges from 4 to 12 years, depending on product type. Some products lasted much longer; for example, 34% of cookers and 25% of refrigerators discarded were over 15 years old.

The survey also found that many appliances have more than one owner during their life cycle. Almost one quarter of all discarded items are donated or sold for reuse, and the proportion for computers (67%), hi-fi and stereo (44%), and video equipment, microwave ovens and toys (around 35% in each case) is particularly high. A further 10% of appliances that were still functional were discarded into the waste stream. This means that, in total, around one third of appliances are discarded even though they are not broken.

### *3.3 Attitudes*

Quantitative research revealed that the UK population is divided almost evenly on whether or not appliances last long enough: 45% stated that they do not, while 50% stated that they do (the remaining 5% holding no opinion). These opinions are not unrelated to behaviour. People who were satisfied with product life spans were significantly more likely to purchase premium range appliances and to attempt to get products repaired. A noteworthy minority have high expectations: more than 10% of respondents thought that the certain types of product should last at least 20 years.

Firm evidence may be lacking, but focus group discussion revealed that many people perceive product life spans to be in decline: "I think things have changed. I think they are made more disposable these days…Things used to last a lot longer" was a typical comment (Cooper and Mayers, 2000, p.13). Another participant hinted at an innate yearning for improvement: "I don't think they ever last as long as you'd like" (ibid). Some were critical of the frequency of change in models and, by implication, of manufacturers: "Every time you're buying one they're ready to bring another one out, and now I think that is so unfair" (Cooper and Mayers, 2000, p.14). There was also a sense that innovations were sometimes unnecessary: "You get these extras on there which you are paying for and yet you don't use half of them" (ibid).

### *3.4 Repair and maintenance*

Consumer decisions during the 'use' phase, such as whether to repair or replace products and whether to pass on products or discard them as waste, help to determine product life spans. Appliances were discarded due to technical failure in around two-thirds of cases, but many of these items were not considered irreparable by their owners. Survey respondents were asked to distinguish broken appliances 'in need of repair' from those 'broken beyond repair' and almost one third were classified in the former category. These represent subjective judgements, but the outcome suggests that people often feel forced to replace broken products that they consider reparable. This is reinforced by another recent study which assessed the condition of items discarded at civic amenity sites and concluded that 77% of upholstered furniture and 60% of domestic appliances could, theoretically, be refurbished and reused (Anderson, 1999).

The increasing cost of repair relative to replacement is a critical influence that perpetuates the throwaway culture. In the E-SCOPE survey well over one third of respondents (38%) said that they rarely or never had products repaired. Over two thirds (68%) cited cost as a reason why they do not get items repaired.

Repair has become relatively expensive because much manufacturing has been relocated to newly industrialised countries. Appliances are made in countries where labour is relatively cheap, yet would have to be repaired in the country of sale where labour costs are invariably higher. During the 1980s and early 1990s the price of new televisions and washing machines increased by 20% and 40% respectively, whereas repair costs increased by over 150% in each case (Consumers International, 1998, p.20).

### *3.5 Technology and upgradability*

Some academics have advocated planned obsolescence as a means of ensuring technological progress (Fishman, Gandal and Shy, 1993). Among the general public, the E-SCOPE study found ambivalent attitudes to new technology. Many focus group participants were somewhat frustrated but resigned to change. In the quantitative survey people were asked to identify the primary deterrent to purchasing longer lasting appliances and fear that they would become 'out of date' was cited by more respondents (30%) than those who cited price (23%). Significantly more men had this concern than women, who were likely to be deterred by the cost of purchase.

The focus groups offered an opportunity to explore different interpretations of 'out of date'. One participant said that a reconditioned case would be acceptable but working parts should be new, while another considered reconditioned inner parts acceptable as long as the case was new! Participants also discussed second-hand products, which account for approximately 5% of the appliance stock. Although attitudes were predictably negative, most people regarding them as inferior and liable to be faulty, some expressed a willingness to purchase them if they appeared to be good value and had an adequate guarantee.

Ecodesign has prompted interest in the potential for upgradeable products. Bayley (1995), in an industry-sponsored report, foresaw a possible consumer backlash against built-in obsolescence and concluded that designing certain products to be upgradeable could offer benefits to manufacturers, consumers and the environment. Some manufacturers already design products to be upgradeable: Miele, for example, offers PC Update, a service which allows customers to have washing machines, tumble driers and dishwashers reprogrammed.

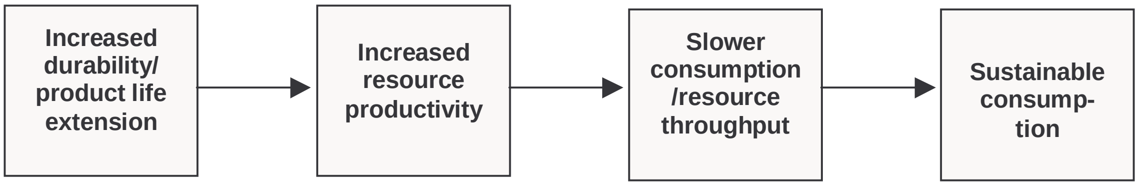
## 4. Product futures

### *4.1 What life cycles?*

Sustainable consumption demands increased resource productivity, to which greater durability could make an important contribution (Figure 2). For most products, longer life spans lead to less damage to the environment, although, as indicated above, optimal life spans for some appliances depend on trends in energy saving innovations.

Historical evidence suggests that it will not be easy to achieve a societal shift towards a 'culture of permanence' (Durning, 1992). People are critical of the throwaway society yet follow trends in fashion and aspire to own the latest products as a sign of 'success'; hence they express concern about the short life span of products while discarding items that function or are reparable. Such paradoxical attitudes and behaviour expose the complexity of issues relating to product life. The following section explores some of the factors that determine product life spans using a structured approach developed by Eternally Yours, that addresses product characteristics (Shapes and Surfaces), people's relationships with material artefacts (Signs and Scripts) and the operational system or context (Sales and Services).

Figure 2: Impact of product life on sustainable consumption




### *4.2 Product characteristics*

Increased product durability demands an element of 'redesign', as the technical specification of products determines operational qualities such as reliability, reparability and upgradeability. The reliability of appliances varies between product types and between brands (Which, 2002). Research by Cramer (1997) concluded that more robust construction, modular construction and alternative supplier/user relationships (see below) are important if product longevity is to be increased.

The quality of the internal workings of a product critically influences its durability (its 'technical' life span). However, the product's 'Shape and Surface', too, influences its likely life span - and often in a way that is less obvious or predictable. It is partly a matter of geometrical characteristics, style or features, but also whether meticulous care for quality and detail is evident, as in hand-crafted products. Ax (2001) has offered the example of shoes, which she notes were once investments but now are often cheap and disposable. She argues that only if shoes are comfortable and attractive will people want to have them repaired rather than replaced and advocates a return to hand-crafted shoes, citing a Wuppertal Institute study that reveals environmental benefits. Moreover, she describes this as a form of sustainable product design, not mere ecodesign, because the customer is involved as 'co-producer' and production is invariably localised, thus supporting regional development.

Consumers often face the problem of inadequate knowledge about the intended design life of products. Describing the work of Manufactum, a German mail order company specialising in durable, craft-made products, Burchardt (2001) argues that it is often impossible for customers to make an informed judgement concerning the price/performance ratio of products. He concludes that decisions to opt for higher priced products have consequently become a matter of trust rather than knowledge. In the E-SCOPE survey 73% of respondents said that they considered information on expected life spans to be very important and 54% were dissatisfied with the information currently available (Cooper and Mayers, 2000). Consumers International (1998) has proposed that policy-makers should encourage improved advice on the durability aspects of products in order to stimulate the market for those that are less damaging to the environment.

The way in which products wear, particularly changes in 'product surface' over time, affects their value. For example, many people believe that wood tends to age better than, say, plastic. Aesthetics are important in creating the appeal of products that underpins their longevity. According to Eternally Yours, products should 'age with dignity'.

### *4.3 New relationships*

Products are not merely functional, but provide important signals in human relationships (Douglas and Isherwood, 1979). Our possessions communicate messages about who we are, or want to be, and reveal histories about our past life. They help to define our human identity and reflect our values. These 'Signs and Scripts' reveal products to be carriers of meaning.

A decision to replace a functional product may signify that we do not want to be associated with items that we consider 'out of date'. Conversely, people may feel increased attachment to a product over time, perhaps through the context of how it was obtained (e.g. a special circumstance) or sheer familiarity. In exploring people's attachment to material artefacts the Eternally Yours Congress drew parallels with human relationships (van Hinte, 1997). How many products it is possible to feel affection towards? If an individual can love only their 'life partner' uniquely, is it equally true that we cannot express care for all of our many possessions?

Fewer functioning items might be discarded if people developed greater attachment to their possessions. On the other hand, growing interest has recently emerged in the amount of 'clutter' in people's lives. In America, a new wave of books describe techniques to dispose of clutter as a 'life management tool', while its National Association of Professional Organizers includes 'Be clutter-free', a consultancy service offering Email advice at $20 per consultation or $100 per week. In Britain, meanwhile, a television series called *The Life Laundry* provides advice to families seeking to rid themselves of clutter, and at least one local authority has promoted 'Clear Out Day', during which residents empty their houses of unwanted goods. The long tradition of jumble sales (and, more recently, car boot sales) is an indication of people's transient relationship with possessions and desire to 'keep up' with changing times.

The significance of 'psychological obsolescence' has long been recognised; Packard (1960, p.74) referred critically to the creation of 'obsolescence of desirability', citing a leading clothing retailer who said "We must accelerate obsolescence...It is our job to make women unhappy with what they have...We must make them so unhappy that their husbands can find no happiness or peace in their excessive savings." Attempts to increase product durability may expect resistance from marketing interests.

### *4.4 Serving without selling*

It is necessary, therefore, to consider how increased product durability could benefit industry. A growing number of researchers argue that a shift in company activities from selling new products to selling the services provided by products is required (e.g. White, Stoughton and Feng, 1999). By addressing 'Sales and Services' in this way, they argue, suppliers will lose the incentive to curtail product life spans prematurely in order to 'shift more boxes'.

This growth of interest in product-service systems, "a marketable set of products and services capable of jointly fulfilling a user's needs" (MEPSS, 2002), has been prompted by a desire for increased resource efficiency. Stahel and Jackson (1993) propose a move from a 'fast throughput' economy to one based on 'optimal utilisation', in which the services provided by products are delivered more effectively. Two categories of product-service system are of particular relevance to product longevity. One is when value is added to the product life cycle by, for example, increasing the quality of after-sales services, while the other takes the form of an 'enabling platform' for consumers to receive a service without necessarily having to purchase products (through, for example, leasing) (Manzini and Vezzoli, 2002).

After-sales services vary in quality and, as noted above, broken appliances are increasingly judged to be irreparable. Manufacturers and retailers in Britain admit that extended warranty pricing does not reflect the actual risk of failure of individual makes and models, which varies considerably, and prices charged have been criticised as excessive (Office of Fair Trading, 2002). It has long been suggested in the debate on product durability that guarantees should apply over longer periods to encourage manufacturers to provide a better after-sales service, with parts in stock for longer and reasonably priced (OECD, 1982; Cooper, 1994).

The second system implies a shift away from the traditional contractual arrangement in which a manufacturer sells an individual product to a consumer, normally through a retailer. Instead, 'eco-leasing' is proposed, in which the supplier assumes responsibility for maintaining and (crucially) disposing of products (Oosterhuis, Rubik and Scholl, 1996). As Bayley (1995) has observed, leasing contracts may encourage durable and upgradeable products. This represents a dramatic change in the corporate culture of 'shifting boxes' but, according to Eternally Yours, suppliers could re-envision a product as a 'conversation piece' that will generate turnover for many years after its birth. This more radical approach may be prompted by producer responsibility legislation, which will make manufacturers responsible for products once discarded. Leasing their products offers one way in which they would be able to keep track of them through their life cycle.

## 5. Summary and Conclusions

This paper has argued that sustainable consumption demands a reduction in the throughput of resources and this, in turn, requires increased product life spans. If our throwaway culture is to be displaced by one that reflects the values required for sustainability, one of the primary challenges will be to discover how to enable people to desire fewer material possessions while forging attachment to those possessions in their care. Sustainable consumption should allow for the value of the material world to be affirmed (i.e. it does not require asceticism) and promote an ethic of good stewardship, while challenging expectations of ever-increasing material affluence.

The paper has exposed the lack of scholarly research relating to the throwaway society or product longevity. Similarly, there is little evidence of Government interest in the development of policies designed to address the throwaway culture, despite its recognition of the need to increase resource productivity. The forces of industrialism remain powerful: politicians appear confident when addressing resource productivity in the context of 'efficiency', but wary of promoting any change that might be portrayed as threatening to change 'modern lifestyles'.

In exploring how to progress most effectively towards sustainable consumption, the emergence of life cycle thinking is proving critically important. Academic study of consumer behaviour emerged in a marketing context, with emphasis on the purchase phase in the product life cycle, and it is now recognised that more understanding is needed of the subsequent phases, use and disposal. Life cycle tools that provide data on the environmental impact of consumer products, however provisional, are essential, although environmental trade-offs between durability and energy efficiency still need to be resolved.

Recent research undertaken in Britain has demonstrated the scale of public concern about the life span of household appliances. The population appears to be evenly divided between people who would prefer longer lasting products and those who are satisfied. A brief survey of factors that shape product life spans has demonstrated a need for products to be redesigned, consumer attitudes and behaviour to change, and suppliers to have a greater incentive to maintain products. The throwaway society still prevails, but signs are appearing on the horizon of an emerging cultural critique of consumption patterns that are too often characterised by speed and short-sightedness.

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# GIS maps and qualitative studies combined provide knowledge of energy and water consumption in households

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## ABSTRACT

Household resource consumption can be visualised and analysed geographically by using GIS (Geographical Information System). Researchers at Danish Building and Urban Research have among others produced GIS consumption maps covering the city of Aarhus. These consumption maps are based on a monitoring system called eco-accounting, which is an environmental accounting system that takes into account inputs and outputs of energy and resources. Combined with GIS maps of socio-economics and the physical conditions of buildings, household consumption patterns can be analysed. These studies showed that the social status of the residents in each type of neighbourhood corresponds to their energy consumption. And that the consumption varies widely from neighbourhood to neighbourhood and within the neighbourhood as well. However, patterns and interrelations do not provide us with an understanding of the actual consumption behaviour in households. To attain this understanding qualitative interviews from households in selected neighbourhoods have been used. This way knowledge has been provided about the use and meaning of home and knowledge about different kinds of everyday life as it is being lived in different parts of the city and in different households. These qualitative studies showed that different household consumption have to be understood as an integral part of the interrelation between technology and culture in everyday life.

## Introduction

This paper gives an introduction to research on household consumption and sustainability conducted at Danish Building and Urban Research (DBUR)[2]. Two approaches are used in these studies focusing on energy and water consumption in households. One approach uses GIS-maps to provide a bird's view of the subject, the other uses qualitative analyses to give a worm's view of the subject. The two perspectives both consider environmental aspects and lifestyle aspects of consumption. The purpose of the paper is to explain working methods and tools and to illustrate how different methods complement each other.

When considering the environmental aspects, it can be noted that the daily use of energy and water in households is highly relevant to study, as one third of all energy in Denmark is consumed directly in the households (Danish Energy Statistic 2001) and more than one third of all tapwater (Danish Statistics 2001).

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[2] Research activities presented in this paper originate from several finished and ongoing projects carried out at DBUR. Two main projects are: Lifestyle and resources, part of the Danish welfare programme, and Energy consumption of houses, differences caused by technique and behaviour, the ERP 2000 programme (The Danish Environment and Energy Agency). An important project within the Danish Welfare programme is Lifestyle, dwelling and consumption. This is an independent, now published, Ph.D. project conducted by J.O.Jensen (2002). Like the projects presented in this paper, this Ph.D. project is based on GIS maps and theories of consumption.

However, when considering the lifestyle aspects consumption of energy and water may not be the most relevant objects for analysis, because theories on lifestyle primarily focus on the communicative aspects of consumption, i.e. how to express lifestyle, group belonging and identity to others or to your self through daydreaming. A certain level of energy consumption, whether high or low, is not a way to express identity or to stage dreams, for one reason because it is a hidden consumption. This does not mean that high or low levels of energy consumption is not related to lifestyle and consumption practices in the sociological or anthropological sense of the word. This and other studies have shown that energy consumption i.e. relates to the size, style and type of a house and to the amount and use of appliances and that all these aspect are highly relevant within a sociological and anthropological understanding of consumption.

A leading idea of this research is to combine lifestyle, resource consumption and physical structure from two points of view. In a bird's view, patterns of consumption are seen by combining the idea of the social geography of the city with the visualisation of the energy and water consumption. From this point of view, physical structure means the built environment. In a worm's view, qualitative analyses of individual households have been performed in order to understand how house, identity and resource consumption are interconnected in each individual case. From this point of view, physical structure means the house with its appliances. Thus far, the two perspectives constitute two strategies.

In the following two sections we will give examples of each of these research strategies. In the first section we will introduce to birds view, with the GIS- based maps, and it is shown how these maps relate to a monitoring system called eco-accounting. In the second section, the qualitative studies of the worm's perspective are introduced and it is shown how these studies are related to different cultural consumption theories.

## Birds eye view: Consumption maps

Segregation is a main characteristic of urban conglomeration. Citizens are different and they become affiliated with different social groups and subcultures, each of them with their own favorite places for living (Jensen and Bech-Danielsen 1999). Lifestyle more or less predestinates the social membership and the acceptable domains for daily life. This has long since been established by urban studies and can easily be confirmed by statistics that take account of for instance the personal income of housing neighbourhoods. By using GIS, the segregation according to income can easily be visualized. However, as will be described later, not only wealth and goods make the distinction.

And now this question: Will it be possible to represent social geography in terms of statistics that address consumption only. For consumption as a whole, this is of course impossible. But, by meters placed in the homes in order to read the amount of heating, the amount of electricity, or the amount of water delivered, these elements of consumption can be emphasized by means of GIS. Meters installed are of course for individual accounts. Nevertheless, by using GIS access to these meter readings can be transformed into a map that shows the distribution of heat consumption in the urban neighbourhoods.

At DBUR consumption maps and other kind of maps of the city of Aarhus have been compiled into a GIS Atlas that shows how statistics of buildings, socio-economics and consumption can be visualized by means of GIS (Jensen and Olsen, 2002). As a research institute DBUR has access to a personal data register in order to obtain socio-economic data (the Danish CPR register contains information on income, education, age, nationality etc. of every person living in Denmark). DBUR has also access to a building data register to obtain information about buildings in Aarhus (the Danish BBR register contains information on building year, size and type of all building in Denmark). Aarhus Technical Department has provided the meter readings. Information about 280,000 people, 133,000 buildings, 70,000 electric meters, 45,000 heating meters and 53,000 water meters have been assemble in the data register to support the atlas production.


Figure 1: Examples of maps picked up from the Danish GIS atlas, one based on data on personal income, the other based data on household heat consumption.

The division of Aahus into neighbourhoods is based on the physical structure of the city, i.e. the age of the neighbourhoods, its location in the urban body, demarcation by the road network, type of buildings and the environment of green areas. In short, this can be seen as a division of Aarhus into naturally demarcated housing neighbourhoods. The signs of the map explain the level of consumption. For Aarhus a map showing heat consumption was made possible by the fact that most housing estates are supplied with district heating.

## Eco-accounting

When studying the heat consumption map, it is worth noting that the average heat consumption is measured in heat units per person instead of heat units per household. This way of interpreting energy consumption comes from the Danish eco-accounting system, and in fact the GIS maps of consumption can considered a visualization of eco-accounting for a geographical area. By benchmarking consumption as an individual rather than a household relationship, it is at the same time stressed that consumption is about responsibility of individuals. The same way of thinking is known from the concept of The Ecological Footprint and the concept of The Ecological Rucksack.

As measures, environmental accountings of this kind are meant to serve as environmental indicators and documentation of environmental improvements. In addition, they should encourage the establishment of new environmental improvements, and whenever possible help promote environmentally sound behaviour. In any case, the benchmarking system provides opportunities for a dialogue with the citizens. It is the overall requirement of sustainable urban development and not least the reductions of carbon-dioxide ($CO_2$) emissions that have caused the demand for the environmental accounting.

In Denmark eco-accounting is a widespread monitoring tool applied to the infrastructure of all kinds of housing areas, from single homes to large social housing estates. Moreover, it has been applied to the infrastructure of schools and offices. A basic assessment tool, based on an Excell spreadsheet, is available on the homepage of Danish Building and Urban Research (www.dbur.dk).

The monitoring method can be seen as an Environmental Accounting (EA) method, but unlike the traditional EA, eco-accounting calculates in substances (mass and energy units) instead of finances (monetary units). The assessment method addresses the efficiency of a specific supply system and moreover the efficiency of the supply system and consumer behaviour as a whole. It is based on the idea of assessing input and output as known from the Life Cycle Assessment (LCA). In eco-accounting like financial accounting, all inputs and outputs have to be balanced and therefor taken into account (according to the physical principle of constancy of energy and substance). However, practical use of the assessment method is limited by those flows of fuels, heat (district heating), electricity, water, and waste that are connected to meters or otherwise are measured.

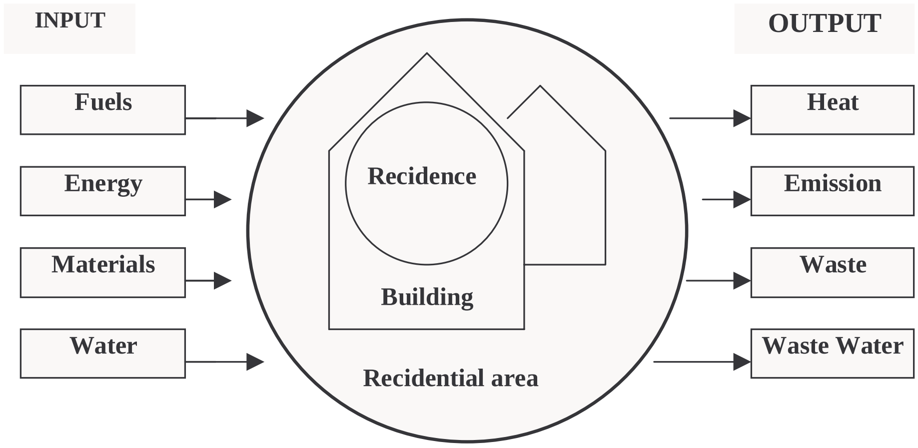


Figure 2. The principle of the double-entry eco-accounting

## Neighbourhood consumption pattern

From a researcher's point of view, GIS-visualised eco-accounting is an important access to understanding energy consumption and household consumption patterns as a whole. This became even more visible when household consumption maps were compared with socio-economic GIS maps and GIS maps dealing with physical conditions of buildings, still based on a geographical division of the city into neighbourhoods.

Main findings of such analyses confirm that the social status of the residents in each type of neighbourhood corresponds to their energy consumption. The analysis also shows that small household (few persons per household) and large dwellings (many square meters per person) are closely related to high heat and electricity consumption. In affluent residential areas, the average heat consumption per person is 200-300% higher than in apartment blocks and the average electricity consumption per person there is 20-40 % higher than in most other neighbourhoods. However, it is also remarkable that often apartment blocks on average consume as much heat per person as ordinary single-family houses. Surprisingly, the age of a building, and thus its technical standard, does not greatly affect the heat consumption except in neighbourhoods with new buildings constructed since the Danish Building Regulations were tightened in 1979 (Jensen and Gram-Hanssen, 2000).

Consumption varies widely from neighbourhood to neighbourhood. However it also varies within the neighbourhood. This variation is of cause biggest in neighbourhoods with big variations in house sizes (Figure 3 is an example of this) although in neighbourhoods with similar houses variation of 300-400% is found.

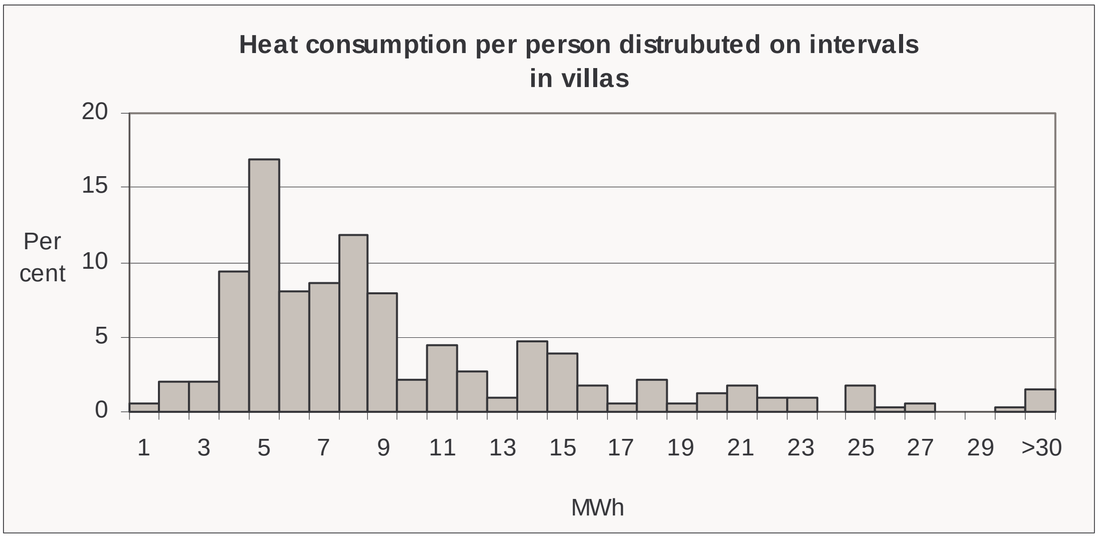


Figure 3: Although the energy consumption varies widely from neighbourhood to neighbourhood, the consumption within neighbourhoods also varies considerably. This gives an example of the variation of heat consumption in a high-status villa area.

## Worm's view: Qualitative studies

In the previous paragraphs it was described how maps of energy consumption and maps of socio-economic factors and building statements can expose patterns of consumption in the social geography of the city. However, one thing is showing patterns another thing is understanding the patterns, i.e. understanding why citizens consume as they do. Concerning this kind of questions qualitative studies can provide valuable knowledge.

Searching for an understanding of consumption behind the patterns of consumption, two different qualitative studies were conducted on why people live where they live, what their house mean to them, how they furnished and equipped it and how they used the house and its appliances. One study focuses explicitly on energy consumption in working and middle-class neighbourhoods with terrace houses, rental and owner-occupied respectively (Gram-Hanssen 2002). Another study focuses on style and identity of middle and upper-classes in detached houses, both the living in old villas and in newer standard houses (Gram-Hanssen & Bech-Danielsen 2002). Each study includes 10 to 12 in-depth qualitative interviews (Kvale 1996) with selected families. All of the interviews were taped, some of them fully transcribed, and others thematically reported and partly transcribed. In the following some results will be presented. First however, an introduction to some of the theories that these studies rely on are in order.

### *Consumer theories*

Consumer theory deals with experiences, motivations and reasons for why people buy things and why different groups of consumers buy different things. Classical studies on consumption have focused on the communicative aspects of signals and symbols in relation to social groups. Douglas describes how humans through social gathering witness and confirm each other's consumption rituals (Douglas & Isherwood 1979). Bourdieu describes consumption and "the good taste" as a way for the higher social classes to distinguish themselves from the lower classes (Bourdieu 1984), and he shows how residential neighbourhoods in this way form part of the symbolic power structure in society (Bourdieu 1996). In contrast to these descriptions based on a class-society, we find the post-modern understanding. The argument is that we are approaching a society with post- or late-modern structures where institutions from modern society such as class, family and community are under dissolution, and where the individual therefor has to express and create his or her own individual identity (Beck 1992; Giddens 1990). In relation to consumption this could be understood as if the individual is free self-consciously to choose to manifest any of the multitude of lifestyles on offer: ”Everyone can be anyone” (Stuart and Elizabeth Ewen here cited from: Featherstone 1991). This discussion on modern versus post-modern consumption theory however focuses primarily on the communicative aspects of consumption. Campbell argues against this, stating that these theories depend on the consumer and the observer sharing a common understanding of the “language” that is used (Campbell 1995). As an alternative to the strong focus on communication, Campbell has proposed a theory of pleasure and daydreaming as the wheel that turns the need for consumption (Campbell 1987).

This kind of consumer theories focuses on why to consume, and not on what happens afterwards in relation to the consumed objects. Talking about energy consumption, it is relevant not only to understand why people buy new appliances, but also to know how they are used afterwards. The subject area known as “domestication of technology” deals with this (*Making Technology Our Own* 1996). Here, the focus is on how technology is used, tamed, and (re)interpreted in everyday life. The concept of domestication of technology thus enables us to understand the mutual construction process between humans and the consumed appliances.

In our studies we have concluded that understanding in which neighbourhood different kinds of people live Bourdieu has a lot to offer, however moving inside the house looking at decoration and renewing more late-modern theories, or theories of pleasure and daydreaming, may be more relevant (Gram-Hanssen & Bech-Danielsen 2002). Whereas understanding the interaction with the house and its appliances we could learn more from the domestication of technology paradigm (Gram-Hanssen 2002). These conclusions will be further elaborated in the following examples of findings.

### Example of empirical findings: Who lives where and why?

From the GIS maps we know that different neighbourhoods have different levels of energy consumption for heating purposes and that the inhabitants have different socio-economic backgrounds. In the qualitative studies we explore why different types of people live where they do. Economic ability is of course an important determinant but as we will see economy is not the only important factor.

In the study comparing rental and owner occupied terrace houses we find that houseowners have a higher income and are better educated than renters. In general the differences between the studied neighbourhoods were however not that great and many of the renters were economically able to become homeowners if they wanted. In the interviews, we explored the cultural reasons why people are homeowners or renters. In the case of some of the residents it was obvious that the question had never really been raised. Whether they were homeowners or renters, they just did the only natural thing, which is simply to follow what you know from home and bring with you as a part of the habitus, which is the unconscious social disposition you are brought up with (Bourdieu 1984). In the case of others, it was an issue, and here we heard different stories about how constructing identity and choosing a neighbourhood were closely related. An immigrant couple, who were homeowners, told how they had avoided many rented houses assigned to them by the municipalities because they did not want to live in what they considered ghettos with too many immigrants. On the other hand one of the families living in rented houses had discussed buying their own house. Many of the husband's colleagues had their own houses, which they worked to maintain and renew every weekend, and he longed to be part of this group. His wife however thinks that buying a house "is not for people like us".

Wanting to learn about the specific culture of a local neighbourhood, it may be informative to listen to those who feel that they are not a part of the local culture, the "Strangers". One example from the study of detached houses was a self-made man who had worked his way up as a businessman and now lived in an expensive area with old villas, and all the neighbours having long education's. The family had built a new villa in the old style, and already before they moved in their neighbours looked askance at them because of this. In the beginning the family said "hallo" to all they met, but nobody returned their greetings. The family explained how after some years they now felt at home in the neighbourhood, and were invited when the professor or the doctor invited the neighbours, though they still felt different. Another "Stranger" was a family in a middle-income standard-house neighbourhood, which suffered from a bad reputation. One of the families told how they, when they bought the house, had to defend the neighbourhood and justify to their friends and family why they wanted to live in such a place. This family agreed that the bad reputation of architecture was deserved. They themselves did not find the houses too beautiful. They bought the house as a temporary solution, however they had grown to like the social life in the neighbourhood and found it more important than the architecture.

This kind of stories gives "flesh and blood" and cultural explanations for the GIS maps showing the social and cultural segregation of the city. And as we know from the GIS maps that different neighbourhoods in the city have different levels of energy consumption for heating according to size and type of buildings the stories also helps us to understand the relations between for instance social status and energy consumption in households. Choosing which house and area to live in is also choosing level of energy consumption for heating purpose, however this was not how it was experienced by the inhabitants, as energy consumption in it self was never a goal.

### *Example of empirical findings: Buying and using appliances*

Understanding different levels of electricity consumption between neighbourhoods and between households in the same neighbourhood is about understanding the type, the number and the use of appliances. To understand more about what influence type, number and use of appliances, we have interviewed respondents about how different appliances were purchased and "domesticated".

An example was a family that bought a new tumble dryer one year ago because the old one broke down. They explained that they were looking for a machine that used less energy. The wife had tried not to use their old dryer too much, hanging wet clothes to dry on a clotheshorse in the evening and then finishing them in the tumble dryer in the morning. Because of the size of the house, there is no room for the clotheshorse in the daytime. Buying a new and more efficient machine means that the wife does not have to think so much about how she uses it. She said that she washes three or more full loads every day, and that they have thought of buying an extra washing machine to increase their washing capacity. Asked how it was possible to generate so much dirty clothing, the mother responded that as she work at home she was able to fill the machines many times a day. By doing so, she avoided discussions or problems with her family about clothes washing. All five members of her family wore their clothes for only one day before washing them, including sports clothes on an almost daily basis. The children showered at home and at sports practice every day, and air-drying the towels in the bathroom was impossible because of moisture problems resulting from a lack of heating in the bathroom. So the mother's solution was to wash (and dry) all the towels after each use.

From this case it was learned that the process of domesticating the technology changed daily routines and involved discussions and relations among family members as well as knowledge (actual knowledge or beliefs) about energy efficiency. This process is interwoven with the physical conditions of their house and the available time of the mother. This family is a good example of what Cowan describes in her book *More Work for Mother* (Cowan 1983). More appliances to do housework does not mean less work for the mother but rather a higher level of service for the family and; these appliances also permit the mother to do the work alone. An additional consequence, we might note, is increased electricity consumption.

In this and related examples we heard stories of how buying and using appliances had to be understood in a complex interaction between family members, the house and the technology. We learned that understanding differences in electricity consumption was about understanding relations between technology and culture in everyday life, and we learned that these relations very often had little to do with awareness and concern for energy consumption.

## Concluding remarks

In this paper we have showed examples of research on households energy and water consumption from two different but complementary approaches. A birds' view of GIS-based maps shows social geography and consumption patterns in the urban landscape, and from a worm's view, qualitative studies of everyday life provide background for understanding the different levels of consumption. Both methods are equally relevant as a research method however both of them are also relevant for a policy and planning approach.

As urban planners are used to maps as an integral part of their planning instruments consumption maps may be a way for them to bring in more focus on sustainable consumption in urban planning. Planning, building and renewing cities is also to build the physical structure of the future consumption pattern and therefor it is important to pay attention to relations between the built environment, lifestyle and resource consumption in the planning process. Consumption pattern is however not totally predetermined by the physical structure. As the qualitative studies of everyday life show the actual resource consumption has to be seen as a result of the interaction between culture and technology, and this knowledge is also useful in a practical context. Information and communication strategies have to take into account that a lower level of resource consumption can not be reached only by focusing on more efficient technologies. How new needs constantly develops needs to be understood.

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## Environmental load from private Dutch consumption

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### Abstract

A systematic approach towards lowering the environmental load from private consumption can only be attained when the impacts of the policy can be monitored. This paper describes the development of such a monitoring system developed by and for the Dutch government. Some results are discussed.

First, an operational approach to determine the worldwide impacts from consumption in the Netherlands is described. An important innovation is the use of linked input output tables that cover the world wide trade and economy, albeit that the input output tables are rather coarse. The framework can also be used to improve input output datasets for other countries or regions, and can be the starting point of a worldwide LCA dataset to which each country can connect its own input output database.

### The effectiveness of ecodesign

Since the early nineties the concept of ecodesign has been embraced as an important approach to decrease the environmental load of products. The focus of ecodesign is to lower the environmental load throughout the lifecycle of the product. An important assumption was that the load should be lowered per unit of function fulfillment. For instance, an environmentally sound car is thought to be a car that pollutes less per kilometer, an environmentally sound light source is an energy efficient light source. Although this seems a logical viewpoint, it misses an important point: improved product performance will often result in a change in consumer behavior. An energy efficient car is a perfect second car for the family, and why not light your garden with the new lamps. In other words, the often claimed win-win situation (lower cost and lower load) can have an important unexpected side effect, through the consumer behaviour.

#### *What limits the environmental load of consumption?*

When we do not look at products per functional unit, but on a macro level, we can understand that in fact there are just a few factors that limit environmental load of consumption:

- The cost of products set an important limit on consumption. In general, consumers have a more or less fixed income, and this income increases a few percent per year. If inflation is lower than income increase, this means they can afford more products if products become cheaper to buy or use (the fuel efficient car), it means they can purchase or use more products.
- The time consumers can spend is limited, in many cases, for instance when choosing between the use of a private car and public transport, time is a decisive factor. Time is also an important limiting factor for the holiday industries

- Volume. Many people have a limited storage space. This is an important factor when deciding for a second car, but also favors the use of compact products, and is a motivation to rent, in-stead of purchase tools.

Of these three factors, probably the most important and fundamental is the cost factor. This means that if we want to limit the environmental load by consumption we need to address the ratio between environmental load and value, and manage a transition from low value high polluting products to high value, low load products.

## The environmental load per unit of value in economic sectors

In earlier research [2] we developed eco-indicators per unit of value added in the major industrial and service sectors in the Dutch economy (base year 1993). Added value is defined here as the difference between sales and purchases of the sector. Figure 1 provides an overview of the results with a few sectors highlighted.

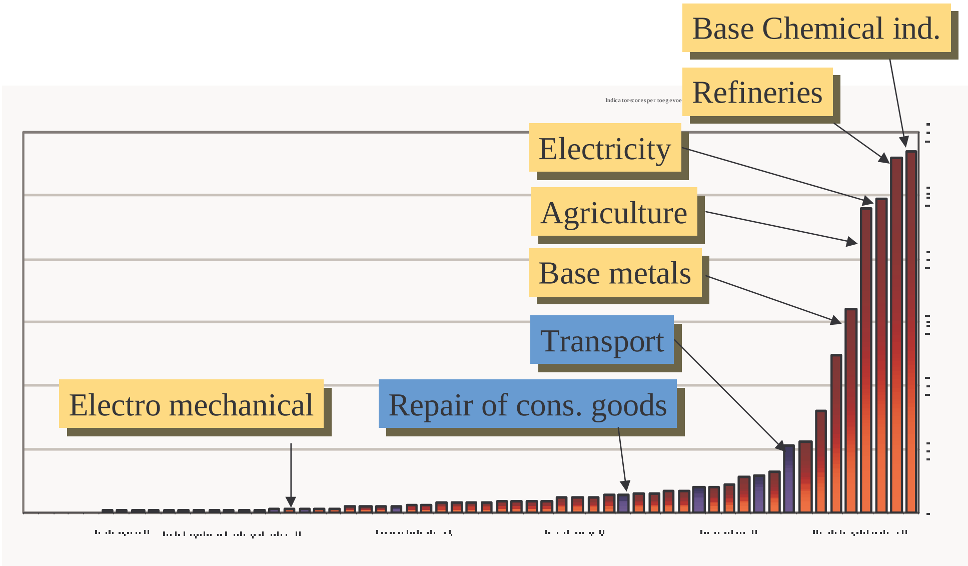


Figure 1: The environmental load from 63 economic sectors (expressed as Eco-indicator 99 points) divided by the value added by a sector in the Netherlands. The blue columns represent service sectors, the red columns represent industrial sectors. A few sectors have been labelled as example.

Clearly the bulk industry sectors create relatively high load per unit of value. This is of course not really surprising. A little more surprising is the observation that service sectors do not always perform better than industrial sectors. For instance the repair of consumer goods is a relatively poorly performing sector, mostly due to the intensive use of small delivery vans.

The ratio is not the only important factor, also the magnitude of the activity is important. Figure 2 provides an alternative presentation, using the E2 vector [2], to plot the environmental load against the added value. The slope of the vector indicates the ratio, the length indicates the magnitude of the sector.

In this representation, we see that there are just a few sectors responsible for the high added value or environmental load. Service sectors seem to add much value and low environmental load.

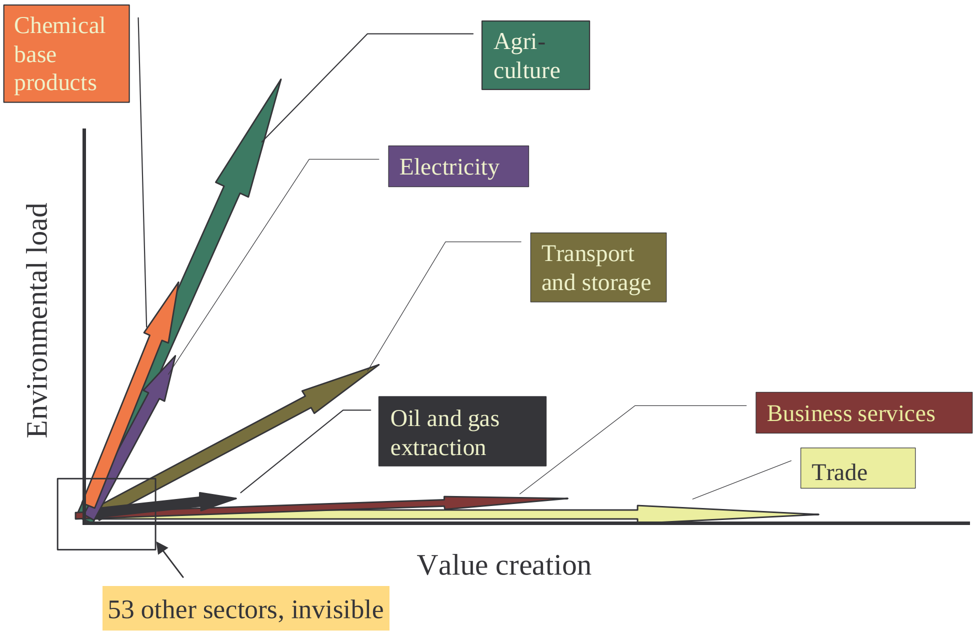


Figure 2: The environmental load plotted against the value creation, using the E2 vectors. The slope of the vector represents the ration between load and value, the length represents the magnitude. For sustainable economic growth the steepness of the vectors should decline, or the flat vectors should grow.

Of course this representation can also be misleading, the apparently very favorable service sectors use much of the unfavorable sectors, such as electricity. In fact it is more useful to follow the whole chain throughout the economy, by linking sales and purchases, and carrying the environmental load per transaction with it. In this way we can perform a so-termed environmental input output analysis.

### *Data collection through Input-output*

Each economy has an economic input output table that specifies the value of the purchases between sectors within the country and abroad (the imports), as well as the supplies to other sectors and the exports. Furthermore all other major costs and revenues are specified.

These tables have been used by several LCA experts to compile input output (I/O) databases; see [1] for a general overview. Environmental data per sector is divided by the added value, resulting in an environmental load per unit of value. These ratios can be used to link the environmental load to all supplies through the economy, enabling us to get a total environmental load of the outputs of all sectors.

### *Towards a system of interconnected IO tables that span the world*

A yet unsolved problem is how to deal with imports and exports. Traditionally LCA practitioners that used IO datasets have used the assumption that the environmental load per unit of added value for imports and exports are identical [1]. An apple in Europe has the same load as an apple in the USA. However, it is clear that there are some problems in assuming that the environmental load connected to an agricultural product produced in the EU has the same load as a product produced in developing countries. Some research indicates that, especially for trade with non OECD countries, the environmental load per unit of value is an order of magnitude higher compared to production in OECD countries [2]

In a large economy such as the USA, the lack of specific data for imports may not be too relevant for most sectors, but when smaller, and more trade oriented economies are analyzed this may lead to significant distortions. This paper describes how we can link a national IO table to a set of three international IO tables that span the world economy. We believe that this approach can be generalized, so that other researchers can add their own National IO table.

### *The environmental load from consumption*

The dataset presented here is the result of a project commissioned by the Dutch government. The project originates from the desire to be able to trace the impacts of its policy on the environmental load of private consumption on a national level. For that purpose, a system has been developed that links consumer expenditure to the environmental load it creates. The intention is to  update the system every 5 years and to monitor the trends.

### *Direct and indirect environmental load*

It is important to distinguish between direct and indirect environmental load caused by consumption.

- The direct environmental load is defined as the load that occurs after a product or service has been purchased by the consumer. IO databases cannot cover such load, they trace economic flows up to the point the consumer purchases the product.
- The indirect environmental load is the load that occurs before the product or service has been purchased. Basically this is the load produced by economic activities. This load can assessed in IO databases

This distinction can be clarified with a simple example. When the consumer purchases paint to decorate his own house, the *indirect* environmental load is the load associated with the production of the paint, the packaging and the distribution, The *direct* environmental load is the load that comes from the emission of solvents. The direct environmental load is *not* the same as the imp[acts from using products (often called the “use phase” in Ecodesign or LCA). For instance electricity consumption is regarded as indirect, the consumer purchases the electricity. Similarly, the production of fuels for a private car is regarded as indirect load but the exhaust gasses from the car is regarded as direct environmental load.

This distinction seems slightly artificial, it is however very useful, as the indirect environmental load can be well covered with environmental input output tables.

### *Consumption patterns*

In most countries a detailed analysis of consumer expenditure is available. Such a statistic specifies average expenditure by consumers over a large range of products and services. For this project we used the data from the Central bureau of Statistics [3] on expenditure over 350 products and services. Some products occur several times in the list. For instance car use for recreation and car use for shopping are kept separate.

The products and services can be analyzed for the direct environmental load. To determine the indirect environmental load a link was made to 105 industrial sectors as defined in the Dutch economic input output table. As we will see these Dutch sectors are also linked to input output tables in other parts of the world.

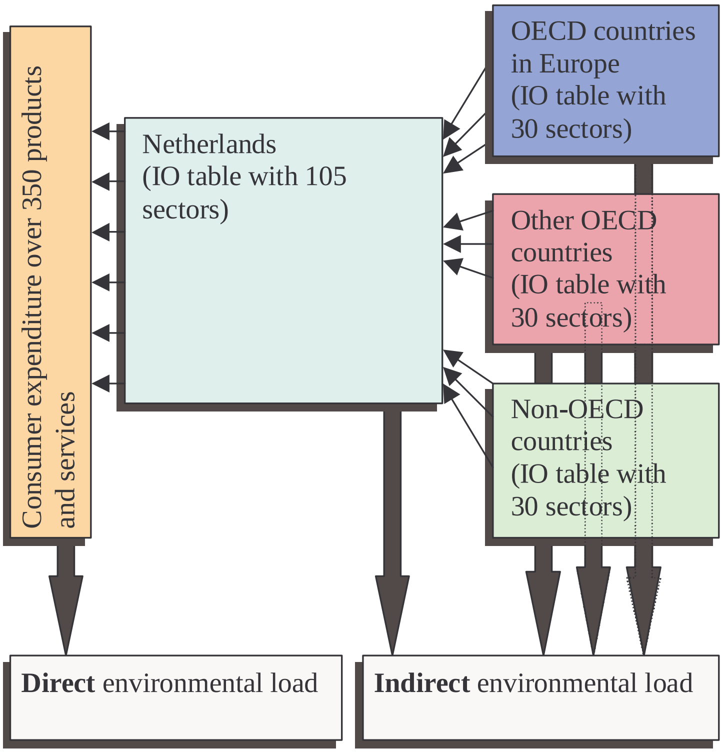


Figure 3: Overview of the financial flows throughout the economies to the Dutch consumption pattern.

### *Selection of environmental stressors*

The Dutch government specified a list of 20 elementary flows or "stressors". These are:

- Emissions of CO2, CO, CH4, NOx, SOx, N2O, HFC's/ HCFC's, non methane VOC, benzene, PAHs, heavy metals, nitrogen, phosphate, PM10 (dust),
- Land use, water consumption, wood use, fish extraction, use of pesticides.
- Truck, Car and Moped kilometers, especially to assess the nuisance caused by noise

### *Direct environmental load*

The 350 products and services have been screened to determine if they result in any direct environmental load. About 20% of these have a direct environmental load. LCA databases and other sources are used to determine the direct environmental load. The products were grouped in following domains (relevant for Fig. 5):

1. Food : Food, catering, electricity for cooling, energy for cooking, washing and food shopping transportation

2. Leisure: magazines, books, recreational transport (incl family visits), holidays, electricity for TV etc
3. House: house and garden, rent and mortgage, insurance, maintenance, incl. energy for ventilation and heating
4. Household: furniture, curtains, flooring, lighting (incl electricity)
5. Hygiene: hot tap water, cosmetics, toilet paper, medical care, - insuranceetc
6. Labour: commuting, education fees
7. Clothing: clothes, shoes, washing

An analysis showed that the major contributions to the direct environmental load are associated with (top 4 only, in descending order):

1. Car driving for work and recreation
2. Wood and Coal, used in fireplaces and old stoves
3. Heating
4. Cleaning

Of course this ranking also depends on weighting across impact categories, here equal weights were used of all elementary flows (emissions, resource use etc.)

### *Indirect environmental load in the Netherlands*

The Dutch input output matrix has 105 sectors. The National "emission registry" system maintains a detailed data inventory for industrial activities. This database has been used to run queries that produce datasheets per sector. Significant amounts of work were needed to convert the data to a format that is consistent with the definition of the stressors and the sectors. For a number of stressors, such as land use, other data sources needed to be used.

### *Indirect load outside the Netherlands*

The "rest of the world" is split up into three regions:

- OECD countries in Europe
- Other OECD countries
- Non OECD countries

For each of these regions, thirty sectors were defined that were taken from the DIMITRI [4] and EDGAR [5] database. These databases already have data on Energy use, $CO_2$, $NO_x$ and $SO_x$ per country and per sector, so it is relatively easy to create datasets for these stressors per region. To cover the other stressors a wide range of sources has been consulted. In order to focus the efforts, an analysis was made using the GTAP [6] database to identify which countries or regions contribute most to an industrial activity. The focus was to find data for these countries and regions first, and extrapolate this data over the whole region. Of course the data collection was not complete, and often extrapolations have had an important influence.

### *Some results*

The results of the procedures described above can be summarized in a few graphs. First we analyze the relative share of the different “consumption domains” to a selected set of impact category indicators. A domain is defined as a group of purchases. Instead of the individual emission an aggregation has been made, mostly using the CML 2001 impact assessment method [7].

Figure 5 shows that for most impact categories food plays a dominant role in the consumption patterns. Recreation and working expenditure are quite heavily dominated by expenditure on car transport. This shows that the use of cars is also an important contribution to the load.

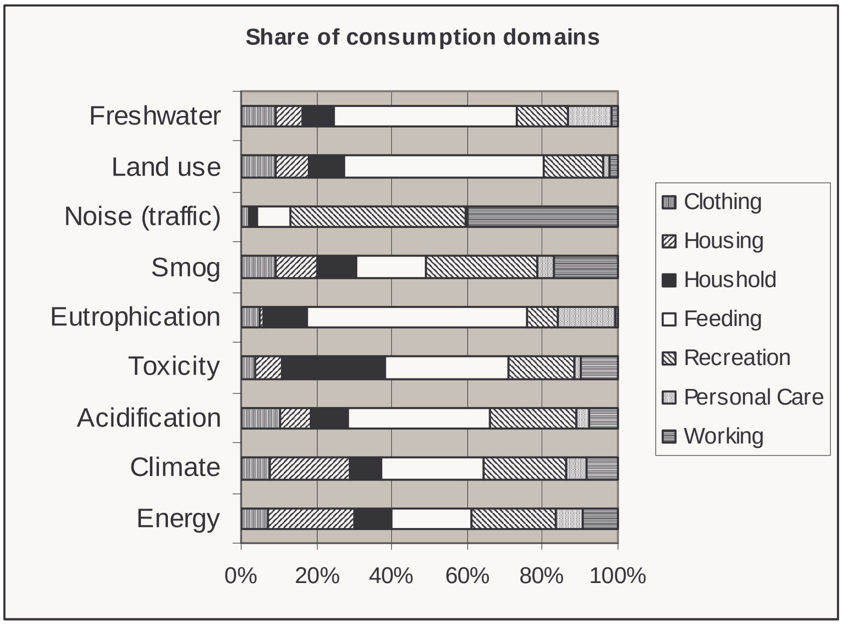


Figure 5: Share of the consumption domains over the environmental impact categories (direct and indirect, all regions).

Another result is the analysis of the direct versus the indirect environmental load. This shows that especially road noise is associated with direct environmental load. This is partly a distortion due to the fact that truck kilometers and car kilometers are considered to have the same impact. Indirect load is dominant in most other impact categories.

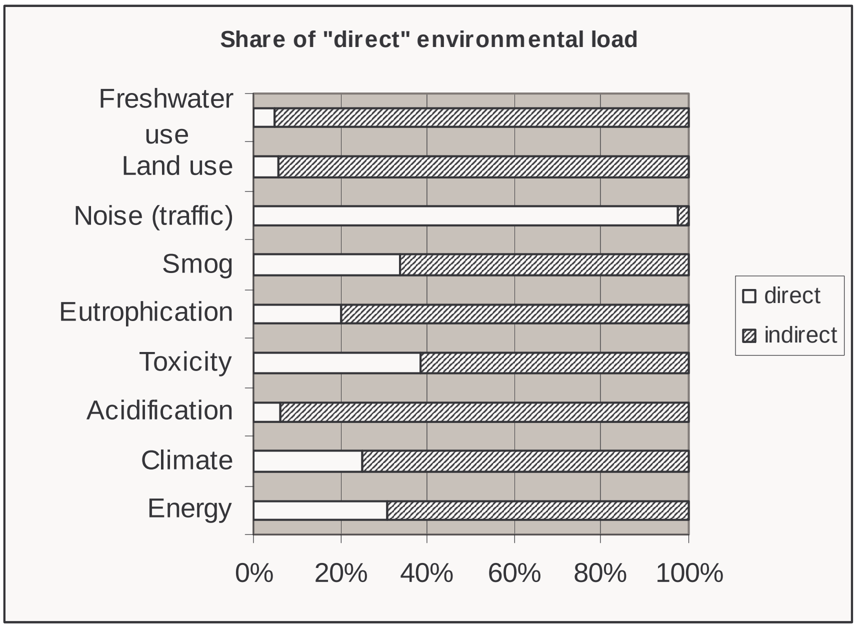


Figure 6: Share of the "direct" environmental load, caused by the consumer, in relation to the indirect load that is caused by economic activities (all regions).

Another view is obtained when we analyze the relative contribution of the load from the regions. Here we can see that the Non OECD have a relatively high contribution, especially in land-use and acidification. This is remarkable, as the value of the imports of this region is relatively modest. The Netherlands get 66% of the imports from Europe and only 17% from the Non OECD countries. The contribution of toxic emissions within the Netherlands is remarkably high. One explanation is that the share of direct consumption of household (which occurs always in the Netherlands) is high for toxicity.

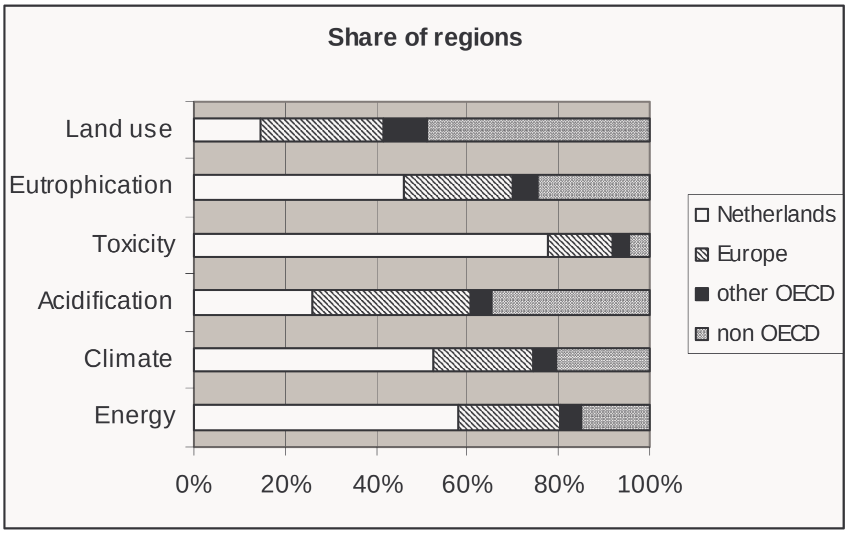


Figure 7: Share of the regions tot the environmental load (direct and indirect)

These results allow us to get an insight into the dominant and less dominant issues related to private consumption. For instance it seems that many LCA studies are focusing on products within the household consumption domain, while this study shows that this is not an important domain. There are other consumption domains that are much more important to focus on. Especially the environmental load related to the food production chain seems to deserve more attention.

### *Implications of the monitoring system*

As the monitoring system has now just been started, we cannot present any trends yet. However in a few years when a second assessment will be made it will become quite clear what the trends of all efforts directed towards improving eco-efficiency are.

The system as it is now, already shows some very interesting results, like:

- The relatively high contribution of the direct environmental load in some impact categories; the load caused by consumers after obtaining a product is remarkable. It should be noted that direct environmental load is not the same as the use phase; important loadings from electricity use due to the use of products is considered indirect load.
- A relatively high contribution of the consumption domains Feeding and Housing, as well as recreation.
- The relatively high land use in Non OECD countries needed for the Dutch consumption

The system developed, shows the power of using the eco-efficiency ratio (value against load) to make assessments on the societal level. In stead of analyzing the environmental load per function performed by the product, we analyze the environmental load per added value, and as value addition is the main function of an economy, we have an analysis of the functionality of the economy.

An important implication is that governments can in fact try to influence consumption domains by developing policies that can address the issues that require priority. Another implication is that government can look at sectors it wants to stimulate or discourage. Finally the system can be used to assess trade between economic blocks, and more specifically trade with non OECD regions. Companies should be well aware that with such tools governments can focus their product policy more efficiently.

The same tools can also be used for assessments on the product level, or for strategic analysis from within the company. The main function for a product, or for a company department is the generation of value with a low environmental load. The dataset has now also been implemented in LCA software, which means it becomes very easy to make the assessments in this way. The data from the input output matrixes can be used in combination with traditional LCA datasets.

For strategic assessments it becomes easier to see which divisions provide high value at low environmental load. It may become an important asset for a company to be able to show this overall ratio and try to concentrate on divisions with the most favorable ratios.

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# What Do Social Systems Consume?
# A Different View on Sustainable Consumption

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## Abstract

There is a small Austrian village with approximately 70 inhabitants who make their living out of farming, part time farming and as employees at a nearby industrial site.

What and how much material do they consume during the course of a year? What has changed and what will change in regard to their consumption? What is the range of consumption between different households?

First I introduce the concept of society's metabolism and one of the headline indicators called Domestic Material Consumption (DMC) defined as difference between the Domestic Material Input (DMI) minus exports. Then I show the DMC composition for both years 1830 and 2001. I discuss the changes in the context of society's transition.

Theyern as social system has changed from a subsistence-based system to a market related one. Modern farming practices based on fossil fuel and fertilizer have risen the material throughput to a different level. This did not alter the DMC very much (5,5 tons per capita 1830 to 7,7 tons per capity in 2001) because both DMI and Export have grown significantly.

Therefore the look at the DMI, Export and DMC reveals better insights compared to a narrative focus on the DMC only.

On the household level Theyern's material flows have changed from a homogenous to a heterogeneous characteristic. The agricultural based household has a DMI of 50,3 tons per capita whereas the private household with people employed at the nearby factory has 3,3 tons/capita DMI in 2001.

The highest potentials for the reduction of material flows can be seen in the agricultural sector and the transport.

Finally I suggest braking down the DMC into various categories to allow linking it with lifecycle data.

## Approaching a small village in Lower Austria: Theyern

There is a small village in Lower Austria called Theyern. It is located halfway between St. Pölten and Krems. It was founded in the 15th century. At first sight the village has not changed at all over the last 200 years. The population of approximately 70 inhabitants remains more or less the same in numbers. The surrounding landscape has still the same characteristics. Even the map of the village itself and most of the buildings have remained the same.

A closer look at the community reveals a different impression:

In 1830 it was a farming community. Everyone was involved in crop farming and in sustaining the appropriate number of livestock for dung, labor and meat supply.

In 2001, some of the inhabitants still work as farms or part-time farms, while others work as freelancers or as employees at a nearby industrial site (Fig 1). Most of the surrounding fields have been leased to specialized medium scale farmers of neighboring villages. The few remaining farmers of the village have focused their activities on fruit farming (mainly apples). Tractors and fertilizers caused big changes in the farming practice. Furthermore, the new modes of transport allow closer links to other socio-economic systems (employment and shopping at nearby cities).

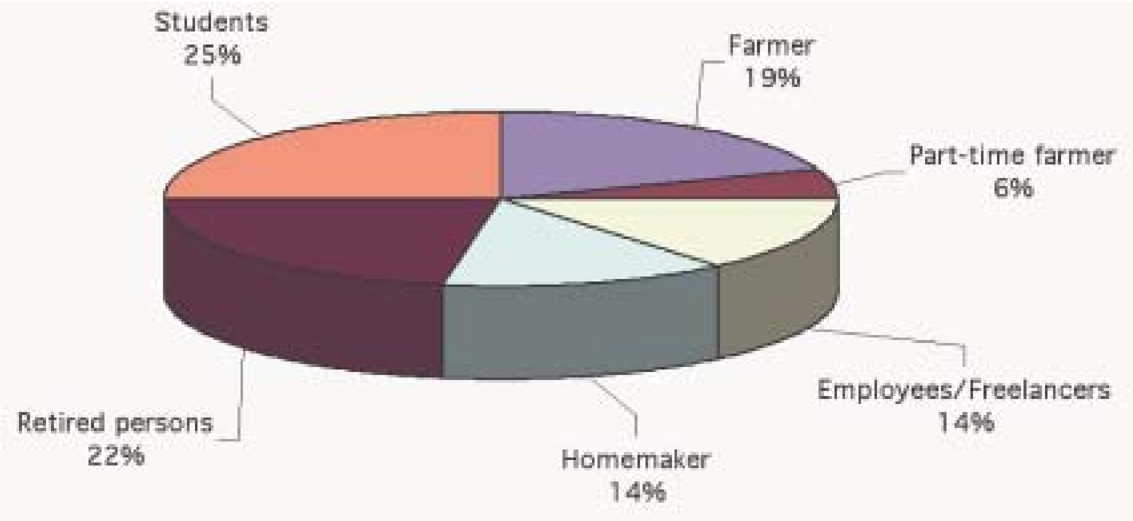



Figure 1: Population in Theyern 2001 (100% = 76 persons)

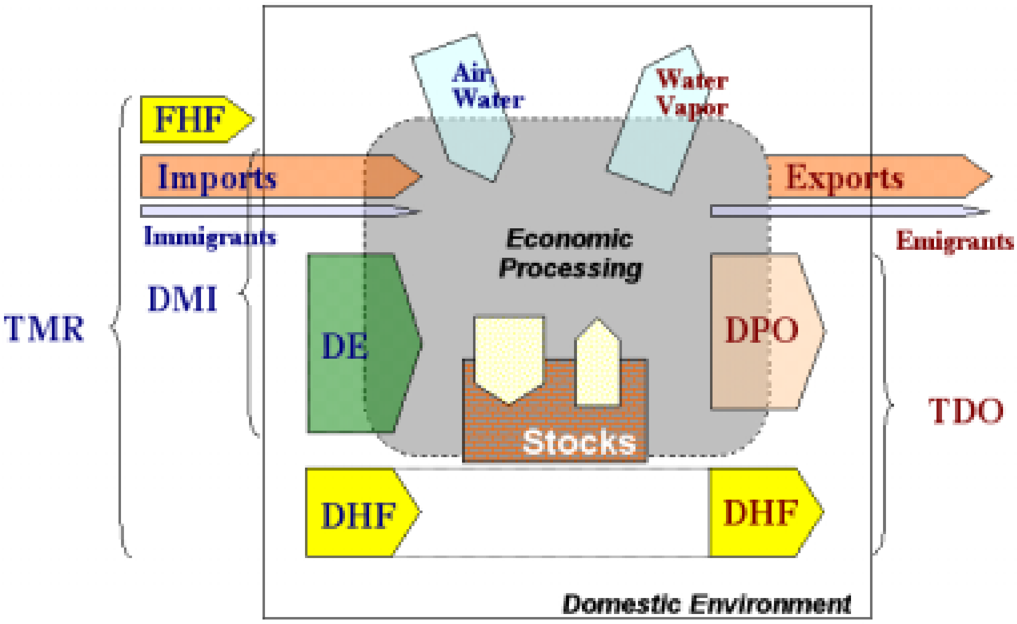
To fully understand the environmentally relevant changes in Theyern, we have applied a concept called social metabolism. This allows the discussion of society-nature interactions in a comprehensive manner.

## Social Metabolism

The concept of social metabolism originated in the traditions of biology and political economy. Social metabolism supposes social systems to be analogous to "organisms" in that they exist in a permanent state of material and energy exchange with their natural environment and other social systems (Fischer-Kowalski et al,. 1996). This exchange is vital for humans' quality of life and is channeled by natural as well as by economic and technological processes. Considerable ecological changes are the result of these processes, in terms of both input (raw material extraction) and output (wastes and emissions).

While energy metabolism has long been registered statistically in terms of energy flow analysis (EFA), we are internationally among the pioneers who are working to methodologically develop material flow analysis (MFA) as a tool for the observation of sustainable development. We see EFA and MFA as more than statistical methods. We see them as tools that are crucial to any description or understanding of the "bio-physical" economics of a society. Quality of life, working hours, trade, transport, communication relations and consumption - all of these are issues that we analyze in the context of their relation to social metabolism.

For a better way of dealing with the data some headline indicators have been developed (Figure 2).
The first set of indicators is closely linked to the input and the output flows of a social system. Domestic Extraction (DE) entails everything taken out of the domestic environment into the social system. Imports are considered as inputs from other social systems. Domestic Processed Outputs (DPO) are any controlled or uncontrolled material outputs to land, air or water. Exports are outputs that enter other social systems. To balance input and output someone has to consider both the changes in the water content of material that is flowing through the system and the oxidation process during an incineration. Since these are not flows of primary interest, they are counted separately. Everything a social system takes in and does not export is assumed as consumption of the system and is called Domestic Material Consumption (DMC).
A second set of indicators focuses on various forms of hidden flows, flows that are triggered by the system's demands but that do not take place within the system. They might take place in other social systems as Foreign Hidden Flows (FHF) or in the domestic environment as Domestic Hidden Flows (DHF). Data on hidden flows are rather uncertain and can vary widely due to the lack of standardization of system boundaries (Weisz et al., 2000, Giljum and Hubacek, 2001). I will therefore not discuss this set of indicators, but rather focus on the first set of indicators.




*Source: Matthews et al., 2000 (slightly modified)*

| | | | |
|---|---|---|---|
| **DE** | Domestic Extraction | **FHF** | Foreign Hidden Flows |
| **DMI** | Direct Material Input = DE + Imports | **DHF** | Domestic Hidden Flows |
| **DPO** | Domestic Processed Output | **TMR** | Total Material Requirement = DMI + FHF + DHF |
| **DMC** | Domestic Material Consumption = DMI – Export | **TDO** | Total Domestic Output = DPO + DHF |

Figure 2: Basic Material Flow Analysis model (MFA model)

## 1830-2001: What has changed in terms of consumption in Theyern?

### *Little Changes in Tons Consumed*

The investigation focuses on Theyern as a social system that is embedded in its domestic environment and has material exchange with other social systems. Theyern is reflected in a simple model with inputs, outputs and an internal structure to process the flows including stocks. The data for 2001 have been generated by household inquiries, through data from the local administration and by our own counting and observation. Additionally a model with agricultural standard factors has helped to double check data. Data for 1830 are taken from a study focusing on the historical situation of agricultural systems (Krausmann, 2002).

A first look at the DMC of 1830 and 2001 reveals a change. However, the change is not as big as someone would expect. Whereas an average person consumed 5,5 tons in 1830, the average person consumed 7,7 tons in 2001. This is an increase of about 40%. A more detailed insight reveals the DMC composition.

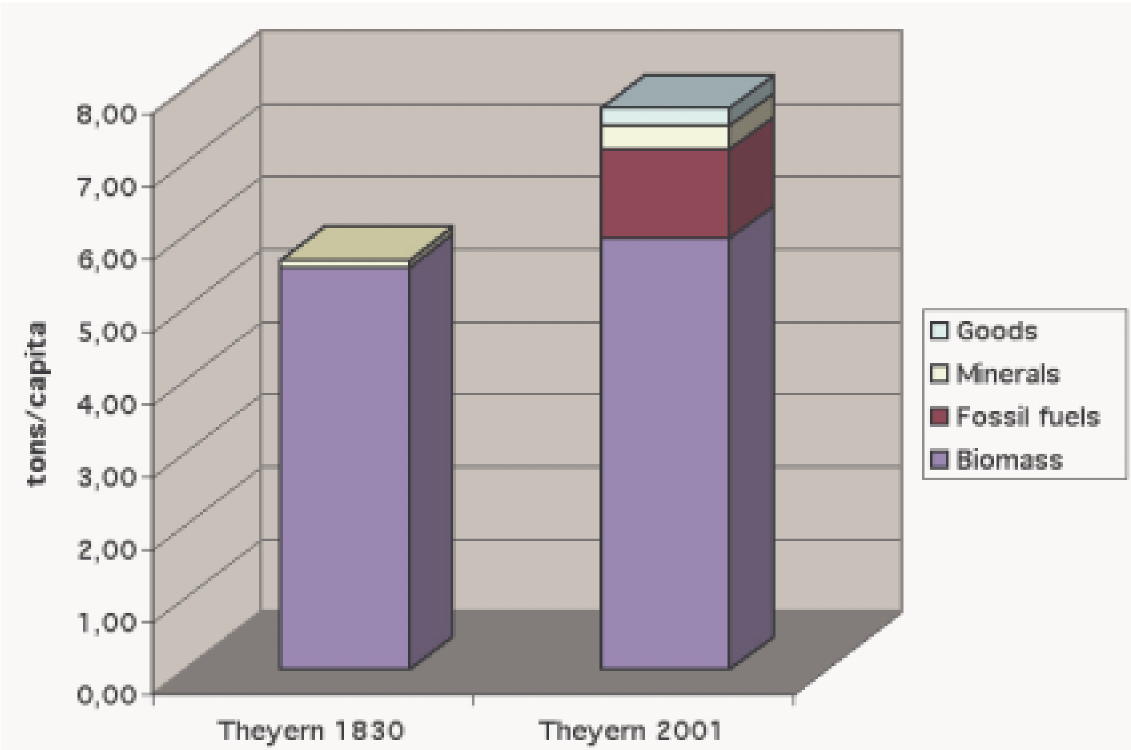



Figure 3: DMC composition Theyern 1830 and 2001

Figure 3 shows that the consumption of biomass has only grown by 7%. The variety and structure of the DMC have changed. In 1830 the DMC was to a very high degree biomass (98%). In 2001 the domestic material consumption included a slightly increased amount of biomass, which has a share of 77% of the total, as well as fossil fuels (16%), minerals (4%) and goods (3%).

As described above, the DMC has not grown much over 170 years. A close look at the indicators domestic extraction (DE), import, export and DMC at the same time can provide a broader view.

## Input and Output Growth Keeps Consumption at the same Level

Due to technological advances like mechanical labor and fertilizer the Domestic Extraction increased by 90% between 1830 and 2001. The import, shown in figure 4 on top of the domestic extraction, grew substantially during the same period. Altogether, the input into the system in 2001 is 2,34 times that of 1830. The export was almost non-existent in 1830.

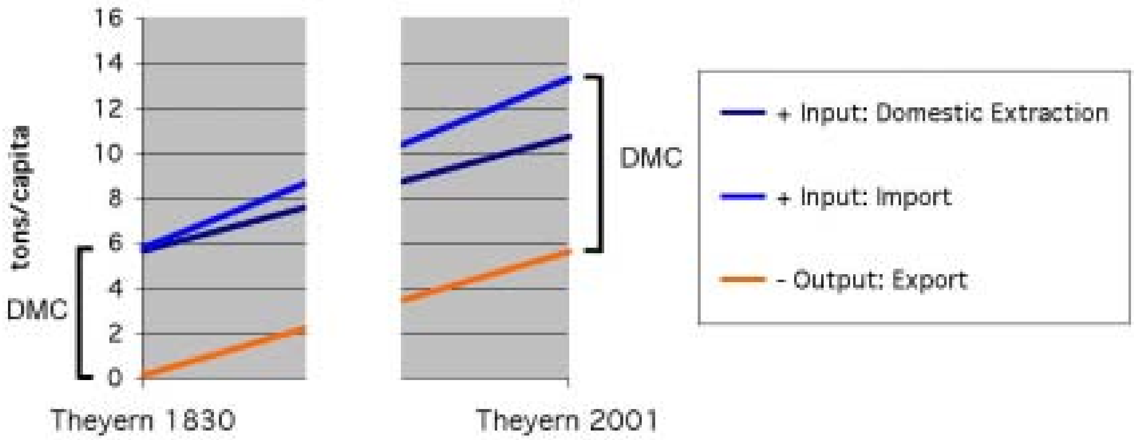



Figure 4: Domestic Extraction, Import, Export and DMC in Theyern 1830 and 2001

Concluding from this there are two significant changes:

1. The level of the DMI has grown significantly. This means that the material input into the system was 5,7 tons/capita in 1830 and 13,3 tons/capita in 2001. Due to a growing export the DMC has not changed a lot.
2. The system characteristics have significantly changed from a closed to an open system, which depends on the exchange with other social systems. Whereas in 1830 the Direct Material Input was almost the same as the DMC, in 2001 DMI and DMC became more or less independent variables.

## A Homogenous Village Becomes Diverse

Up to now we have looked at average data. In 1830 all the farms employed the same agricultural production mode. The only reasons why DMI and DMC per capita might have differed between various farms is the size concerning number of people, area, number of cattle and imbalances in the distribution of wealth. It is therefore assumed that the per capita DMI and DMC did not vary in a wide range.

In 2001 the village had comparable high diversity. There are two different agricultural specializations. Some focused on fruit plantations, others on crops. In addition, some farmers became part-time farmers and started working at a nearby factory. In addition, there are families where no one is involved in farming and one or more persons earn their money as employees or freelancers. Finally, a number of persons is retired and receives a pension (see figure 1). This means that both the DMI and DMC have a wide range. The DMI varies between 3,3 and 50,3 tons per capita in 2001; the DMC between 3,3 and 33,2 tons per capita.

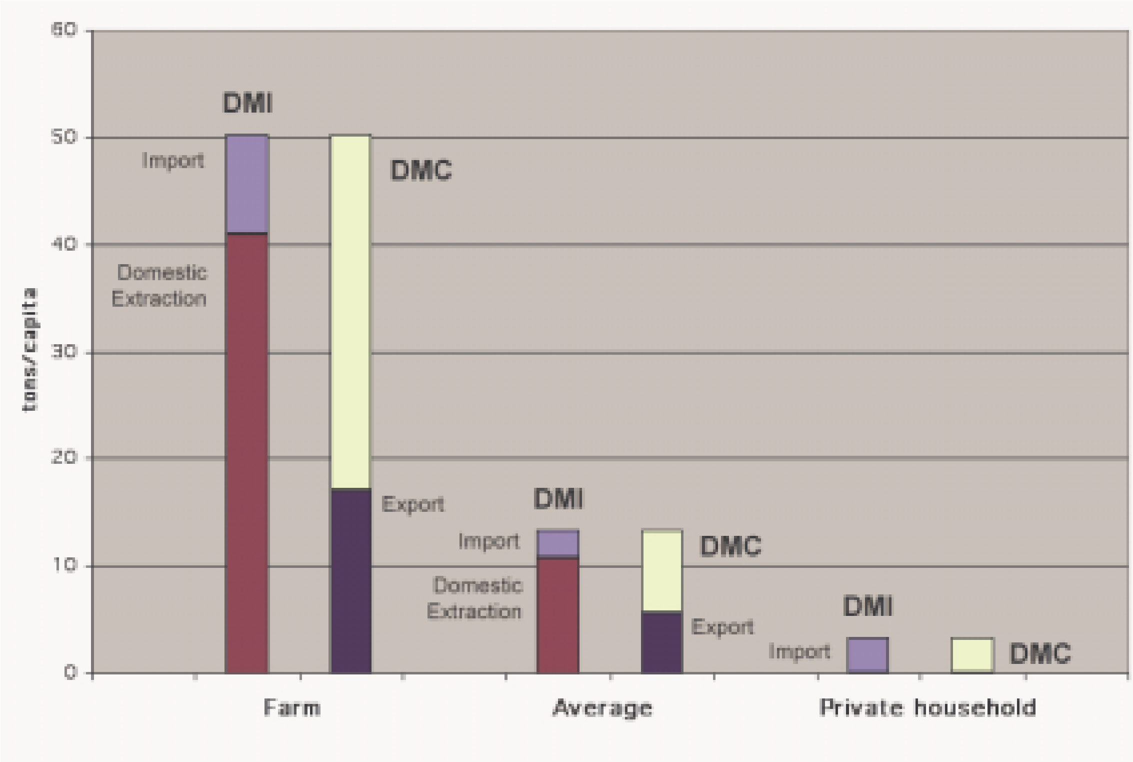


Figure 5: The ranges of DMI and DMC in Theyern 2001

The most striking DMI growth is between an average farm in 1830 (5,7 tons/capita) and one specific farm that was taken to represent today's farming practices in Theyern (50,3 tons/capita), an increase of 780% (see figure 6). This reflects the modernization of the agricultural system: Less people work with assistance of machines, fossil fuels and fertilizers. At the same time they achieve a much higher yield due to optimized crop and optimized growing conditions.

## In Comparison with the Austrian Average

Austria's current DMC is about 18.3 tons per capita and year (Matthews et al., 2000). This is considerably lower than the Direct Material Input (DMI) which amounts to 22.8 6 tons/capita and year. Austria's per-capita DMC is a larger than the average of the EU15 countries of 15.6 tons/capita and year (Weisz et al., 2002). In Austria, construction minerals are the largest fraction of DMC (52%). Biomass accounts for 25%, fossil fuels for 16% and industrial materials (e.g. ores) for 7%.

Measured as metric tons, biomass DMC increased by about 20% from 1960 to 2000, whereas the input of construction materials and fossil fuels increased considerably faster.

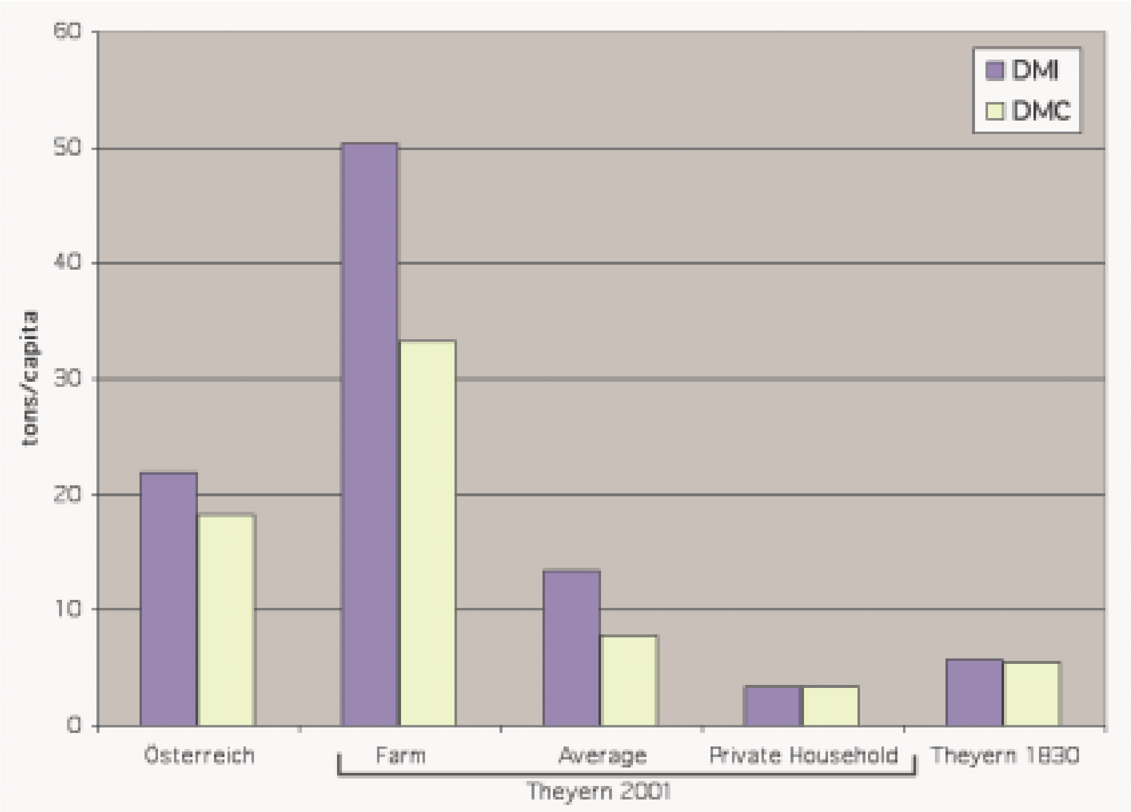



Figure 6: A comparison of DMI / DMC in Theyern 1830 / 2001 with the Austrian average in 1996.

The most significant difference between Theyern and the Austrian average are construction materials. Theyern is a small village and the study investigated only one year. In this period there was no significant construction work going on. If a couple had built one 120 $m^2$ building during the course of one year this would mean approximately additional 150 tons per capita and year for DMI and DMC for each person of the household. For the average DMC per capita in Theyern this would mean an increase by 30%. This aspect of possible spikes at the local level needs to be considered when comparing local data over time or with other local or national data. Figure 6 illustrates as well that changes can be viewed far better in the DMI than in the DMC. While the DMC range among the different sets of data is 18 tons/capita, the DMI varies by 45 tons/capita.

## Conclusions

The DMC and the DMI show the high significance of the agricultural system (see biomass in figure 3). It seems that during the next 10 years the part time farming will disappear. This will reduce both the village’s DMC and DMI. The few farms specialized in fruit farming will then dominate the two indicators. Changes in farming practices can have a huge impact on the village’s environmental performance. This sector should receive more attention.

DMC and DMI show that further attention should be drawn to transport. Theyern’s cars and vans use approximately 40% of the fossil fuels in 2001.

For detailed discussion, the investigation of DMI, Export and DMC reveals better insights than a narrow focus on the DMC.

Considering this broader view, the DMC as indicator to discuss consumption in the light of sustainability seems to offer some substantial advantages. The indicator can be looked at in time series. The DMC of neighboring systems can be added together without double counting.

At the same time the reduction or the increase of a social system's DMC might have a reason that is not necessarily dependent on its environmental performance. In order to discuss this I would like to look at lifecycles of goods and how they might be reflected in a social system's DMC.

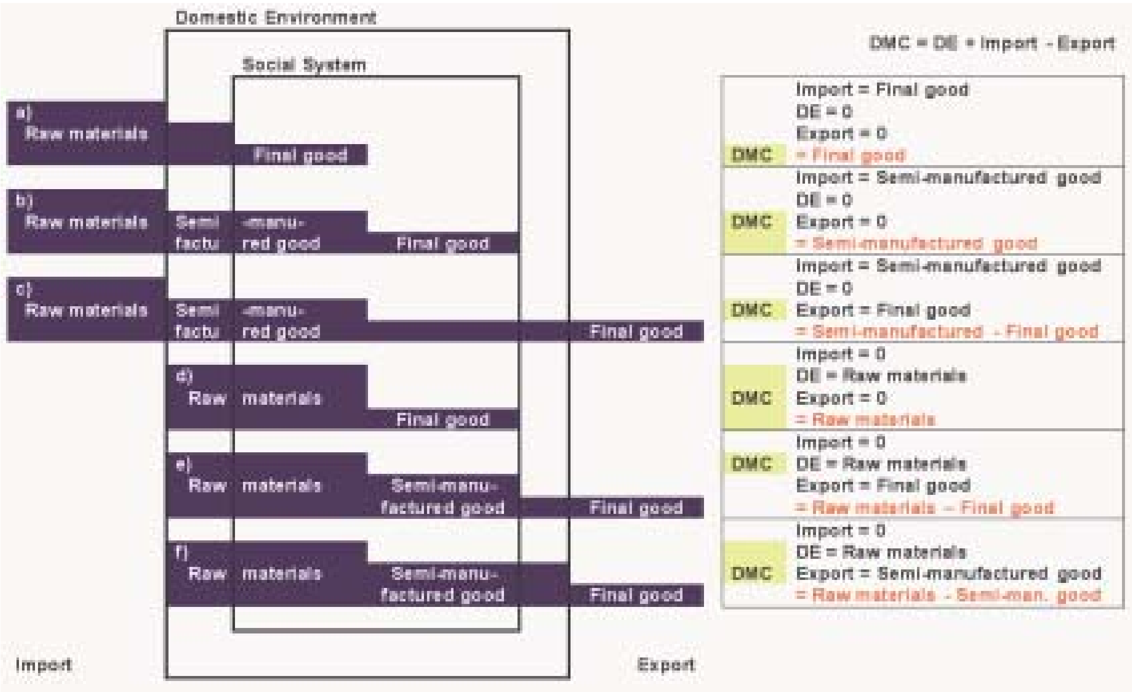



Figure 7: Lifecycles of goods and how they might be reflected in a socials system's DMC

A system that imports final goods only might have a very low DMC compared with a system that uses the same quantity of final goods but which extracts the raw materials within its domestic environment. This case study suggests that it might be possible to brake down the DMC into these categories. This would allow a discussion of both lifecycle data and system based indicators like the DMC at the same time.

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# Promoting sustainable product culture and consumption

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This paper outlines how the National Consumer Research Centre is developing constructive technology assessment as a tool to promote sustainable consumption. First, some of the problems with conventional LCA approaches are identified. Then, the background and context of constructive technology assessment (CTA) is introduced. Some illustrations of how we have used CTA are presented. A summary of our arguments is given in the final discussion.

## Addressing sustainable consumption: the problem with LCA

LCA has become the established way to assess the environmental impacts of consumer products. It provides data on the environmental profiles of product alternatives (e.g. paper vs. cloth shopping bag), and helps to identify at what stage the most relevant impacts occur (e.g., product manufacturing vs. product use). Thus, it provides important information for environmental labelling, product development and the provision of consumer information.

Over the years, a variety of shortcomings in the LCA model have also been identified (e.g., Tukker 1998; Heiskanen 1999; Bengtsson 2002). The final weighting of impacts is a value-laden decision that cannot be modelled objectively. Moreover, LCA is primarily a quantitative method, and has difficulties in integrating data that is not readily quantifiable, such as impacts on biodiversity or social impacts. Furthermore, LCA models do not as a rule consider the social systems surrounding the technological processes studied. Thus, LCA is not sufficient in addressing, e.g., how well toxic chemicals such as chlorine compounds can be managed in closed systems, or the variety of socially-mediated impacts of genetically-modified organisms (GMOs).

Yet the greatest shortcoming of LCA, in our view, is the lack of compatibility between the broad systems picture that LCA paints, on the one hand, and the limited powers of individual decision-makers on the other. It is not so difficult to identify the optimal environmental product system in principle – on the drawing-board – but no one is actually capable of influencing such broad systems. Consumers and businesses have only limited and indirect influence on the entire product life cycle, whereas authorities cannot micro-manage each product life cycle in detail. Thus, many today believe that the variety of actors in the product chain should be more involved in environmental assessments, that co-operation among the actors is needed, and that improvement options should be considered in realistic settings (e.g., Heiskanen 1999; Bengtsson 2002).

### CTA as an alternative approach to sustainable consumption

LCA is one method of, or input to, technology assessment (Böhm and Waltz 1996). Two problems have been identified in conventional technology assessment (TA). One is the technocratic reliance on experts, whereas the issues considered are usually quite political and value-laden. This has led to a variety of approaches that aim to engage different stakeholders in the assessment process, such as the policy-Delphi (Turoff 1975) and consensus conferences (e.g., Joss and Durant 1995; Rask et al. 1999). Another is the lack of input of external stakeholders into the technology *development* process – conventional TA identifies threats and possibilities of existing technological developments, but not, for example, what kind of technologies are needed to address the problems of society (such as sustainable consumption patterns).

Constructive technology assessment (CTA) is a new approach developed in the Netherlands (e.g. Schot 1992). The idea is to incorporate the needs and requirements of society ("the selection environment") into the technology development process ("variation", i.e., the development of new alternatives). One could say that CTA is an attempt to merge technology assessment and technology development, on the one hand, and engage a variety of interest groups in the process, on the other.

Another guiding idea in CTA is that technological change is usually a slow process that requires considerable adaptation at various levels in society. If we want to develop technologies for a sustainable future, we need to start early, and we need to identify the variety of changes that will be required for the technologies to be accepted, and to meet their aims. One example of such an application is the Dutch project on novel protein foods (see Weaver et al. 2000), which aimed at developing factor 20 environmental improvements in the food system. Based on a thoroughgoing environmental, social, and economic analysis, and through the engagement of a broad range of stakeholders, the most promising novel protein technologies and applications were identified, and R&D consortia were set up to continue their development.

### Examples of CTA studies at the National Consumer Research Centre

Much of the early work on sustainable consumption at the National Consumer Research Centre (NCRC) focused on consumers' environmental attitudes and the environmental impacts of consumption patterns. However, we were soon disillusioned with the atomistic and rationalistic view of consumers embodied in standard economic and marketing theory. On the one hand, advances in consumer research have presented a more sophisticated picture of consumption as a cultural phenomenon. On the other hand, historical technology studies have shown how technical systems structure the way we consume, and how changes in consumption are conditioned by broader market and technological developments. Finally, consumers' attitudes to "greener products" or recycling seemed rather trivial in the light of the momentous changes required by environmental sustainability. Thus, we felt a need to explore new approaches to sustainable consumption.

### *Early developments: product chain actors' views on the environmental impacts of consumer products and GMOs*

One of the new approaches adopted was to consider consumers as one group of market actors influencing consumption – and its environmental impacts – together with others. This gave rise to studies with a "product chain" approach. We studied, for example, how different actors (consumers, retailers and manufacturers) in the product chain of four consumer product groups (clothing and textiles, detergents, appliances and paper products) perceived the environmental impacts of these product groups, and how they viewed their own and others' abilities and responsibilities to improve them (Heiskanen et al. 1998). This study later formed part of an in-depth study of how consumers make sense of the environmental attributes of products (Niva and Timonen 2001; Timonen 2002). We also studied how consumers adopted more environmentally sound practices in laundering, using questionnaire data and laundry diaries (Aalto 2002).

Another study focused on how different actors in the product chain perceive the risks, benefits and ethics of gene technology in food production (Jauho and Niva 1999; Niva 2002). It was found, not surprisingly, that consumers tended more frequently to have a negative view of GMOs, while the retailers and manufacturers more usually were positive. Yet there were also very positive consumers, and quite critical business representatives.

Furthermore, the arguments employed by the proponents and opponents of gene technology differed (Jauho and Niva 1999; Niva 2002). While the proponents focused on food security, and the relative safety of genetically modified foods, the opponents focused on the substantially different nature of gene technology from conventional techniques. Their concerns about the risks were related to the unpredictable impact of GMOs on ecosystems, on the one hand, and the ethics of human interference with the foundations of nature, on the other. Interestingly, the risk analogies of proponents and opponents also differed. While proponents compared gene technology to everyday risks (e.g., driving, flying), opponents drew analogies with technological failures (nuclear spills, DDT), and were concerned about the capacity of society to manage the related risks. By revealing the fundamentally different way of reasoning among the proponents and opponents, the study identified a central impediment to reaching a constructive dialogue on the issue.

These studies made progress, in our view, in engaging different stakeholders in environmental and technology assessment, and in identifying different lines of reasoning that lead to divergent views and actions. We felt, however, a need to go one step further and try to engage the stakeholders in finding solutions, as well as problems.

### *Constructive technology assessment of electronic grocery shopping*

In early 2002, the first attempt was made to conduct a full-blown CTA. Electronic grocery shopping was selected because of the public interest in the potential of ICT-based solutions to reduce the environmental impact of consumption. A number of LCA-studies have indicated that electronic trade could be a way to reduce the environmental impacts of grocery shopping, especially by reducing the use of private cars for shopping trips (Freire 1999; Orremo 1999; Punakivi and Holmström 2001).

Yet the studies also indicated that an environmentally efficient system requires a sufficiently large and centralized clientele and well-coordinated drop-off times, so that delivery routes can be planned efficiently. Many other uncertainties make it difficult to assess the true environmental potential of electronic grocery shopping: whether it replaces or merely complements supermarkets, whether it actually reduces private car use, and how it influences consumers' ability to select environmentally benign products, as well as how it impacts consumption levels in general. These uncertainties are due to the early stage of development of electronic grocery shopping. At the same time, this early stage makes it possible – in principle – to integrate environmental improvements into the service development process.

The CTA project was conducted in the following manner. A booklet of background material was compiled, summarizing the findings of LCA studies, alternative electronic grocery systems available, and existing views on future developments, possibilities and problems in electronic grocery shopping. A variety of actors were invited to a workshop on the issue: all in all, 200 invitations were sent out to retailers, technology developers, new businesses in the field, authorities, experts, NGOs and consumers from the NCRC consumer panel. The two-day workshop was organized in May 2002, with 31 participants representing retailing and other related business (11), experts and authorities (9), and NGOs and consumers (11). A large share of the CTA workshop time was devoted to group sessions concentrating on three different issues: efficient deliveries, product information and alternatives to current electronic shopping. On the first day, the groups identified central possibilities, threats and uncertainties in the environmental impact of electronic grocery shopping, whereas the second day focused on developing scenarios for preferable future developments. At the end of both days, the groups convened, presented their findings and had a general discussion.

The workshop led to a number of innovative suggestions for future development. These included, e.g., the combination of a variety of deliveries (food and other shopping, post, medicine and recycling), the development of city logistics (e.g., shared warehousing and logistics for different retailers), alternative ways to access electronic grocery services (in the shops, in collective facilities, using the mobile phone), and alternative ways to improve the competitiveness of local corner shops and local producers through electronic services. For the present, it remains to be seen how these ideas will influence the future development of electronic grocery shopping. At least one retail chain has, however, published a plan to combine local corner shops with electronic ordering of groceries. The study continues this autumn with an interview of key participants (especially business and technology developers) concerning the impact of the workshop on their work and plans.

In the future, the NCRC plans to organise a CTA in the food sector. The project is part of the research centre's research programme "Consumers, trust and the food chain" and it aims to bring the actors in food production, retail and consumption together to critically assess the conditions for trust, trustworthiness and accountability in the food sector. The objective is to advance the dialogue between the actors and to facilitate consumers' viewpoints to be heard and consumers to be involved in forming future food policies.

## Discussion

In our view, much of the existing discussion on sustainable consumption is based on problematic assumptions of rational consumption and rationalistic decision-making. Rationality is always bounded, and all decisions are socially and historically shaped. In order to bring about changes in the prevailing product culture or culture of consumption, the acceptability of new solutions needs to be addressed, as well as the conditions for their adoption. This means looking at how consumers perceive consumption alternatives, how they adopt them in their everyday life, and what lifestyle changes they imply. It also means addressing the system of actors and technologies that are connected to even the simplest consumer product – technological change is usually slow, and requires considerable societal adaptation.

Finally, the unforeseen consequences of technological change need to be addressed (eg. Geels and Smit 2000). Even though, for example, ICT in principle enables the elimination of paper-based communication, the paperless office has not emerged – in contrast, we use more paper than before. Similarly, electronic grocery shopping (if poorly designed) may increase traffic rather than reduce it. Thus, an analysis of broader systems (including social systems) is required. At the same time, we need to target the variety of actors running that system to find where changes can be introduced, where and how changes are acceptable, and who has an interest in initiating them. A CTA approach appears to have the potential to address at least some of these problems. Our further work will continue to explore the potential of this method in promoting sustainable consumption patterns.

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# Pollution embodied in Norway's import and export and its relevance for the environmental profile of households

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## Abstract
The environmental profile of households is commonly assessed by combining consumer expenditure survey data (CES) with environmentally extended input-output analysis. The pollution intensities are calculated only for domestically produced products using information from the national accounts, such as the National Accounting Matrices including Environmental Accounts (NAMEA). Import is either neglected or treated as having the same pollution intensity as domestic production. The question is whether this can lead to serious oversights or distortions in household environmental profiles. This is likely to be the case if a country has a high degree of economic specialization and imports many products it does not produce itself. Both of that is true for Norway. We present an exploratory investigation of the role of imports combining assessments of the Norwegian pollution intensity with that of selected trading partners. Here we present the results for key greenhouse gases.

## Introduction
Norway is an open economy that produces oil, gas, fish, and materials for the world market. It imports a significant fraction of the finished goods used. We investigate the environmental burden associated with the import and export of goods from Norway. The environmental burden embodied in a product, also called the emissions intensity, refers to the emissions and resource use associated with the production and distribution of the product. It accounts for all upstream processes, cradle-to-gate. We compare the emissions intensity of Norwegian industry with that of selected trading partners, China and Japan. We evaluate the importance of trade for the environmental profile of the average Norwegian household accounting for both emissions caused by household activities directly (e.g. fuel combustion) and those embodied in the products consumed. We want to answer two questions:

1. How does the emissions intensity of Norwegian domestic consumption compare to that of Norway's export? Is the profile of domestically consumed goods significantly different from that of exported goods? Is the profile of imported goods different from that of exported and domestically consumed goods?
2. What is the 'environmental trade balance'? How much of the emissions that a typical Norwegian household is responsible for occur abroad?

These questions are highly relevant to a number of public policy issues. Due to its access to clean, inexpensive hydropower and the availability of wood and oil, Norway has a competitive advantage for the production of energy-intensive products. For both economic and environmental reasons, it makes sense to locate for example aluminium refineries in Norway. But to what extent does this specialization impact Norway's ability to meet its obligations under the Kyoto protocol? To what degree should this specialization continue? The second question is relevant with respect to the concerns about the issue 'carbon leakage', i.e. the hypothesis that emissions-intensive industries will relocate to countries not obligated to reduce emissions under the Kyoto protocol. There is also a strong public concern about manufacturing conditions in developing countries with respect to child labor, lack of health and safety standards and lack of enforcement of environmental regulation. The latter issues are not addressed here, because we will focus on a few basic greenhouse gases. We have conducted the same analysis for common air pollutants, SO2, NOx, and ammonia, but to not report the results here.

## Methods and Data

### *The Norwegian National Accounts*

We use data from the Norwegian national economic and environmental accounts (Hass et al. 2002), including a set of supply and use tables, emissions data (Flugsrud et al. 2000), and trade statistics. Our approach follows the general approach for the use of input-output tables for embodied energy and emissions calculations as pioneered by Bullard and Herendeen (Bullard III and Herendeen 1975; Herendeen and Tanaka 1976; Herendeen 1978). More detail and background is provided in a number of papers in this volume, including the contribution of Munksgaard et al. In terms of terminology and symbols, we follow Lenzen (2001). We focus on the year 1997.

For Norway, four different tables are used:

1. The supply table V, 297 suppliers x 1319 products.
2. The use table U, 854 users x 1319 products.
3. The import table M, which follows the structure of the supply table. While the supply table includes import as a single supplier, this table accounts for the sector supplying the goods. These statistics follow a 5-digit sector code and a 6-digit product code, which is part of the NACE classification system. The import table distinguishes between competitive and noncompetitive import.
4. Trade statistics describing the imports and exports by source/destination country. The goods are classified by 2-digit SITC code.

The supply and use tables (SUT) are the heart of the Norwegian national accounts. The accounts include intermediate accounts for the production of investment goods, which are used by dummy investment sectors, which again contribute to gross fixed capital formation (GFCF). GFCF indicates the investments in industry (suppliers). Investment in housing stock is also counted as GFCF, and expenditure for owner-occupied houses and flats is accounted for as self-payment of rent.

Following matrices were calculated from the supply and use tables:

- X The intermediate industry-industry matrix was formed assuming that, for each product, suppliers have constant market shares for all using sectors. This reflects the industry-technology assumption (Strømman and Gauteplass 2002).
- $K_d$ Intermediate inputs (from industry sector) required for GFCF of each industry were calculated through 3 matrix multiplications, also assuming constant market shares. The first multiplication determined the production in the dummy investment sectors (NACE code 28xxx) required for GFCF. The second multiplication determined the market shares of producing industry sectors (23xxx) contributing to the production of the dummy investment sectors. The third multiplications combined those to matrices to link producing industry sectors to GFCF.

Competitive and noncompetitive import were separated into two tables, which have exactly the same format as the supply table. Products are either supplied by competitive or noncompetitive import, never by both. Competitive import can be treated as if it was produced by domestic sectors. For non-competitive imports, it is possible to do this to a limited degree: Some product classes are broad enough to include similar products that are domestically produced (e.g., potatoes and sweet potatoes), while for other products there is no domestic production (e.g., wine, coffee). For noncompetitive imports, we assume domestic production of similar products where such products exist and neglect the products (and their environmental impacts) if no such products exist. We produce following tables:

- CI Specifies the intermediate industry input of competitive imports from supplying industries in foreign countries, assuming the same industrial structure and market share as Norway. This is similar to the assumption of a mirror economy (Strømman and Gauteplass 2002).
- NCI Specifies the intermediate industry input of non-competitive imports from supplying industries in foreign countries, assuming product similarity and the same industrial structure and market share as Norway.
- $K_{ci}$ Competitive imports required for GFCF by supplying sector, assuming the same industrial structure and market share as Norway.
- $K_{nci}$ Non-competitive imports required for GFCF by supplying sector, assuming product similarity and the same industrial structure and market share as Norway.

All tables are specified as monetary flows from supplying to using sectors. In addition, matrix E specifies the air emissions of $CO_2$, $CH_4$, $N_2O$, $SO_2$, $NO_x$, and $NH_4^+$ per million Kroners (MNOK) of industry output. The vector x specifies the total industry output of different sectors. From this, we calculate four different multipliers.

| | |
|---|---|
| $\mathbf{M1} = \mathbf{E}\left(\mathbf{I} - \mathbf{X}\hat{x}^{-1}\right)^{-1}$ | Domestic emissions due to the upstream production processes |
| $\mathbf{M}2 = \mathbf{E}\left(\mathbf{I} - \left(\mathbf{X} + \mathbf{CI} + \mathbf{NCI}\right)\hat{x}^{-1}\right)^{-1}$ | Domestic and foreign emissions due to the upstream production processes |
| $\mathbf{M}3 = \mathbf{E}\left(\mathbf{I} - \left(\mathbf{X} + \mathbf{K_d}\right)\hat{x}^{-1}\right)^{-1}$ | Domestic emissions due to production processes, including capital inputs |
| $\mathbf{M}4 = \mathbf{E}\left(\mathbf{I} - \left(\mathbf{X} + \mathbf{CI} + \mathbf{NCI} + \mathbf{K_d} + \mathbf{K_{ci}} + \mathbf{K_{nci}}\right)\hat{x}^{-1}\right)^{-1}$ | Domestic and foreign emissions due to production processes, including capital inputs |

These calculations are based on the assumption that both emissions factors and production structures of the trading partners are the same as those of Norway. Both of these assumptions do not hold. Therefore, it is important to investigate the emissions intensities of Norway's trading partners.

### Emissions intensities for China and Japan

In comparing emissions intensities of different economies, the problem is that different classification systems are used to define industry sectors. Most European countries use the NACE classification, but trading partners such as China, Japan, or the USA have their own systems. Classifications reflect the industry structure of the time they were developed. There is no 1-to-1 correspondence. For the purpose of comparison, we mapped the more detailed sector classifications onto the 2-digit NACE code (57 sectors). These sectors do not cover exactly the same industries in the different countries; due to this mapping it is likely that a certain fraction of companies would be in one NACE classification in China and in a different one in Norway.

Hubacek and Hertwich (forthcoming) estimate emissions intensities (M1) for China 1997 at a resolution of 120 sectors, based on earlier work (Hubacek and Sun 2001). Nansai et al. (2002) present emissions intensities (M1 and M2) for 1990 and 1995, using four different levels of detail in the sector classifications. For 1995, the numbers of sectors considered are 399, 186, 93 and 32. We mapped the Japanese 186 sector classification onto the 2-digit NACE classification (57 sectors). For a number of Japanese sectors, no Norwegian equivalent was found (from 'gas supply' to 'office supplies' and 'activities not classified elsewhere'). We found matches only for 53 NACE sectors. The M2 multipliers are a weighted average of M2 for the more detailed Japanese classification. A similar procedure was applied to the Chinese and the Norwegian data.

## Results

### *The Norwegian National Accounts*

Figure 1 shows the direct and indirect greenhouse gas emissions intensities for the 157 industry sectors that are part of the industry-industry input output table. For each sector, the direct emissions intensity E and the multipliers M1-M4 are charted. The sectors were sorted by emissions intensity. Fig 1 indicates that the emissions intensity spans a large range. For some sectors, there are no direct emissions, for shipping, the emissions are 0.5 kg/NOK. For energy-intensive sectors, the direct emissions intensity E accounts for a large fraction of the total emissions, whereas for the majority of sectors (sector number <120 in Fig 1), upstream emissions are most important, and the multipliers M are significantly larger than the direct emissions intensity.

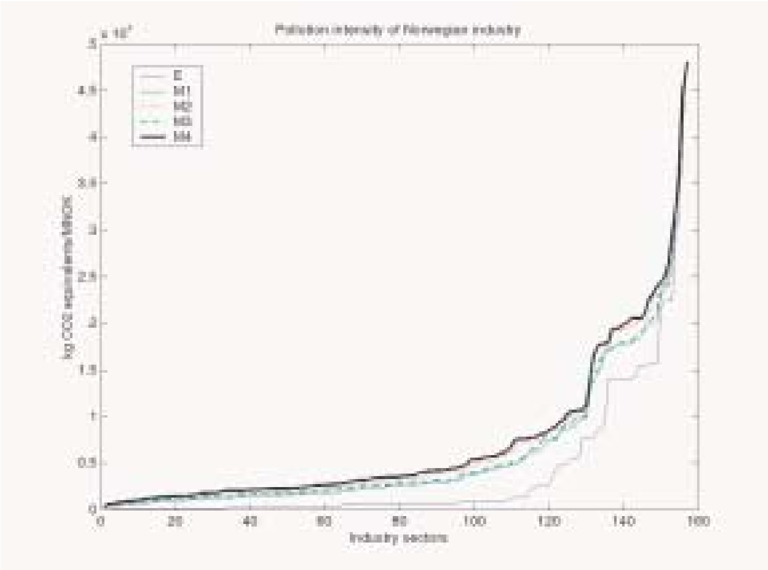


Figure 1: Direct emissions per revenue (E) and indirect emissions intensities (multipliers, M) for greenhouse gases in different industry sectors in Norway.

The difference between the different multipliers is not that large. It is important to take import into account, but if the country of origin is like Norway, the impact of import is never larger than 20%. The calculations indicate that importance of capital investment is not very high (M1 vs M3). This contradicts the findings of Lenzen (2001) for Australia and needs to be investigated further.

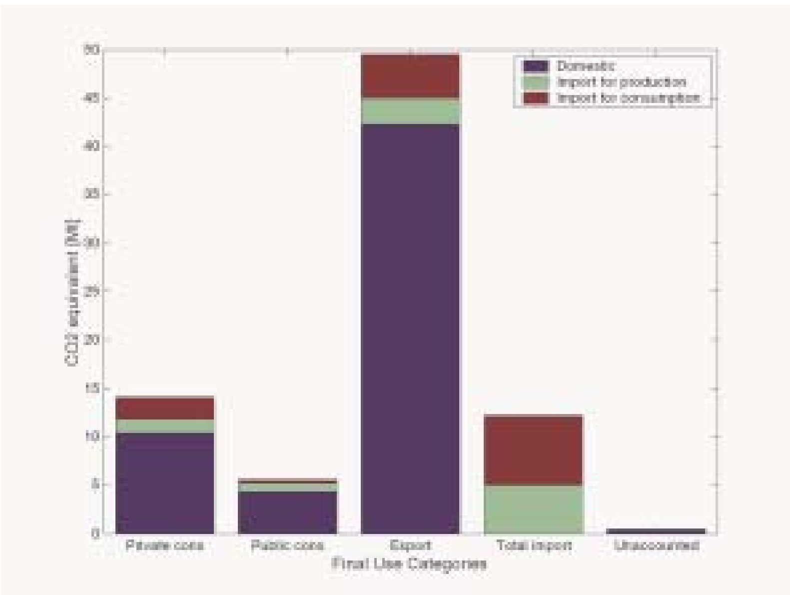


Figure 2: Industry GHG emissions by purpose and origin. (Does not include combustion of fuel by the consumer, i.e. the use phase of products. The total import bar does not note a purpose but merely sums the import from the 3 other bars for the purpose of comparison).

The allocation of Norwegian GHG emissions, and those contained in imported products to final demand indicates that >70% is associated with export (Fig 2). This confirms the findings of Hass et al. (2002). Note that we no longer have a final demand category 'investment', as we use multipliers (M3, M4) that take capital investment into account. The emissions allocated to export are about 3 times as large as the emissions associated with the import of products. The difference is larger than the total emissions allocated to final consumption in Norway. This clearly demonstrates the importance of the issue. If the receiving countries had, on average, 50% higher emissions intensities, the emissions savings through Norwegian export would be as large as the emissions due to final demand in Norway.

Note that in Figure 2, there are products imported for final consumption that are associated with export. This is because we assumed the same market share for imported products as for domestically produced products for all final demand categories. This is probably a bad assumption. The furniture that is imported is probably used in Norway, while a larger share of Norwegian-produced furniture goes to export. If we changed the allocation or got better data, most of the red area of the export bar would probably be shifted to private and public consumption, while the blue area would shift into the opposite direction.

The 'unaccounted' bar indicates the potential importance of those products of non-competitive import for which no pollution intensity was used, e.g. coffee. We simply used the Norwegian average pollution intensity and multiplied it with the value of the products not accounted for in any other way. The unaccounted products are not substantial.

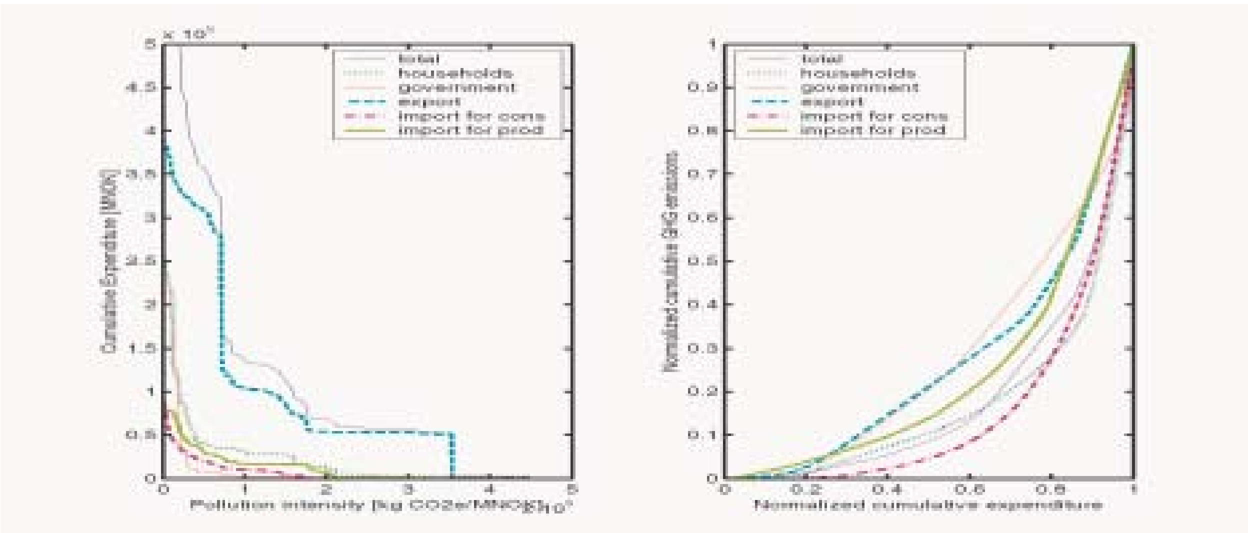


Figure 3: Emissions profiles of different purposes. (a) Cumulative expenditure of total production, household consumption, government (public) consumption, export, and import versus pollution intensity. The area under the curve gives the total emissions. (b) Distribution of the emissions over expenditure.

The emission profile displayed in Fig. 3a was produced from the emissions intensity of products (M3), where the products were again sorted by emissions intensity. Expenditures are accumulated starting with the highest emissions intensity. Fig 3a indicates that most of the emissions-intensive industry output goes to export. Much of that is not in the form of final, but of intermediary products. Again, this graph does not include direct emissions by households. Imports for production are more emissions intensive than those for consumption. Another way of displaying these numbers is to look at cumulative emissions (Fig. 3b) as a function of cumulative expenditure. Fig 3b corresponds to a Lorents curve in economics – a way of displaying income and wealth disparities in an economy. If all emissions intensities were equal, the curve would be just the diagonal. This would be ideal from the perspective of emissions reduction (Sommervoll and Aasness 2001). We can see that export and government consumption is most like this; for different reasons, however. Export is dominated by pollution-intensive products, while government consumption consists almost exclusively of products with low pollution intensity.

A more detailed investigation of household GHG emissions by consumption purpose shows an interesting pattern (Fig. 4). The highest indirect burden is associated with food, as several other studies have indicated. Here, the emissions of methane and nitrous oxide are more important than those of CO2. It also indicates the importance of diet, as the emissions of GHGs per calorie vary significantly.

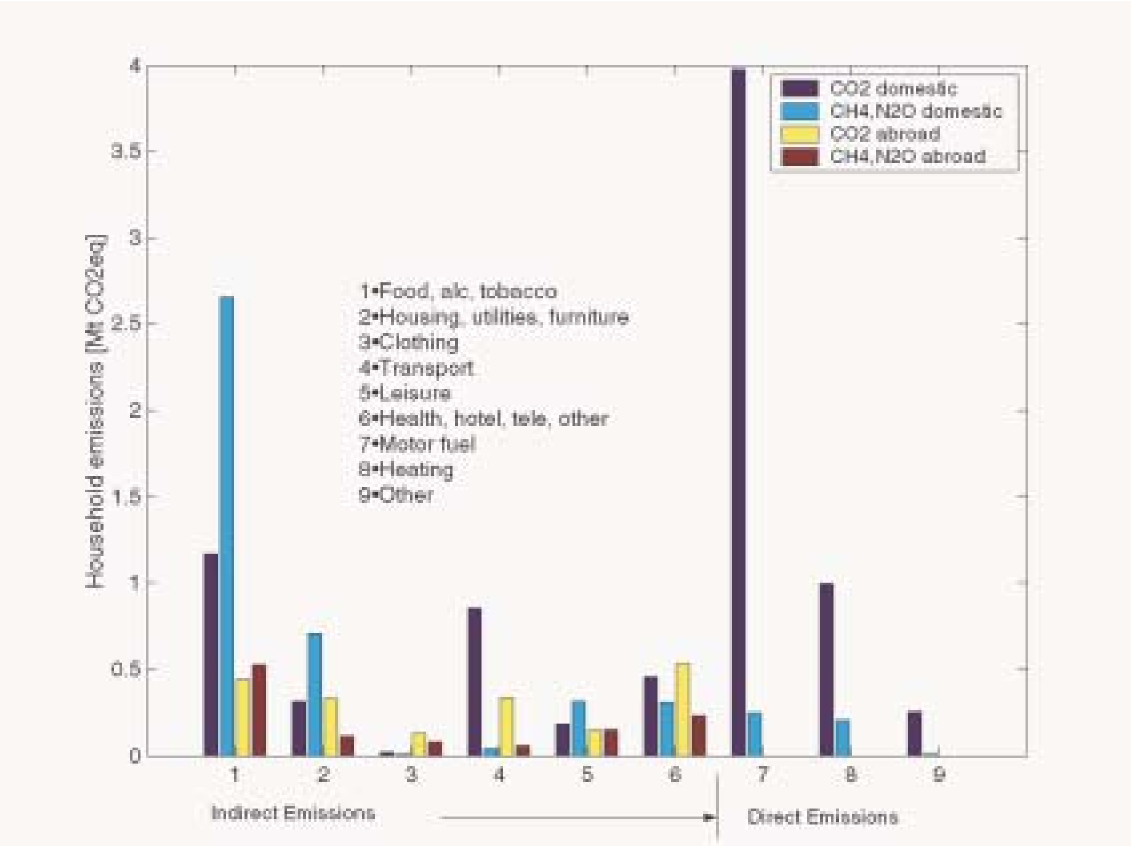


Figure 4: Distribution of GHG emissions by different consumption categories.

Indirect and direct impacts of housing (categories 2 and 8, respectively) are less important than in other countries. This is due to the use of hydropower for heating. The total emissions associated with the use of motor fuels in private cars and motorbikes is about as important as nutrition. The indirect emissions, associated with car manufacture and petroleum refining, but also with the use of airplanes and trains, are significant.

### *Import from China and Japan*

There are several difficulties with taking into account the emissions associated with imported products. For one, exchange rates vary. The trade margins are not known. The assumption here is that products can be compared in basic prices. Trade margins, including transport costs, are not included here, but they are potentially important. The other issue is that product qualities can vary, so that in fact much larger quantities are associated with one million Norwegian Kroners of products imported from China, compared to those produced domestically. If we would compare the satisfaction of household demand, we would compare emissions intensities adjusted by purchasing-power parity, but that is not appropriate for traded commodities, which are per definition exchanged at the market exchange rate.

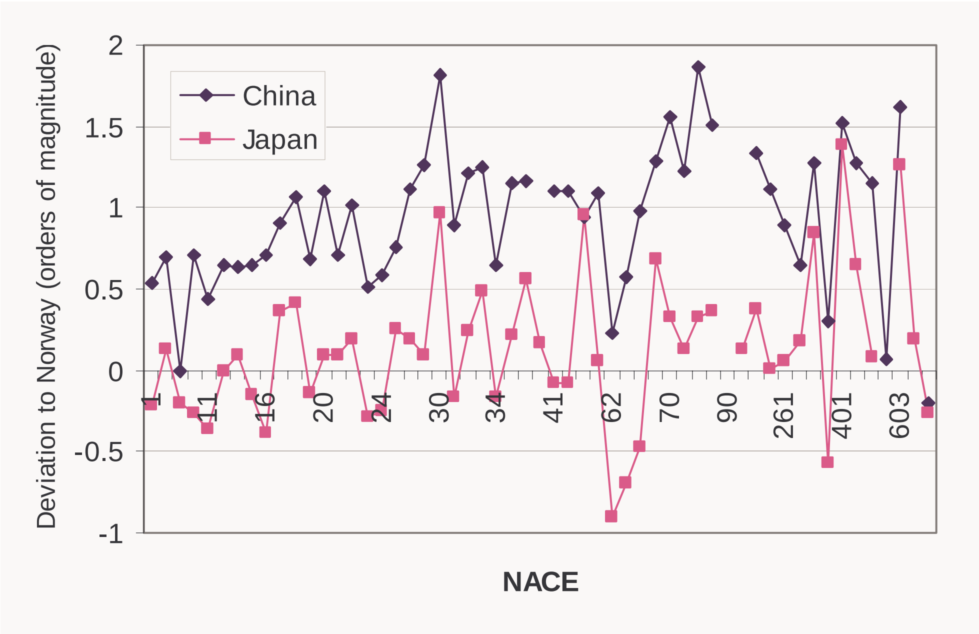


Figure 5: GHG intensity of China and Japan relative to Norway, by industry sector in NACE code.

The results indicate that the emissions intensities of Norway and Japan are similar. On average, the M2 value for Norway was 49 tCO2/MNOK in 1997, that for Japan was 46 tCO2/MNOK in 1995, using 1995 market exchange rates. The values for the individual industry sectors, however, differ up to an order of magnitude, as Fig 5 shows. Fig 5 displays the $\log_{10}$ of the ratio of M2 in Japan (China) to the M2 in Norway. The variation may have several causes. For some sectors, the clean Norwegian electricity from hydropower may lead to low intensities, in other sectors, differences in actual products produced may be to the advantage of Japan, which has a more technologically oriented economy with more final products and a higher value added.

China shows a significantly higher pollution intensity than Norway or Japan, ca. 300 tCO2/MNOK on average. In Fig 5, most industry sectors also show much higher pollution intensities. It should be kept in mind, however, that this refers to the pollution necessary to produce a unit output valued in Norwegian Kroners. The difference may reflect the terms of trade, not just differences in the energy efficiency and economic structure of the two economies.

## Conclusions

We have shown that a significant fraction of the GHG emissions are associated with the production of items for export. The importance of import for household emissions, while not insignificant, looks smaller. This latter conclusion, however, is based on Norwegian emissions intensities. The investigation of emissions intensities of Japan and China show that Norwegian emissions intensities are not representative for those of countries of origin. Some countries, like China, will have significantly higher emissions. Even for countries with practically identical average emissions intensities, the emissions intensities of individual sector outputs/products can be very different. Given the overall importance of exports and imports for an open economy like Norway, our research calls into question the practice of using domestic emission intensities for imported products. While the error may not be larger than 20% when investigating aggregate quantities like a household emissions profile, they are larger for individual components, especially when going down to the product level. This severly impairs our ability to use results based on endogenous imports for identifying opportunities for improvement, either through product shifts or shifts in lifestyles. A better accounting for imports is required. The problem is that Norway trades with almost every country in the world, and no country accounts for more than 4% of foreign trade. A further investigation taking into account more trading partners, as well as differences on the product-level, is warranted.

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# Sustainable consumption: an NGO's dream about data, tools and insights

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## Abstract

For many years, WWF Switzerland has been engaged in sustainable consumption work. This includes the creation of information labels for products and services (FSC, naturemade, goût-mieux etc.), member information on products and behavior and lifestyle assessment.

Research on sustainable consumption should not only allow to ask new and more precise questions but also to support GO's (like UNEP) and NGO's in their dissemination work. What type of data, tools, and insights does a group of consumption and lifestyle campaigners dream about if they would have unlimited resources? This paper summarizes an attempt to get first answers to these questions that help to understand better the demand side of research and may prove helpful in directing transdisciplinary research.

## 1. Background on WWF and past activities

The World Wide Fund for Nature (WWF) has a long tradition of promoting direct protection of national and global fauna and flora. However, WWF Switzerland also informs consumers on indirect effects of their (purchasing) behavior on the depletion of natural resources and quality of life.

In the area of "consumption and lifestyles" – this is one branch's name – members of WWF are informed on the consequences of consumer decisions. This is done by four major ways:

1. information published in the WWF magazines and guide books
2. lifestyle tests
3. development and promotion of product labels, and
4. careful selection of products that are sold in WWF's Panda shop.

ad 1) This includes the whole spectra from information on nutrition, housing, appliances (www.topten.ch ), mobility, flowers, paper, electricity, textiles but also green investments (see www.wwf.ch -> Konsum).

ad 2) Since 1992 lifestyle tests have been provided to members to allow them to check with which behavior they cause major environmental impacts. Initial versions focused on energy use and $CO_2$-emissions. Then, a version included also potential savings in monetary terms. The most recent version uses the ecological footprint method (see www.footprint.ch/).

ad 3) WWF has been instrumental in developing and supporting initiatives to establish product labels that fulfill high environmental standards and can become a market force. Usually, this is done together with industry and/or other interested parties. Examples include the FSC label for sustainable wood products (www.wwfwoodgroup.ch/html/), the label Naturemade Star for least polluting and renewable electricity (www.naturemade.ch ), the label Natureplus for environmentally preferable building products (www.natureplus.org) and as an extension of product labels most recently a label for restaurants that provide a selection of organic dishes and fulfil other environmental criteria (www.goutmieux.ch).

ad 4) The WWF-owned Panda shop is not just a fund raiser but also pays attention to ecological and social criteria, prefers labeled products, aims at highest quality and was in the past successful in stimulating producers to design new products (www.pandashop.ch/).

From this list of activities, available information, and tools it becomes obvious that for WWF Switzerland the trendy term “sustainable consumption” is not just a label for consumer-oriented research but daily practice. This means that the research community may look at this available data, insights and tools and choose to further develop their foundation, richness and robustness. However, it also means that the present state of practice has been driven by the available data and tools known to the NGO. It also means that those people that have been running the consumption and lifestyle campaign (among others those co-authoring this paper) are not starting from scratch. Their dreams and thinking is heavily biased by what they have been doing in the past and this should be considered when judging this paper's contributions.

## 2. Method

This paper is based on an unstructured brainstorming session with the three co-authors as major sources of input and the main author as rapporteur and compiler of the mentioned points in this paper. After the face to face session, two of the co-authors provided also a written input on issues connected to extreme changes in consumption patterns (see Section 3.2a).

## 3. Results

During the session the contributions and discussion circled around two main areas where more research, better data and tools would be very helpful for WWF:

- Assessment dimensions and indicators
- Relevance of changes in consumption patterns

These two major areas will be discussed in the subsections below.

Further discussion has emerged around the terms ‘lifestyle’ and ‘lifestyle changes’. Nobody thought that they are able in their work to actually change lifestyles and little interest to do so was expressed. It was agreed that one can and should repeat the potential of alternative lifestyles but that the major potential for transitions is seen on the level of (small) changes in consumption for specified groups of goods. When the discussion turned to mobility it was also mentioned that political measures may be more useful than voluntary consumption changes. However, it was also mentioned that much has to do with the positive image of traveling abroad. As long as traveling to Cuba, Maldives, or Vietnam is rewarded by social prestige while walking the nearby forests or climbing the rocks that are just a bicycle ride away is considered boring, it will be hard to achieve major changes in mobility. One co-author mentioned that he believes in factor 4, which means that he believes in measures to increase the efficiency rather in appeals for a sufficiency society. This viewpoint was certainly supported by his experience in consumption campaigning. However, this could also indicate that neither insights nor tools are available that support lifestyle changes. Better understanding under which circumstances[3] individuals are willing to *change their lifestyles* may well be considered an area of research that might bring this topic back onto the agenda of WWF.

The main author confronted the co-authors with the notion that if the limitations of consumption factors such as disposable income, time and space are changed this may cause relevant changes in consumption patterns and lifestyles. *Rebound effects* that are caused through changes in limited factors may either support sustainable consumption or stimulate additional unsustainable consumption. Although it was acknowledged that such indirect and induced effects may result as a consequence of some of their campaigns, they thought that considering such effects goes beyond their ability to communicate, that things get even more complex, and this indirectly raised issues, including that economic growth is beyond the scope of this branch. These reactions may again hide the need for research that clarifies the mode of action, size, and relevance of these aspects and helps to break it down into communication pieces. It may even be that in future such rebound effects are considered automatically when environmental impacts of products are assessed and that only rebound-adjusted results are used in campaigns. The suspicion that these topics cover research potential was confirmed by a former branch chief in a separate interview.

These two examples of lifestyle changes and rebound effects reveal the shortcomings of the chosen method. Brainstorming with consumption campaigners in the middle of a busy day in an office of WWF does not allow for expressing dreams that go far beyond current knowledge and foci. Further, facilitating and summarizing such a brainstorming by an involved researcher in the field allows him to interpret lacking interest as either low priority for NGOs or a high research need in order to allow it to become a high priority. Future assessments of user needs for sustainable consumption research should take this into account through more careful selection of individuals, brainstorming places and make sure that enough time for dreams is available. Here we "solve" this dilemma by the opportunity for the co-authors to correct the bias of the author.

## 3.1 Assessment dimensions and indicators

### *The three pillars*

It was well understood that sustainable consumption covers the three pillars of sustainability: society, environment and economy. So far, WWF focused on the environmental consequences of consumption. Of course, the Panda shop does consider fair trade aspects. It was also mentioned that it would be great to have more information on ethical aspects and working conditions along the supply chain of imported goods.

[3] „Circumstances" may include economic or social incentives, moments in time, e.g., puberty, start of working life, start of family life etc., or provision of information and infrastructure.

However, no clear concept is available of which social impacts need to be considered, for which consumption items they may be most important or how they would be traded off with environmental impacts. Although WWF focuses on environmental impacts, it seems that available insights and data on social consequences of consumption that can be related to single products may be a research gap and deserve further study.

The economic dimension was so far considered in terms of product costs and sometimes in supporting small or new businesses. However, at WWF the economic dimension is even less developed than the social dimension.

*Indicators for the environmental dimension*

Much of the discussion concerned the question on what indicators should be used to assess the environmental preferability of product alternatives. It was clear that those indicators should be quantitative and not just follow a gut feeling on good or bad. Although LCAs have been used and even commissioned by this WWF branch, the branch has a limited overview on the different available impact assessment methods.

One co-author mentioned that the overarching goal of WWF is to protect the biodiversity. Therefore, biodiversity should be the top goal. (Tropical) Forests, water use and climate are three important focus areas of WWF International and Switzerland. This suggests that these could become sub goals and that indicators for these three impact areas may operationalize the top goal biodiversity.

From their experience they know that very often trade-offs are needed in order to come up with recommendations for certain products. Therefore, highly aggregating methods have been useful in the past. However, they have also very high aspirations on the validity, transparency, and “perceivability of indicators” of the methods. Ideally, a method allows both, a clear ranking of alternatives or even quantification of differences in effects between alternatives but also transparency on the major cause-effect relationships. Ideally they would not just communicate that washing detergent A causes 20 points less environmental damage than B but that the total shift from A to B would cause an increase in trout population of *x*%, avoid the eutrophication of *y* lakes and increase the use of unsustainable harvested palm oil by *z* tons.

After having commissioned the lifestyle test that works with the ecological footprint as assessment indicator (www.footprint.ch), they mentioned that they would not do so again. Although the ecological footprint’s strength is its visual presentation and ease of understanding, the footprint does not link to the major WWF goals and except for experts it is very hard to understand the results.

LCA and its impact assessment methods are seen as focusing too much on energy related impacts and not adequately dealing with the mentioned WWF goals water, forests and biodiversity. Further, they often fail to address the dimensions landscape and soil quality that are, e.g., relevant in relation to food production.

## 3.2 Relevance of changes in consumption patterns

Much emphasis has been put on the need for data and tools that allow to “play” with different consumption patterns. Three different “wishes” were aired:

a) Large and extreme changes: What happens if the share of organic food increases from 10% to 80%? Or, if all new houses and all renovated apartments fulfill the requirements of the Minergie-Standard[4], what does this mean in terms of savings in energy by 2010? If a consumer makes consistently environmentally preferable choices: how much does this reduce her total environmental load compared to the average consumer?

b) Detailed product comparison tool: Does it matter whether I choose wooden floors from massive wood or rather a laminate product? Do carpets from sheep wool differ from other wool carpets and how do wool carpets compare to synthetic carpets? What is the environmental difference between specially conserved organic milk and fresh conventional milk?

c) Consumer support tool: This tool comes close to what available lifestyle tests have tried in the past. It should provide consumers within a short time with insights regarding their consumption patterns and some simple rules of thumb. They should be able to remember these when selecting goods in front of the shelf.

Some more details shall help to better understand the characteristics of these three needs.

### *a) Large and extreme changes*

The idea of looking into large changes is to get an idea whether such changes would help to achieve relevant goals in future or not. This is important for an NGO to concentrate its limited resources to the big issues. Further, some consumers can only be motivated to follow certain advice if they can expect macro changes, i.e., if half of the population would reduce the meat consumption to one third then we could retire so many hectares of land (or reduce import), improve surface water quality by this and that amount or completely switch to organic farming.

Since consumption comes often in patterns, it was suggested to “design” a list of extreme consumers, such as:

**Organic-regional vegetarian:** Such an archetype consumes just regionally produced[5] and organic food that has been grown during its best season.

**Organic food with little meat:** The type of organic food reflects the averages observed by the big retailers in terms of origin and season.

**Regional fan:** Only regional produce is bought. However, the share of organic food reflects the grand average.

**Budget consumer:** This archetype is very keen to choose the cheapest products. One big Swiss grocery created a special Budget product line for this consumer group.

**Exotic lover:** Such consumers want to meet the global village on their dining table. If there are alternatives to national products they choose foreign produce.

**Convenience and high meat diet:** Such persons choose more than average amounts of meat (and usually the better parts) and prefer convenience food, i.e., pre-conditioned

4 This is a Swiss energy standard that limits the use of heating energy per m2 as a function of the used heating systems.

5 Regionally produced means in Switzerland mostly a distance from less than 300 km from the place of consumption.

and sometimes pre-cooked food that also needs a cooling chain for the high share of frozen food.

For the activity field ‘housing’ one could imagine an extremist who:

- lives in an apartment with a heating demand of only 15 kWh per $m^2a$

- uses less than 17 kWh/m2a electricity that is 100% from renewable sources

- occupies less than an attributable share of $30m^2$ heated living space

- uses less than 80 liter water per day

- produces less than 110 kg of household garbage per year

- buys furniture and lives in a house where only FSC-labeled wood was used

- prefers linoleum, cork, natural caoutchouc or ceramic tiles for floor coverings

- paint and glue are labeled eco-products

- products with the label ‘natureplus’, where available, or comparable labels are preferred

- products from the second hand market are preferred

Such an archetypical consumer could then be compared to the average consumer.

So far, researchers in consumption patterns relied on consumption data provided by the statistical offices. Very often, the available categories are not distinct enough for our purposes or it is not possible to know whether somebody who eats much carrots is also a fish lover or not. Big retailers have started some years ago to offer customer cards that are used each time the holder purchases something from the retailer. Consumers get a certain benefit dependent from the total yearly amount they spend. In return, the retailers gain insights in purchasing patterns that are used to rearrange shops more practically and to advertise more focused. However, this data provides also a maximum information on consumption patterns. The products are identified by 100% and usually a card is used by not more than one household (one retailer distributed close to 2 million cards in Switzerland, which has little more than 3 million households). Since these retailers are also strong in non-food items, furniture, gasoline stations, travel agencies, insurances, banks etc., the coverage is really broad. If one could access this data collection then consumer styles could be generated based on the actual consumption patterns found.

### *b) Product comparison tool*

As indicated above, such a tool would allow to analyze and compare existing products (and services). The tool would require considerable input information and skills in interpreting the results. It would probably come close to commercial LCA software with the added value of a huge database that allows to analyze and compare – say – the 1’000 most important products. In a NGO's daily business such a tool would be used to answer specific questions from members, to produce information that can be used in the articles for the magazines, to support the development of labeling criteria, and to come up with rules of thumb (see c).

*c) Consumer support tool*

The early versions of lifestyle tests using $CO_2$-emissions or energy use as indicators or the most recent version using ecological footprint as indicator are seen as good starts. As mentioned in Section 3.1, the assessment indicators need further work to make them even more comprehensible for the consumers. Next to this, the tools should be further improved by being detailed enough to really capture the major consumption choices made by consumers but also by communicating the major screening parameters. It was found that it is not useful, e.g., to differentiate between retailer M *versus* C or to differente between two different species of tomatoes if the environmental differences are affected by other parameters.

In this context it was mentioned that the work of Niels Jungbluth[6] used a very good level of simplification where organic/conventional, regional/imported (with different distances and modes of transport) and seasonal/frozen, etc. were used to characterize the consumption alternatives. The idea is to educate consumers to look at a small set of criteria when making purchasing decisions.

Realizing that many WWF members belong to a societal group that is well off it is recognized that such a tool should also include financial services (well, it should actually cover all environmentally relevant choices that individuals make). For this purpose, it may be useful to quantitatively assess the different green investment plans that are offered from financial institutions. These analyses should not just focus on performance and investment criteria but also on effectiveness in shifting funds to sustainable activities.

For both tools in (b) and (c) researchers may combine input-output analysis and process analysis. Therefore, researchers may ask what should be the reference unit, 1 kg of bread or 1 Euro of bread? The co-authors opt clearly for physical units because this is the way consumers think. Further, it was also realized that such a tool needs to be designed specifically for Switzerland or even for the different language regions of Switzerland. All-European versions would be of little help because consumers would realize that certain aspects or products do not apply for them and therefore the whole tool may not be useful for them.

## 4. Concluding remarks

This paper is a first attempt to understand better the user needs for research in sustainable consumption. The chosen method and setting was probably not well suited to elicit visionary thoughts and needs and the presentation and interpretation of the mentioned topics may be biased by the professional bias of the facilitator and main author. However, the paper confirms the usefulness of some directions that have already been taken by the research community and gives further advice to direct such endeavors.

Further work in assessment dimensions (to also better capture the social dimensions) and environmental indicators (to produce images that stick with the users) may clearly profit from working closer together with potential users.

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[6] See http://www.ulme.ethz.ch/index.html?/ulme_start.htm and a more recent version from R. Hanselmann and O. Tietje that on http://andros.ethz.ch/exp/simulme.asp.

The three different types of tools that allow a) to show the consequences of macro changes and the potential of extreme consumption patterns, b) to support activists in their daily work on a semi-technical level and c) comprehensible consumer support tools that are focusing on major drivers for environmental pollution but are comprehensive enough to allow individuals to set priorities themselves.

Finally, lacking confidence in the possibility to change lifestyles and account for rebound effects may be interpreted as a need for research that may provide insights and tools to make these two areas accessible for consumption campaigns.

# A Proposal of the Quantitative Evaluation Method for Social Acceptability of Products and Services

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## Abstract

Sustainable consumption is one of the key concepts to establish the sustainable economy. An index representing the willingness by customers/consumers to use ecoefficient industrial products or services can be the ratio of the social acceptability of the products and services to their environmental loads[1]. While the environmental loads could be calculated following LCA methods, it has been thought that the quantitative evaluation of the social acceptability of the products and services are difficult since acceptability is subjective, and individual preferences show significant diversities.

The aim of this study is to propose a new method to evaluate the social acceptability quantitatively. We are now qualitatively extracting the elemental requirements of the customers/consumers, which might be universal regardless of the products and services, and the secondary requirements under the elemental requirements, which depend on the products and services chosen by consumers/customers. If we could weight quantitatively the elemental requirements or the secondary requirement by interview using questionnaire, the social acceptability of the products and services can be evaluated quantitatively using the format proposed here. The format is an application of "Quality Function Deployment" [2], which is commonly used in the field of the design for the industrial products.

## Introduction

Social acceptability of the products has been studied in the field of the marketing research, where a product are hardly sold to all consumers but usually sold to the specific target groups of consumers who have similar characteristics. To distinguish the target group, consumers were classified into a few clusters or groups by certain attributes such as demographic attributes like age and sex, social and economical attributes like occupation and income, geographical attributes, psychological attributes including life style, and behavioral attributes like frequency of purchasing certain kinds of products and brands

These experiences suggest us that consumers belonging to the same cluster have similar attitude in purchasing products. Their elementary requirements to a certain product are universal in the same cluster. If we could extract their elementary requirements and quantify them, it might be possible to evaluate social acceptability of a certain product quantitatively in the same cluster. However it is thought that the elementary requirements of one product differ significantly from those of another. The elementary requirements might be dependent on the the consumer's intensions.

The aim of this study is to propose a new method to evaluate social acceptability quantitatively. For the first step of the study, we are now extracting the elementary requirements of consumers on a few of their activities by Internet-survey, where we are extracting the secondary requirements simultaneously that are specific for each activity. It is expected that the elementary requirements are universal independently on the activities, even if their weights on each activity are significantly different. The secondary requirements must be used in order to weight the elementary requirements considering their correlation, and should be used in order to evaluate the social acceptability of each product quantitatively.

## Extracting the Preferences of Consumers

Consumers use products and take services as a means of achieving a certain purpose. Consumers choose the most appropriate products and services. For example, commuters utilize products and services, such as cars, trains, and other public transportation systems, for the purpose to go to their office or school. They choose the option that brings them greatest benefits besides the main purpose, such as “low cost,” “comfort,” and “punctuality”, which could be defined as the secondary requirements spesific to the activity or here for “commuting”, and could be related to the elementary requirement.

In order to know consumers' preferences for achieving specific purposes, an Internet survey on three typical daily activities “commuting,” “having dinner on weekends,” and “doing laundry” was conducted by asking open-ended questions. Out of 600 questionnaires that were sent to the people aged 20-59 on the panel of a survey company, 242 were returned, and then 45 to 50 words were extracted on each behavior by combining similar words and omitting the words that have little or no relationship to the study. After that, they were integrated into more general nine words with Laddering Theory[3]□[5], which present the elementary requirements, “economy,” “health,” “convenience,” “comfortableness,” “harmonization with the nature,” “interpersonal relationships,” “unusualness,” “time,” and reliability.” (Figs.1 to 3)

In this survey, we found that  the primary requirements (or preferences) for the three activities could be integrated into these nine elementary requirements. However it was though that the weights of priorities of these nine elementary requirements were different on each behavior. This is shown in Table 1.

Table 1: Elementary Requirements for the behaviors

| | Commuting | Having Dinner on Weekends | Doing Laundry |
|---|---|---|---|
| Economy | ○ | ○ | ○ |
| Time | ○ | ○ | ○ |
| Convenience | ○ | ○ | ○ |
| Comfort | ○ | ○ | ○ |
| Unusualness | ○ | ○ | ○ |
| Health | ○ | ○ | ○ |
| Harmonization with the Nature | ○ | ○ | ○ |
| Interpersonal Communication | ○ | ○ | |
| Reliability | ○ | ○ | ○ |

## Future Work

As mentioned above, the aim of this study is to propose a new method to evaluate social acceptability quantitatively. If the priority of the elementary requirements or the secondary requirements of consumers has been determined, it is possible to introduce the approach of the quality expansion table of QFD (Quality Function Deployment), shown in Table 2.

Where, the elementary requirement's importance level is expressed

$\{A_i \mid i = 1 \cdots\cdot I\}$

The secondary requirement's importance level is

$\{B_j \mid j = 1 \cdots\cdots J\}$

The relevance levels between the elementary requirement and secondary requirement is

$\{X_{i,j} \mid i = 1 \cdots\cdots I, \; j = 1 \cdots\cdots J\}$

it would be expressed as follow,

$$A_i = \sum_{j=1}^{j} X_{ij} \qquad B_j = \sum_{i=1}^{i} X_{ij}$$

Then, the social acceptability of the product could be evaluated by the summation of the acceptability values of the product on each secondary requirement. This was obtained by multiplying the secondary requirement's importance level by the characteristic of the product on each secondary requirement measured physically or from engineering viewpoints. This is displayed in Table 2.

Table2: Quality Expansion Table for “Commuting”

| | | Elementary Requiremant Importance Revel | Secondary Requirement: economical | always available | no restraint of weather | no need to walk | can carry things | no need for transfer | can shop on the way | can read books | not crowded | free time | own space | can drive a car | good excise | less air pollution | can chat with friends | no traffic jam | no need to wait | no need to find parking space | less dangerous |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elementary Requirement | Economy | 1 | 1 | | | | | | | | | | | | | | | | | | |
| | Time | 7 | | 1 | 1 | | | | 1 | 1 | | | | | | | | 1 | 1 | 1 | |
| | Convenience | 5 | | | | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | |
| | Comfort | 5 | | | | | | | | | 1 | 1 | 1 | 1 | 1 | | | | | | |
| | Unusualness | 0 | | | | | | | | | | | | | | | | | | | |
| | Health | 1 | | | | | | | | | | | | | 1 | | | | | | |
| | Harmonization with the Nature | 1 | | | | | | | | | | | | | | 1 | | | | | |
| | Interpersonal Communication | 1 | | | | | | | | | | | | | | | 1 | | | | |
| | Reliability | 4 | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 |
| Elementary Requirement Importance Revel | | | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 1 |
| Means | Bus | | 1 | | 1 | | | | | 1 | | | | | | | 1 | | | 1 | 1 |
| | Taxi | | | | 1 | | 1 | 1 | | 1 | 1 | 1 | 1 | | | | | | | 1 | 1 |
| | Owner Car | | | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | | | | | 1 | | |

When the characteristic of the mean on each secondary requirement is expressed

$$\{C_{kj} \mid j = 1\cdots\cdots J, \quad k = 1\cdots\cdots k\}$$

Acceptability values ($V_k$) of the mean would be expressed as follow

$$V_k = \sum_{j=1}^{j} B_j C_{kj}$$

We are now planning the next survey in which we would try to prioritize the elementary requirement or the secondary requirements. Practically, it might be easy to prioritize the secondary requirement, which were specific for each activity. The results of prioritization of the secondary requirements would lead to the prioritization of the elementary requirements. We could compare the priority of the elementary requirements of a certain activity with others. If they would be universal, the format that we proposed here could be utilized for all products and services regardless the differences among the activities. If not so, this format would be useful to evaluate social acceptability of each product.

## Conclusions

In this paper, we proposed a new method to evaluate social acceptability quantitatively. It is an application of QFD method using the experiences of marketing research. The usefulness of this format should be further evaluated.

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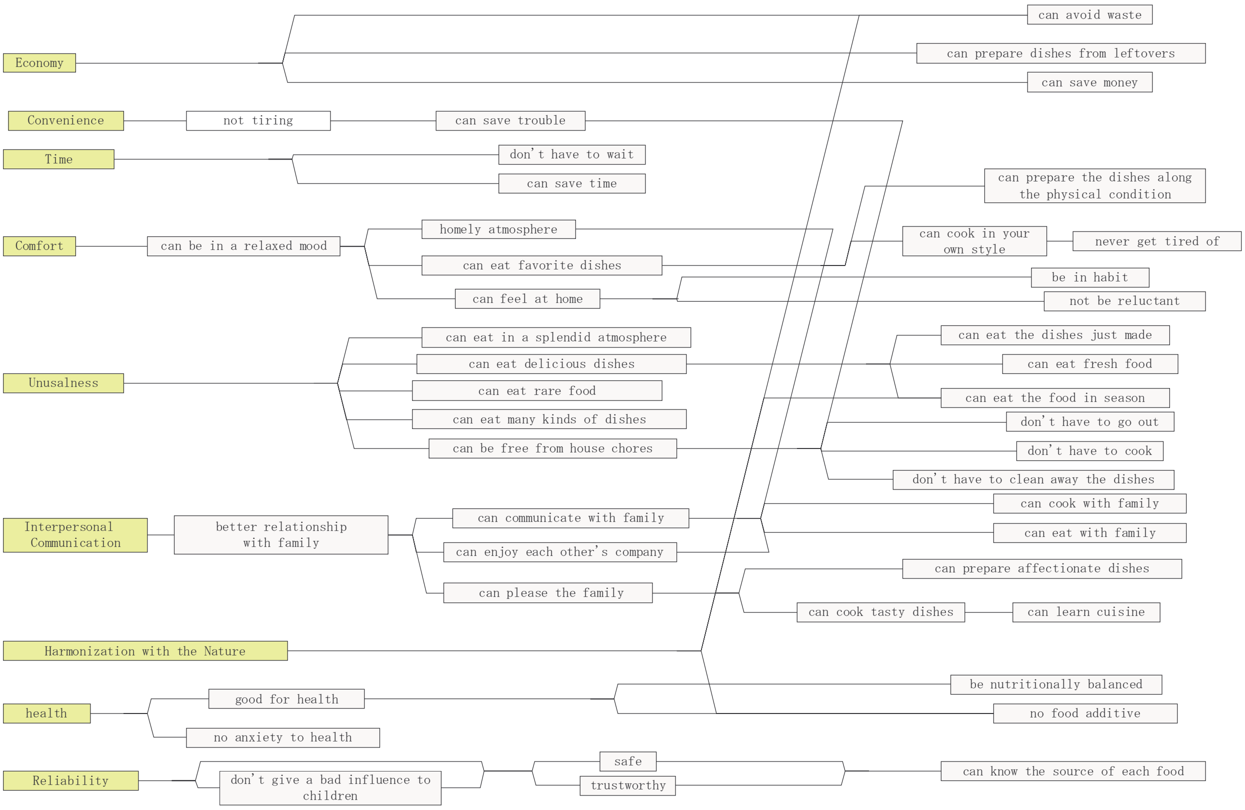
Figure 1: Require Quality Map Expressing “Having Dinner on weekends”



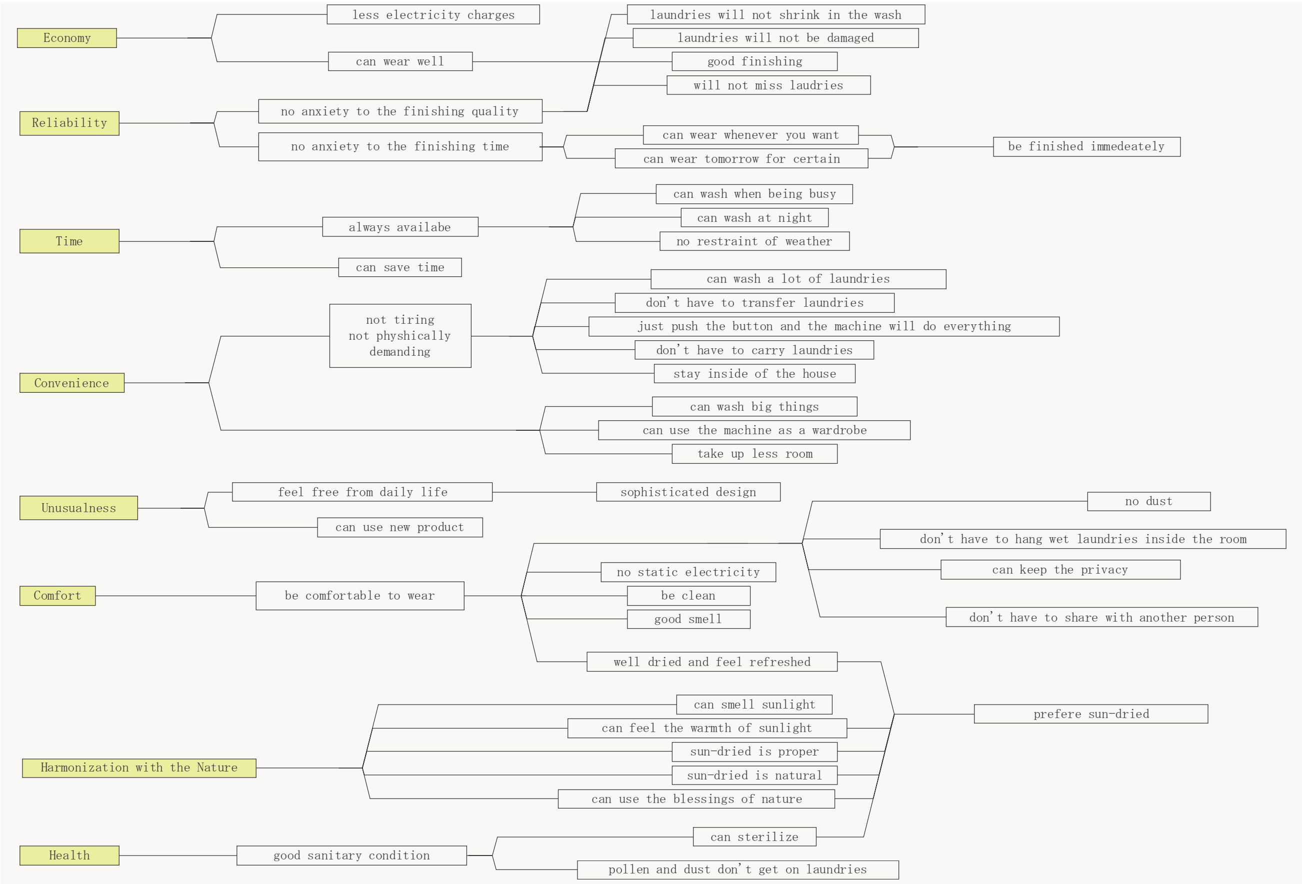



Figure 2: Require Quality Map Expressing "Doing Laundry"

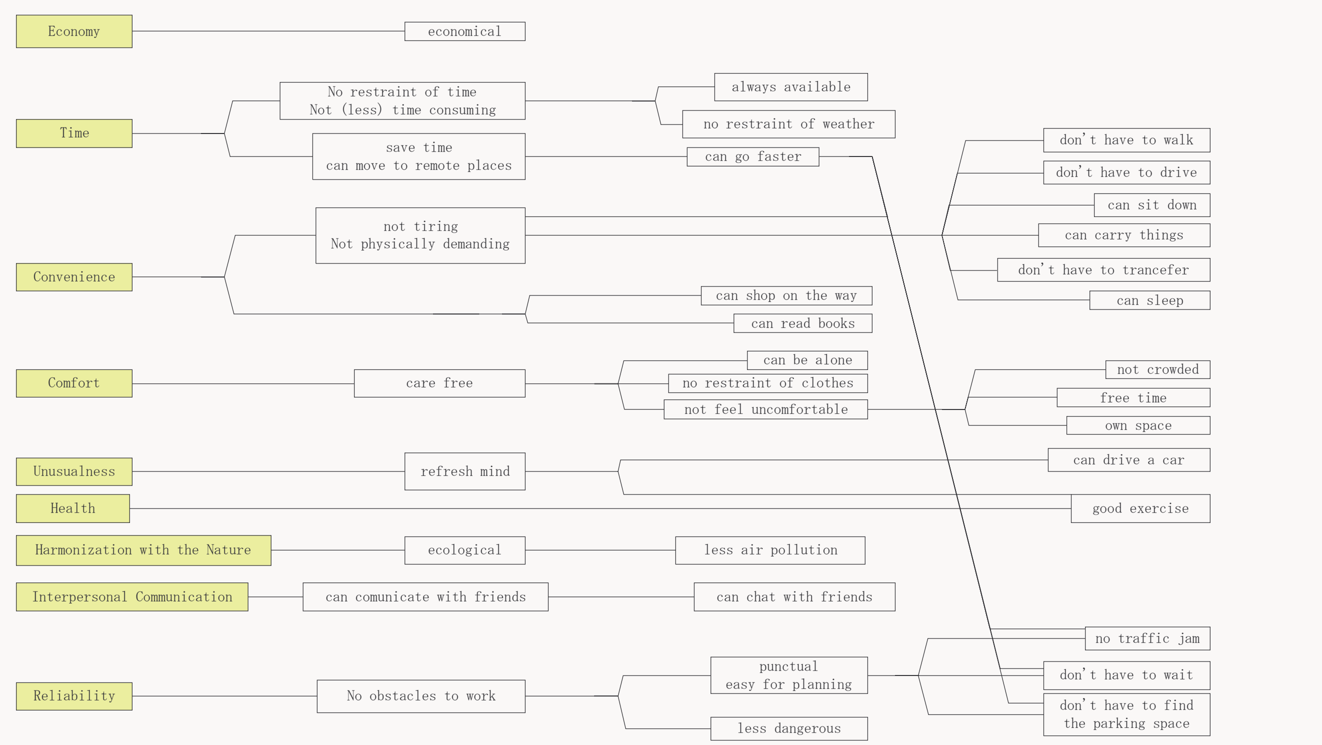



Figure 3: Require Quality Map Expressing "Commuting"

# Changes in China's economy and society and its effects on water use

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## Abstract

China's development over the last few decades can be characterized by high rates of economic growth, migration from rural areas to the fast-growing cities accompanied by changes in life styles, and steady population growth. These developments have made severe marks on resource availability and quality. In this paper we will investigate in a scenario analysis using a structural economics framework what effects lifestyle changes and other major developments might have on water resources.

China has one of the longest traditions of water resources and river management in the world. Its civilization has sought to control the effects of floods and drought for many thousands of years, and utilize the water flows for irrigation and navigation. In the last century competing uses such as domestic, municipal, and industrial water consumption have also become reasons for the regulation and abstraction of water.

In order to investigate these changes in economy and society and its effects on the water situation in China a set of scenarios has been developed and analysed within a structural economics framework.

## 1. Competing usage of water

China's development over the last few decades can be characterized by high rates of economic growth, migration from rural areas to the fast-growing cities accompanied by changes in life styles, and steady population growth. These developments have made severe marks on resource availability and quality. In this paper we will investigate in a scenario analysis using a structural economics framework what effects lifestyle changes and other major developments might have on water resources.

In order to investigate the water situation in China in the coming decade a set of scenarios shall be developed and analyzed within a structural economics framework using input-output (IO) analysis. Resulting regional water requirements for the year 2025 shall be compared to regional water availability of ground water, surface water, and further irrigation potentials.

China has one of the longest traditions of water resources and river management in the world. Its civilization has sought to control the effects of floods and drought for many thousands of years, and utilize the water flows for irrigation and navigation. In the last century competing uses such as domestic, municipal, and industrial water consumption have also become reasons for the regulation and abstraction of water.

Increasingly, China faces severe water problems. Every year, 26.6 million hectares of land is under drought. The water shortage is 30 billion cubic meters in irrigation areas and 6 billion cubic meters in the cities. The water situation can also be characterized by low-level figures per capita and per acreage of water resources. For example, the per capita water resource availability is only about ¼ of the average level in the world. This problem is compounded by uneven spatial distribution of water resources with surpluses and deficiencies. Generally speaking, the South is rich in water while the North is short of water. Furthermore, there are seasonal variations of water resources and interannual disparities with frequent flood and drought disasters. (Department of Hydrology. Ministry of Water Resources 1992; China Water Resource News 2000). Since settlement patterns in China reflect these greatly varying precipitation levels seasonal surplus of water affects many more people in China than a lack of water – more people are affected by flooding rather than droughts (Heilig, Fischer et al. 2000).

Traditionally, most of the water used in China is for the agricultural sectors. While most of the water – some 78% - are still used in this sector, the increase in agricultural water consumption has been remarkably low. The Nanjing Institute of Hydrology and Water Resources estimated that in between 1980 and 1993 China's agricultural water consumption had only increased by about 3.6%. The amount of water used for irrigation even declined by over 4%. At the same time water use in industry increased by 94% in Southern China tripled and urban water supply grew by 256% (United Nations 1997; Heilig 1999).

The decrease in water quality is the result of contamination by untreated residential and industrial wastes or from leakages from outdated waste-treatment systems, and contamination from agricultural fertilizers and pesticides. About 80% of the wastewater is untreated. The concentrations of water pollutants are among the highest in the world, causing damage to human health and lost agricultural productivity (Asien Development Bank and Chinese Ministry of Water Resources 1999). Studies show that one-third of the rivers in the whole country and over 90% of the rivers flowing through cities are polluted. Some major lakes are in various phases of eutrophication[7], and coastal areas are hit by seawater intrusion. The water sources in more than 50 percent of China’s major towns are not suitable for drinking. In southern cities, pollution causes 60 to 70 percent of total water shortage. (Ministry of Water resources, 1996, quoted after Xu, 2001)(China's Agenda 21 no date).

In addition, global climatic changes will have a lasting impact on China’s water resources as has already been shown by a high frequency of droughts and floods all over the country. Rising sea level will lead to increased sea water intrusion in coastal areas and will have ecological and economic effects on low-lying or coastal areas (China's Agenda 21 no date). For example, modeling exercises by Fischer and Wiberg (Fischer and Wiberg 2001) show that increased output in agriculture is bought by an increasing share of irrigation leading to additional needs for water transfer schemes. Furthermore, climate variability is expected to increase under all scenarios resulting in increasing frequency of extreme events.

At the same time water is severely wasted. As Xu states: “We use 10-20 times more water than those advanced nations to produce the same amount of profit.” For example in agriculture, about 60% of the irrigation water is lost by canal seepage at different levels (Xu, 2001). Inefficient irrigation causes not only water loss, raises the water table and with it the ineffective evaporation of the ground water, but also leads to soil

[7] In addition, the total lake area have decreased by more than 14% over the last 30 years

salinization and water logging, both can lead to decreases in agricultural productivity.[8] Other socio-economic factors adding to the water problem are the lack of adequate pricing mechanisms and political and institutional frictions between various administrative levels. The fragmented nature of the mandates of the ministries and uncertain relations between provincial governments and the central government does not permit a coherent integrated approach to solving urgent and complex problems of water management (World Bank, 2001).

Flood damages, polluted rivers, droughts, soil degradation, sedimented rivers and estuaries might not only entail considerable environmental long-term effects but might have disastrous implications for the social and economic fabric of the nation with severe ripple effects beyond its boundaries. Water shortages especially affect irrigation in North China, industrial use of water supply for the energy base in Shanxi and mid-South Lianning and the Shandong Peninsular.

This situation has attracted considerable public attention and research interest. Research and policy focus has been to increase (non-conventional) sources of water supply such as water loss reduction, reuse or recycling of water, inter-basin transfers, and desalination of seawater and groundwater rather than the political difficult decision of reallocating agricultural water use to higher value users. Allocating water among many conflicting potential uses presents a major dilemma to governmental agencies. Government must achieve a consensus on policy among the multi-sectoral interests by introducing appropriate incentives and institutions. The prospect of water scarcity and increasing environmental, social, economic, and financial pressures calls for coordinated decision making beyond optimization of water resources in sectoral isolation and through fragmented institutional control (Bouhia 2001). Water must be considered as an integral part of a larger system in terms of its functions and interactions between economic sectors, residential use, environment, public health, and other national goals. Lifestyle changes cannot be modeled in isolation. We will therefore use the comprehensive systems approach of structural economics for our long-term scenario analysis.

## 2. The structural economics framework and its application to water consumption

### *Structural economics and scenario analysis*

Scenario analysis investigates interactions among selected possible trajectories of major driving forces and shows the development of and interaction among the relevant systems. It supports decision-making and policy development and serves as a tool to foster creativity and to stimulate and guide discussion on the points of interest (Clark and Munn 1986; Toth, Hizsnyik et al. 1989; Prieler, Lesko et al. 1998). A well-established theoretical framework is a key for such investigations. In this paper we employ a structural economics framework in which scenarios about possible future

[8] Salinization refers to a build up of salts in soil, which decreases the osmotic potential of the soil so that plants cannot take up water from it. When soils are salty, the soil has greater concentrations of salts than the root, so plants cannot get water from soil. Water logging is the result of a raised water table. When soils are water logged, air spaces in the soil are filled with water, and plant roots essentially suffocate -- lack oxygen. Water logging also damages soil structure.

stages can be analyzed. The focus of structural economics is to describe the state or structure of an economic system and its quantitative and qualitative changes that take place over time (Duchin 1998). "Scenario" in such a setting means the change of the structure of the economy as represented by production and consumption patterns and their associated flow of biophysical resources and monetary flows.

The core of our approach is a recursive input-output model expanded by water use coefficients. The basic purpose of an input-output model is to predict levels of output, value added, and employment given a certain increase in final demand (representing various socio-economic scenarios). The integration of regional IO tables, very detailed biophysical information in a geographic information system, and consumption data for rural and urban population allows us to especially address the regional disparities of water availability and needs based on changing demographic, economic, and lifestyle questions.

### *Specification for an input-output model for long-term scenarios in China on a national and regional level*

In order to combine monetary data and physical data within a common methodological framework, we need to extend the economic tables by a set of natural resource coefficients representing consumption of water for each sector.

The enlarged IO table, as presented below, provides as with an accounting scheme for economic activities *($z_{ij}$, $V_{kj}$)*, household and other final consumption *($u_{is}$)*, environmental inputs *($L_{rj}$ and $L_{rs}$)*, and effects on the environment *($d_{ir}$)*. Whereas the inner parts of the table are in monetary units the outer part is physical units (in cubic meters).

Table 1: A Schematic Presentation of an Extended Input-Output Table

| | Grain, Other-crop, livestock, … | Rural, Urban, … | Total Output | Water |
|---|---|---|---|---|
| Grain<br>Other-crop<br>Livestock<br>… | Inter-industrial flows<br>($z_{ij}$) | Final deliveries<br>($u_{is}$) | Goods, Services, and Final deliveries ($X_j$) | Depreciation and Degradation<br>($d_{ir}$) |
| Capital<br>Labor<br>… | Factor inputs (value-added)<br>($v_{kj}$) | | | |
| Total Input | Goods, Services, and Factors ($X_i$) | | | |
| Land<br>Water<br>… | Natural resource inputs<br>($L_{rj}$) | Natural resource uses<br>($L_{rs}$) | | |

Source: modified after Fischer and Sun (Fischer and Sun 2001)

As a next step in our analysis we have to transform the enlarged IO table to a coefficient matrix. This is achieved by dividing the various flows between the economic sectors

($z_{ij}$) by total output, the sum of interindustry flows and final demand ($X_{,j}$). The coefficient matrix gives an empirical measurement of the relationships among the various sectors of the economy. To calculate input coefficients of natural resources, we divide the natural resource inputs by total sectoral output ($X_j$). These coefficients represent the direct or first round effects of the economy.

Based on the coefficient table the Leontief multiplier matrix can be calculated. The multiplier accounts for the total effect on output and resource consumption depending on the sectors that are affected by the initial changes in final demand (first-round effects) and all sectors previous in the production chain. Water use multipliers represent an indicator of the effect of a change in final demand on total water requirements, including initial, direct, and indirect effects.

Changes in final demand are driving water consumption in an input-output framework via direct and indirect water consumption of economic sectors producing goods for final consumption and via direct water consumption for residential purposes.

Water use priorities are modeled in the following way: We assume that requirements for urban and rural residents are met first, industrial and service sector requirements are met second, and agricultural requirements received the lowest priority. This ranking is included in the formulation of the supply-constrained model: residential requirements are deducted from the water supply; the available water under consideration of water use coefficients deliver potential output (exogenous $X$) for the constrained sectors; finally, the unconstrained sectors (industry and services) are allowed to expand freely based on the exogenous changes in final demand.

### Representation of the Economy at a national and regional levels

In our analysis we use the input-output tables for 1992, which were compiled by the Chinese National Statistical Bureau (State Statistical Bureau of China 1996). The table is aggregated to reflect the significance to the national economy of the various sectors. Since about 85% or 406 billion cubic meters of the water is used in agricultural sectors their detailed information was maintained by disaggregation into grains, horticulture, fisheries, forestry, and handicrafts. Other important consumers of water are the energy sectors with about 51 billion cubic meters and the manufacturing sectors with 41 billion cubic meters, respectively (United Nations 1997). In general, industrial sectors show enormous differences in water use due to the requirements of the respective products and production technology. Thus, it was necessary to disaggregate the previous 11-sector model to differentiate growth rates for fertilizer production, energy production, and other industrial sectors (Hubacek and Sun 2001). In addition, our model includes the increasingly important transportation and service sectors. Currently there is no record of the amount of water used by economic sector in the required detail level of this study. Thus Strzepek *et al*. (Strzepek, Holt et al. 1998) provided a further disaggregation of available Chinese government statistics. The use of these coefficients in a scenario analysis would give us total and sectoral water requirements at present-day efficiency.

In terms of final demand we use the classification categories of the National Statistical Bureau of "non-peasants" for urban population and "peasants" for rural populations. Institutions include Government, investment, inventory, and net-exports. Value added categories, reflecting the value of factor inputs, are capital income, labor compensation, taxes, and profits.

In our I-O model, China is divided into 8 regions based on their unique geographic, agro-climatic, demographic, and economic development levels, and consolidated with provincial level administrative boundaries for the sake of data availability and consistency.

A basic problem of modeling water use within an economic framework arises from the discrepancy between economic regions and watershed regions. Demand figures for water use are based on economic boundaries as derived from the input-output framework. The water supply figures have to be based on hydrological conditions. In order to assign water supply quantities to our economic regions we apply the hydrologic model, *Climate and Human Activities – sensitive Runoff Model* or CHARM developed by Wiberg and Strzebek (Wiberg and Strzepek 2000). The model is applied to the nine major water resource regions of China to estimate the natural available water supply in each of the economic regions. Water not used in one hydro-economic region flows downstream to the next, which could bring it to a different economic region. CHARM models surface runoff, evapotranspiration, and sub-surface runoff for individual cells. The output of this grid-cell level approach can then be aggregated to form our economic units.


Table 1: Hydro-economic regions in China

Note: The overlay of the economic and watershed (hydrologic) regions results in hydro-economic regions. The first digit in the hydro-economic region code represents the hydrologic region and the last digit represents the economic region.

Regional differences do also exist in terms of water consumption of households, industrial and service sectors based on availability of water resources and therefore habits of dealing with an abundant or scarce resource. For industrial and service sectors as well as the household sectors we calculate regional water requirement and productivity coefficients based on water use and economic output of the base year.

## 3. Structural change in production and consumption

The impact of changes in economy and society on water consumption will be dictated by the future patterns of both consumption and production. The possible future patterns of consumption and changes in technology are discussed in the sections below.

### *Economic Growth and the Consequent Per Capita Income Growth*

Since 1978, China’s GDP has expanded at an average rate of nearly 10 per cent and total exports at 17 percent per year. The Fifteen-Year Perspective Plan (1995-2010) identifies two fundamental transitions to sustain future growth: 1) from a traditional planned economy to a socialist market economy; and 2) from the extensive growth path, based on increases in inputs, to an intensive growth fashion, driven by improvements in efficiency. (World Bank 1997). Assuming the continuance of high saving rates supporting high investment rates, of the market-oriented reforms, and of high factor productivity growth, the World Bank projected growth rates of annually 6.6 percent until 2020. (World Bank 1997). According to the World Bank, the pace of GDP growth will be slowing down over time, from some 8 percent of today to 5 percent in 2020 due to a then stagnating labor force, diminishing marginal returns, and lower gains from structural change.

These aggregate growth trends mask diverging paths for different parts of China. There is a large body of literature dealing with the regional disparity in China (Liu, Yao et al. 1999). It is generally acknowledged that three regions have emerged with discerned development paths in the past two more decades: 1) the leading coastal areas characterized by high income level and high growth rate; 2) the catching up central regions with average income level but rapid structural changes from agriculture to industry and services; and 3) the backward regions in the west, with a much slower growth rate, and with a small share of the population dominated by national minorities. Another significant disparity exists between rural and urban areas. The per capita income ratio of rural to urban residents has been around 1 to 2.5 in the past two decades.

GDP growth rate is a comprehensive indicator that is not independent of population growth (implying labor force growth) and technological progress. To make income growth rate be independent of other driving forces, we subtract the foreseen growth rate of population and the part corresponding to technological progress (about 35 percent of GDP growth) from the predicted national GDP growth rate (World Bank 1992; World Bank 1997). As a result, we obtained a net per capita income growth rate. For simplicity, we call it per capita income growth rate. In order to accommodate to the regional and rural versus urban differences discussed above, we distinguish growth rates for urban and rural areas and for two large development zones.

### *Population Dynamics and Urbanization*

When the People's Republic was founded in 1949, it had a population of 540 million; three decades later its population was more than 800 million; and present China's population has approached 1.3 billion. Today's high share of young Chinese in reproduction age has created a strong population momentum that is now driving China's population growth despite already low levels of fertility. China is confronted with two counteracting trends: while economic growth, urbanization and the associated lifestyle change may lead to lower fertility rates, modernization and the opening of society might lead to opposition to the government's strict one-child policy in family planning (Heilig 1999). In its most recent (medium variant) projection, the UN Population Division estimates that China's population will increase to 1.49 billion in 2025 and then slightly decline to 1.488 billion in 2050 (United Nations Population Division 1998).

In the past two decades, two opposite trends have coexisted to shape the population dynamics across regions. On one hand, migration from Western and Central China to the eastern regions, especially the coastal areas, adds percentage points to population shares of the eastern regions. However, on the other hand, the fertility rates moving upward from the eastern to the western regions have basically counter-balanced, if not exceeded, the impact of migration (Jiang and Zhang 1998). In addition one has to consider the moving of traditional industries, particularly, heavy industry, from the eastern regions inward to the western regions and the new strategic movement of the Chinese government to reduce regional disparity. As a comprehensive result of these three trends, the accumulative impact of migration on regional population distribution up to 2025 may not be very significant.

Despite the fact that the urban population is constantly increasing, China can still be considered a predominantly rural society. In 1997, after the rapid increase of the officially defined urban population for more than a decade, only some 30% of the population lived in urban areas. The rather recent increase in urban population is mainly due to the promotion of towns into cities, thus increasing the number of cities altogether. Another reason for the increase in urban population has been the loosening of strictly controlled internal migration to meet the labor demand of the growing cities and towns as well as a wave of temporary "illegal" rural-urban labor migration. The United Nations Population Division (United Nations Population Division 1998) estimates that by 2025 about 50 percent of the Chinese population will live in urban areas.

### *Change in diet*

With respect to changes in consumption patterns, changes in diet structure are the most relevant for agricultural water use. In China's food tradition, cereal products have been of overriding importance; other food products such as meat, fishery products, vegetables, and fruit played only a residual role. This pattern has been changing due to recent social and economic developments. Urban residents typically prefer a more diverse diet and eat more processed foods. Today's Chinese eat more meat and dairy products, which has boosted livestock production. China's population has enormously increased its meat consumption and also eats more fruits and vegetables, whereas direct consumption of grain has leveled off or even declined (Wu and Findlay 1997). Despite these developments, China's average food calorie supply per person per day is still below the average level of developed countries (FAOSTAT 1998). Therefore, an increase in per capita calorie consumption can be expected in the future.

To calculate aggregate final demand from households for the products of each production sector, we multiply the above-listed average expenditures of urban and rural residents, respectively, by the total numbers of urban or rural residents in each region. To obtain total final demand corresponding to each production sector, we link other final demand components to household consumption according to their current ratio to the level of aggregate household consumption.

### *Technical change*

In the 1960s, first long-range forecasts of water consumption made in the US predicted an increase in annual fresh-water consumption of 2-2.5 times from 1970 to 2000, mainly due to increases in water use in industry and heat power generation. However, in the 1970s and 1980s a transition from extensive water resources consumption to intensive and multi-purpose water resources utilization brought about a stabilization of water consumption. Similar trends were observable in some countries of northern and western Europe ((Shiklomanov 1994).

Also in China important steps have been made towards water saving. Recently six ministries, including the State Economic and Trade Commission, the Ministry of Water Resources and the Ministry of Construction, jointly confirmed the ten-year goal for saving water in industrial companies. The share of reused water rate is target to increase from the present 50% into 60% in 2005 and 65% in 2010 (Anonymus 2000).

Based on the assumption that most industries in China will recycle their water to a very high degree Thomas *et al*. use a recycle rate of 90% for their study (Thomas, Conrad et al. 1997). Chen Junfeng in a scenario analysis assumes recycling rates between 25% and 90% depending on the regions (South-North Water Diversions by Chen Junfeng, IGSNRR). Our estimates for the industrial sector follow the projected trend of the official water saving efforts of the relevant ministries in China assuming a recycle rate of 85%.

For the service sectors we can observe two opposing trends: inefficient water use and increasing water demand based on higher expectations, health and hygienic standards. Unfortunately, statistics for water use in service sectors are hard to find. In China the water use in the service sector is subsumed under urban water use. We therefore use the regional variability of urban water consumption for our water use scenario in 2025. In terms of technical change we use labor productivity since water use in there service sector is derived from worker-output ratios (Strzepek, Holt et al. 1998). During 1985-2000, the labor productivity in the service sector increased by 3.12% per annum (Statistical Yearbook of China, 2001, pages 22, 30, 52), we assume a gradual slowdown of the labor productivity growth in the future in the sector. At the average, the annual growth rate is about 2.5% annually.

Also in the agricultural sectors there is lot of room for improvement. Unfortunately, field data on effectiveness of water saving technology is not readily available because over the last 20-30 years, the emphasis has been on water supply rather than water conservation (World Bank, 2001, p. 73). Efficiency of irrigation network is only about 40-50%. In North China Plain areas, the efficiency is around 55-65% (Liu and He 1996; Ministry of Water Resources 1998). There seems to be potential for water saving through better management and infrastructure. But part of the water lost upstream through percolation and seepage returns to the hydrologic system and is available to downstream users. Real savings could only be made from reductions in evapotranspiration and the flow to the ocean through measures such as for example, improved crop genetics, plastic and organic mulching, irrigation scheduling and best farm management practices (World Bank 1999)(World Bank, 2001).

In order to facilitate these changes the Chinese Government is promoting water saving irrigation; the State Council has approved the establishment of water-saving/yield increasing counties as well as water-saving well irrigation districts, across the nation. Water use efficiency is planned to increase by 15% by 2010 (Xu, 2001, p.3).

## 4. Results and implications of alternative development scenarios for land-use change

In this study, we selected diverse scenarios based on different combinations of the widely expected developments on population growth, changes of lifestyles, level of migration, and economic growth for a 30 year-period. Given the assumed extent in technological progress, we show how these combinations might affect demand for water consumption in China. The increases in final demands and sectoral outputs would drive the associated water needs to exceed projected supply in certain regions. In other words, these regions in China would not be able to support the increased demand without significant improvement in water productivity, water savings measures and/or increasing imports. The major results of our scenario analysis are presented in following table.

Table 2: Renewable Water Supply and water demand for 2025.

| Region | Water Supply | ***Water Demand*** |
|---|---|---|
| North | 95.76 | 150.86 |
| Northeast | 125.15 | 51.78 |
| East | 256.19 | 125.49 |
| Central | 507.89 | 76.87 |
| South | 600.89 | 119.82 |
| Southwest | 694.11 | 74.50 |
| Northwest | 155.47 | 243.38 |
| SUM | 2,435.46 | 1,226.36 |

Notes: The Plateau is missing in our scenario analysis due to lack of data. Water supply is based on Wiberg (manuscript); water demand is based on own calculations.

The table shows water supply vis-à-vis of water demand for each of the economic region. In the Northwest and North regions the demand for water exceeds its potential supply. The North region can also be considered water scarce, which is region surrounding the capital Beijing was only 226 cubic meters per capita. Anything below one thousand cubic meters per capita is generally considered water scarce.

This table shows the importance and advantage of a regional over a national analysis. If we compared water supply at a national level we would not be able to see the water shortages on the regional level and might conclude that the availability of water is not a problem in China. This advantage is achieved at the expense of further sectoral detail, which limits the usefulness of the present setup to questions of lifestyle changes at a finer sectoral level or product level. This is a general problem that economic regions and its associated tables do not match the region relevant for a certain pollutant or resource (in this case the watershed).

For further analyses of the water situation the current framework allows evaluating changes in population and urbanization, dietary changes, and changes within broader sectoral categories as well as technical change and water related efficiency gains, and incoming growth rates. In a next step we will also evaluate the effects on water consumption associated with each of the product groups represented within each economic sector and thus the potential relieve through relocation of water intensive sectors.

In the literature a number of reasons for the apparent water shortage have been discussed. Our study has identified and quantified the water shortage as result of overpopulation, in rapid increase of the rate of urbanization, and steady and fast economic growth.

The underlying causes at an institutional level are the compulsory development of irrigated agriculture and deficient funds in water improvement measures (Chen 1992). For Yang and Zehender, the root cause of inefficient water use lies in the undervalued price of water. To obtain an intrinsically important commodity so cheaply does not provide any incentive for using water more efficiently. Therefore, one of the instruments to remedy this situation is the implementation of water charges. Local governments have shown quite some enthusiasm to use such a mechanism since increasing water prices become a de facto source of revenue (Yang and Zehnder 2001).

China must allocate its scarce water resource to its highest economic return. Agricultural water use value is lower than in non-agricultural sector. This necessitates moving from the constraining goal of food self sufficiency to the more flexible notion of food security. Therefore, it is necessary to expand the food market beyond its borders to allow for flexibility in cropping decisions on the farm level producing and exporting the crops it grows best and importing to cover the remaining demand (quote). Or as Yang and Zehender (Yang and Zehnder 2001) phrase it “virtual water import,” in the form of grain imports, should be incorporated into current regional and national agricultural development strategies. Food self-sufficiency has been a heavily disputed topic. Many Chinese believe that a high level self-sufficiency in grain is necessary. Policy-makers are often hesitant to move water away from agriculture to sectors that would provide higher economic returns. This is due to the fact that currently some 40% of the Chinese population works in agriculture.

Needs some flexibility in cropping pattern that allows a substitution to less water intensive crops. Over the last two decades the trend has been to shift from grain crops to high-value crops such as vegetables and horticultural products. But such a shift will lead to an increase in water use per unit of land. Agricultural production in general is heavily reliant on irrigation. Agricultural production may need to move from the north to the water-rich southern parts of China or to import grain (Yang and Zehnder 2001).

The same logic applies to the industrial sectors. It might be necessary to relocate of water-intensive industries to water-rich areas. Currently the heavily water consuming industries such as power, petrochemicals, coal, and metallurgy consume the largest amounts of water are located in the north, where there is a shortage of water resources.

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# On the Way to Sustainable Development, Resource Efficiency and Dematerialisation.The Importance of Repair and Upgrade

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## 1. Vision: the Performance Society[9]

Modern industrial society has reached perfection in the production of disposable goods, but at the same time has become dependent on it: without mass consumption no economies of scale, without economies of scale rising prices for goods and less consumption! A new focus on sustainable development requires a new way of thinking in the sense of a "Performance Society", an economy, in which the preservation of values has priority over value added. This calls for a new central notion of value: the utilization value, which replaces the exchange value of the industrial society.

We therefore talk about a "reservoire economy" (as opposed to a flow economy), which is centred on the management of fleets of goods and on selling results and performance – as has always been the case with investors letting rental apartments. Due to the fact that customers now pay a flat fee for the services received, every breakdown or repair means a reduction in profit, while today the same events lead to an additional income for some economic actor. Preventive Engineering, e.g. the prevention of technical breakdowns or of the misuse of goods by the user, becomes the new key capability to increase company profits. Furthermore, the highest profits in the "Performance Society" are not achieved through efficiency- but "sufficiency"- strategies such as loss prevention and the application of the precautionary principle.

The term "Performance Society" does not mean the tertiary (or services) sector nor the virtual "e-economy", but it describes a different way of managing the material goods of the industrial society over their life-time. As the selling of services will increasingly replace the selling of goods, the virtual and the material economy will in the future merge: the boundaries between product, process and service are disappearing gradually.

While the manufacturing society is comparable to a river – its revenue comes from resource throughput – the Performance Society may be compared to a lake, optimising the application of knowledge and the utilization of fleets of goods through a dynamic fleet management; its central notion of value being the utilization value. As every quality impairment of the lake now also means a reduction of a company's assets, this comprises a new quality definition over longer periods of time emerges. Preventive measures like loss prevention and waste reduction become a vital part of the self-interest of the economic actors involved.

The Performance Society decouples economic success from resource consumption, and substitutes "reversed incentives for zero-solutions" (which are sufficiency strategies) for the efficiency thinking of the industrial economy. An extension of the product-life of goods corresponds to a substitution of manpower for energy and material, and changes

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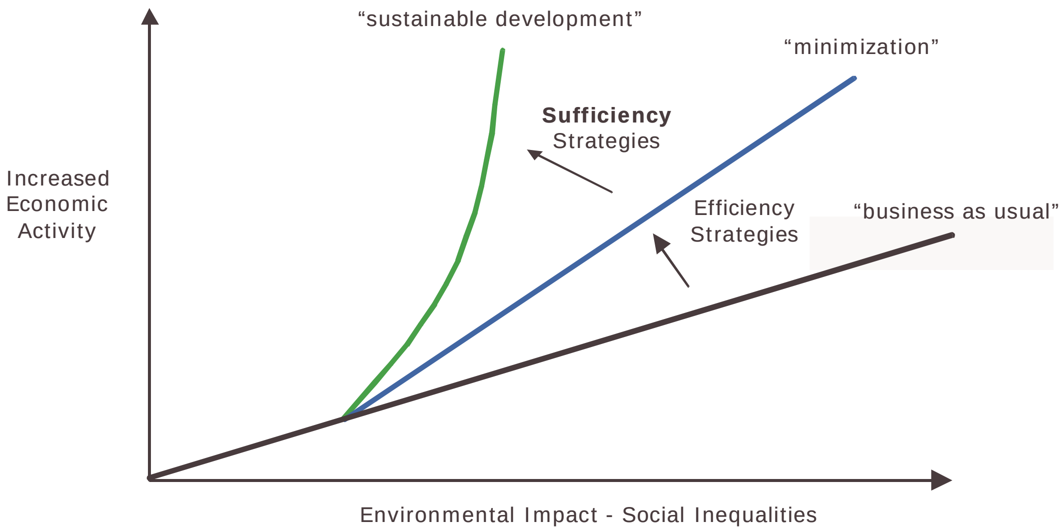
[9] Orio Giarini, Walter R. Stahel „Die Performance- Gesellschaft: Chancen und Risiken beim Übergang zur Service Economy", Metropolis, Marburg, 2000, ISBN: 3895183202

in the structure of the economy by which regional workshops replace centralised and global factories.[10]

The following illustration[11] shows the transition from „business as usual“ to dematerialisation and sustainable development, and the relative importance of „efficiency-“ and „sufficiency“-strategies.

***Shifting development paths towards sustainable development***




*Source:* ECOTEC for DG ENV

The central objective of the „lake economy“ is the management of existing values. The smaller the loop, the higher the value preserved: re-use comes before repair, repair before remanufacturing, remanufacturing before recycling, recycling before disposal. In addition, some types of goods can be upgraded to the state of the art with regard to technology and/or fashion. This option is of special interest in combination with re-use, repair and remanufacturing activities.

## 2. The Importance of Repair and Upgrade

Strategies of repair and upgrade represent key elements of the Performance-Society, and will play a major role in all efforts towards a more sustainable development, an increased resource efficiency and dematerialisation (factor 10).

The importance of repair and upgrade strategies has so far only been shown in micro-economic terms and on a qualitative basis. Few quantitative facts and figures are available so far on the importance for a national economy over longer periods of time.

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[10] Stahel, Walter and Reday, Geneviève (1976) The Potential for Substituting Manpower for Energy, a report to DG V of the European Commission, Brussels; (1981) Jobs for Tomorrow, Vantage Press, N.Y..

[11] Source: "Sustainable Production, Challenges & Objectives for EU Research Policy", Report of the Expert Group on Competitive & Sustainable Production and Related Service Industries in Europe in the Period to 2020, July 2001

Equally missing are more concrete concepts or scenarios exploring future developments towards a balanced future state, broken down into lines of business and groups of products and goods.

### 3. Project

The result of the project shall be facts and figures concerning the importance of repair and upgrade on the way to the Performance Society along the time axis and divided into lines of business, groups of products and goods respectively. Thus should enable to assign repair and upgrade their correct value within the strategies for a more sustainable development and for increased resource efficiency, and to include them in any such strategies in a concrete way.

The results of this research project should also help to transmit the desire for sustainability to economic actors on both the supply and demand side. The results should further be used as an input for a new marketing approach of sustainable development, which materializes, quantifies and particularizes its benefits. Economic actors shall thus perceive their specific opportunities in the Performance Society and move increasingly into that direction in order to realise their potential.

If we succeed to raise the desire for sustainability in all players, instead of reducing sustainability to an ideal,  instead of generalizing it and enforcing it through legal compliance, then sustainability might become a self starting and continuing action!

## Sustainable Consumption and Factor X in the Food and ICT Sectors

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Unsustainable patterns of consumption and production in industrialised countries were identified in Agenda 21 as the major cause of the continued deterioration of the global environment. The Johannesburg Summit reaffirmed the need for fundamental changes in the way societies produce and consume, and called on developed countries to take the lead. In the light of both conspicuous consumption in the developed world, and the developing countries' opportunity of leapfrogging to more sustainable growth patterns, Factor X strategies can play a crucial role.

While considerable improvements in resource use efficiency have been achieved in the last decades, the sustainability agenda is gradually shifting to include consumption alongside production. Eco-efficiency strategies and policies have resulted in environmental gains that translate into less resources used per unit of product or service, contributing to the factor 4 and 10 increase targets in resource efficiency. However, eco-efficiency gains may be offset by trends on the demand side towards new life styles and rising levels of consumption. The two sides of the equation—consumption and production—hence need to be addressed if Factor X goals are to be achieved.

It is production and consumption systems (PCS) that need to be changed. PCS are both the adequate target and the necessary scope for implementing Factor X strategies and measuring progress towards more sustainable patterns of consumption and production. Only those strategies that are based on life cycle thinking and reflect local cultures and values will produce real effects. Indices that capture the entire system can assist in assessing the potential and the success of Factor X solutions in the system.

This paper discusses the potential of Factor X in two specific PCS: the food and the information and communication technology (ICT) systems. The aim is to identify where in these systems, and how, business can intervene to promote more sustainable consumption and production patterns, and further to highlight differences between the two sectors. While efforts in resource efficiency have thus far adopted a product or production process scale, a shift to a life styles scale, that takes the consumer as a starting point, is being called for. It is argued that new indices are needed that capture the complexity of PCS, thereby promoting a closer interaction between business and the consumer in the search for more sustainable consumption and production patterns.

## Outlining consumption and production systems

While research and action has targeted both consumption and production separately, the challenge remains to describe the entire PCS system, accounting for the dynamic factors that influence the system. While rational theories of consumption have been dominant in the policy communities, advertisers and marketers have been more open to using cultural and social theories. This is often seen as the reason for the greater success that advertising has had in impelling consumption than government policies have had in controlling and channelling it.[12]

Different models have been suggested to describe CP systems, such as the needs, opportunities and abilities model[13], which examines the specific forces underlying consumer behaviour at both the macro-level of society and the micro-level of the household. **The provision, motivation and access** (PMA) model[14] provides a framework to ensure that the introduction of a more sustainable product or service is successful, which can only happen when the three areas—provision, motivation and access—are addressed through appropriate policies and programmes.

**The provision, motivation and access model**

| **Motivation**<br>incentives and disincentives that shape the market for goods and services | **Access**<br>Factors that include or exclude consumers from participating in the market | **Provision**<br>Structures of creation, delivery, utility, disposal and information for products and services |
|---|---|---|
| **Individual and socially contingent motivations of consumers**<br>▪ Personal concerns<br>▪ Social and cultural influences<br>▪ Habits and established routines<br>**Motivations of business**<br>▪ Market competition and "recognition "<br>▪ Long term planning<br>▪ Regulation<br>▪ Relationship with customers<br>▪ Company 's culture<br>▪ Protection of brand image | ▪ Income<br>▪ Time<br>▪ Availability and ownership of infrastructure of essential goods and services<br>▪ Availability and choice of products and services<br>▪ Information<br>▪ Education and training | ▪ Design of products and services<br>▪ Production of products and services<br>▪ Distribution of products and services<br>▪ Disposal of products and services<br>▪ Set of expectations and established practices of consumption<br>▪ Price<br>▪ Marketing strategies |

Figure 1: Illustrates the basic structure of the model, which is used here to examine the food and ICT sectors

[12] Wilk, R. Culture and energy consumption. In Online handbook Consumption, everyday life and sustainability. http://www.comp.lancs.ac.uk/sociology/esf/session3.htm

[13] model developed by Vlek *et al.* In OECD 2002. Towards sustainable household consumption? Trends and policies in OECD countries.

[14] The term *systems of provision* has been used by Chappells *et al.* (2000) to describe a framework for understanding production, consumption and lifestyles. The PMA model is based on sustainable consumption literature and case-studies of multi-stakeholder action to shift patterns of consumption and is presented in Ryan C. 2002. Sustainable consumption – A global status report. Draft for comment, April 2002. UNEP.

## Outlining the PCS in the food and ICT sectors

Research into material intensity has highlighted the variations between the different economic sectors, and between the origins of the material flows within each sector. The promotion of sustainable patterns of consumption and production hence calls for a sectoral approach, whereby suitable strategies and priorities are defined for each sector. The core of the UNEP programme on sustainable consumption and production, presented in the World Summit on Sustainable Development[15], takes a similar approach by addressing functional clusters, such as food, housing, clothing, mobility, health, leisure and education. The differences between the two sectors examined here, often stemming from the differing nature of the products, services and PCS in question, illustrate the need for a sectoral approach.

The **food sector** is directly or indirectly involved in a fifth of the total material flows per capita in Germany, ranking second in material intensity after housing. Just under a quarter of that total derives from private use of energy for preparation of foodstuff and shopping trips, while processing and trading account for more than three-quarters of the total.[16] A study into eco-efficiency in the Swedish food supply chain has shown that a factor 4 increase requires a radical reduction in the use of resources such as energy and phosphorous, that can only be achieved through technological developments, better organised flows and a change in the behaviour of individuals and companies.[17]

The figures above show that the impacts arising from the act of consuming are linked not only to the consumer's behaviour, but also to product and process characteristics. The most significant environmental impacts are upstream in the product chain. However, households influence trends in these areas through their choice of diet and their food-related services.[18] LCA research into consumption of vegetable products, for example, has shown that avoiding products flown in from overseas and deep frozen products results in the highest change in environmental impacts.[19] These characteristics are determined upstream in the chain, but can only be fully realised if the consumer takes the "right" decisions. Consumers' decisions, in turn, are dependent upon their motivations, as well as on the provision and access to more sustainable food products and services (Figure 2).

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[15] UNEP 2002. Proposal for a Work Programme on promoting sustainable sustainable consumption and production patterns. Briefing note for distribution at WSSD. http://www.uneptie.org/outreach/wssd/

16 Sachs, W., R. Loske, M. Linz et al. 1998. Greening the North. A post-industrial blueprint for ecology and equity. pg54.

17 Nordic Council of Ministers 1999. Factors 4 and 10 in the Nordic Countries. The food supply chain

18 OECD 2002. Towards sustainable household conumption? Trends and policies in OECD countries. Pg. 25

19 Jungbluth 2000

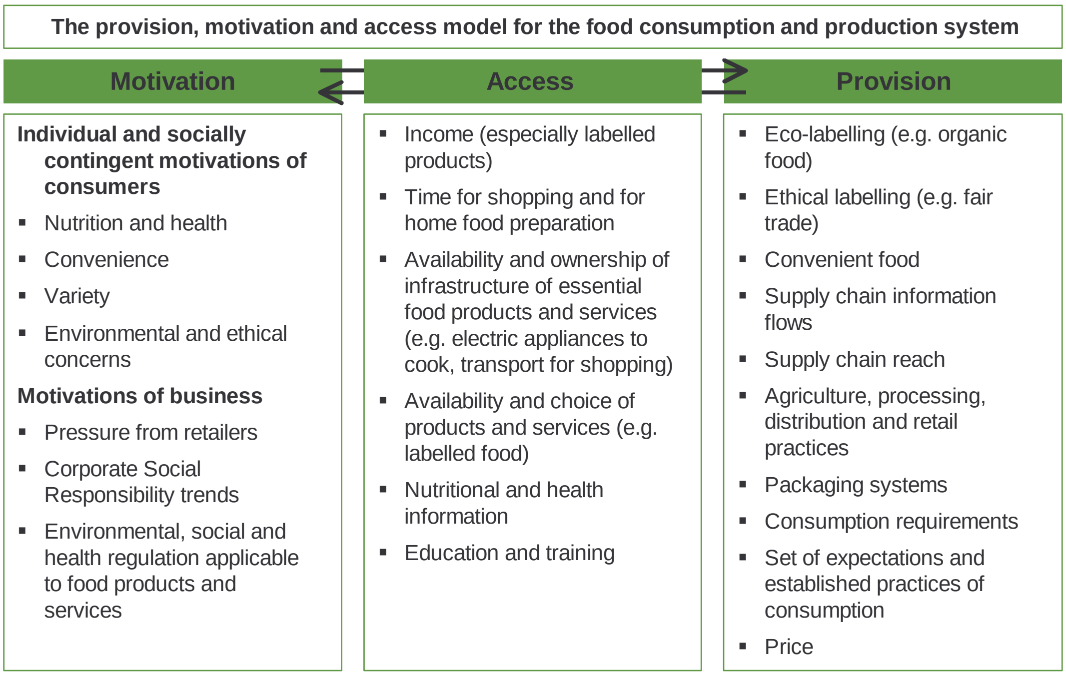

Figure 2: The food consumption and production system according to the PMA model

Sustainable food production and consumption need to be approached from a product chain perspective, which evaluates the potential for increased resource efficiency and offers consumers the option to buy more eco-efficient food products and services. Research in the food sector has often taken a life cycle approach, examining the impacts of food products from agriculture to consumption. Business is gradually, though often in a piecemeal fashion, incorporating product chain oriented actions into their environmental strategies, with the interaction between food processors and farmers taking the form of education and training, procurement standards, and research projects.

Going one step further means addressing the entire PCS, so as to ensure that products and services that are improved upstream in the chain actually meet the consumers' motivations and can be accessed by them. Food has strong underlying values and concerns, rendering information and education issues paramount. Organic food, for example, may be inaccessible to consumers with lower income, inadequate information, or more difficult accessibility to selling points. Other products, such as frozen food, result in high impacts in the consumption phase. Improved information and education are needed in these cases, to ensure increased energy efficiency from the consumer side.

From the screening of the food quality initiatives established by various actors along the food supply chain in European market, it can be concluded that they have claims of quality aspects. These aspects include healthfulness, safety, nutritive value, environmental friendliness, animal welfare, ethical concerns, use of GMOs, biodiversity, social responsibility, enhancement of local economy and cultural value preservation. However, their coverage of the supply chain varies (Figure 3).

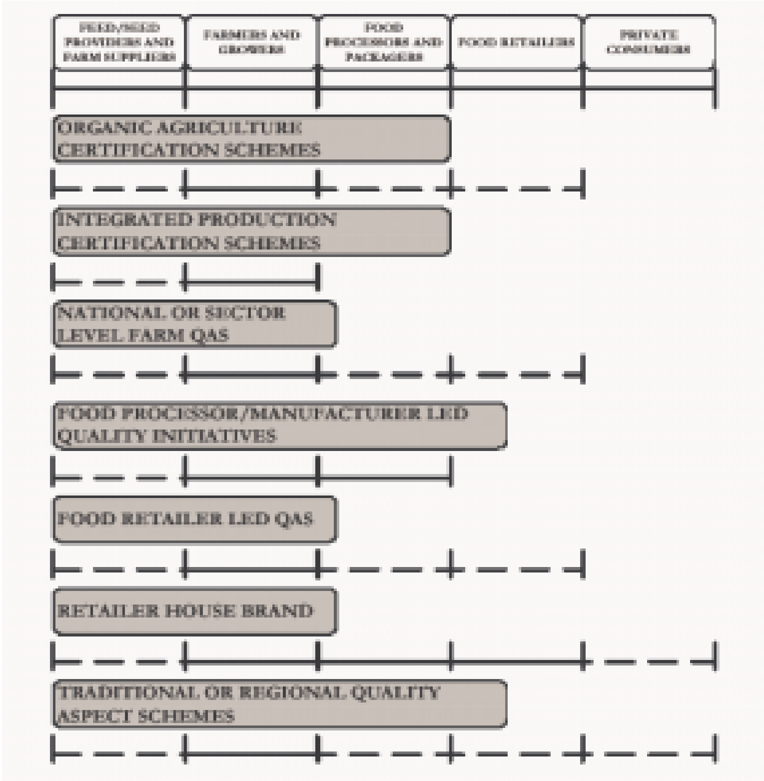

Figure 3: Initiatives in the food supply chain and the coverage of their claims[20]

While organic agriculture certification schemes and integrated production certification schemes claim to be environmental friendly by applying organic agriculture and Integrated Crop Management (ICM) respectively, national/sector level farm quality assurance schemes claim to assure this aspect through compliance with national environmental legislation. Retailer Led Quality schemes refer to integrated methods of production, while food processor/manufacturer led quality initiatives and retailer house brands address eco-efficiency measures down stream in the chain in addition to sustainable primary production practices. Traditional or regional quality aspect schemes claim to assure environmental friendliness mainly through less intensified production and processes, which follow strict criteria or traditional ways, together with an emphasis on decreased transportation distances.

Sustainable agriculture certification schemes focus primarily only on the primary production phase. National or sector level farm quality assurance schemes put emphasis mostly on the primary producer level activities to accomplish safe food production with rare referral to the activities of processors and retailers. Food processor and retailer driven schemes emphasis corporate citizenship leading to a wider perspective in addressing quality aspects such as inclusion of ethical issues or social and human capital or more strict environmental criteria development and also use a variety of tools such as operational indicators or stakeholder dialogues. Use of product brands allows the schemes to deliver consumers a single coherent quality message and provides the opportunity to develop brand loyalty and in turn increase in consumer confidence.

[20] Tuncer, B. 2001. From farm to fork? Means of assuring food quality: an anlysis of the Europan food quality initiatives IIIEE Reports 2001:14 Lund 2001

Regional and traditional quality aspect schemes address a whole different set of quality aspects whilst managing to build full credibility with shorter supply chain coverage. However, they still lack international referral and performance evaluation systems that would assist in continuous improvement. While benchmarking schemes can be seen as quality management tools, which possess the advantage of forming a pool of best practice applications and illustrations of supply chain collaboration.

Other approaches in the food sector use the concept of product-service systems (PSS), such as the Dutch Odin case study presented in Box 1.

**Box 1**: An example of Product-Service Systems in the food sector

*Odin Holland* supplies **organically grown food to consumers by subscription**. Once a week, the consumer receives a paper bag with assorted vegetables and accompanying recipes from a store in the neighbourhood. The consumer received a fixed amount of food, enough for consumption by 2 to 4 people for 4 days.

*Odin* only sell organically grown vegetables with the *EKO* organic food label certified by SKAL, which is an organic agriculture certification organization. Furthermore, Odin supplies regionally grown food, aiming to minimise the environmental impact caused by transport. For variation purposes a small amount of food is imported, especially in winter time.

The supply is based on fixed price contracts between Odin and farmers, without intermediates such as auctions or wholesalers. This enables planning in advance and provides distribution advantages. Contracts with the consumers are the main advantage for such strategy.

This approach offers financial benefits to the farmer, facilitates access by consumers to food products that are organically produced and that require less packaging and transport, and further it provides adequate information to the consumer. However, questions may arise with regards to the “set of expectations and established practices of consumption”. While consumers are provided with the food and recipes for a number of days, the actual needs may be different from expected or planned, the result being higher levels of consumption.

Recent changes in the **ICT sector** are accelerating the shift to a service-oriented economy, in which more ‘value’ is associated with immaterial features and knowledge. There is some evidence to suggest that a structural shift towards a service-oriented, digital economy may support the dematerialisation of industrial production and consumption patterns.[21] The current growth of ICT infrastructure is based on the (expected) expansion of demands for different ICT applications, ecommerce being one of them. Ecommerce can simply be understood as the buying and selling of goods and services on the Internet. The process of economic transactions can be separated from the information phase, including product information, bids and contracting, delivery and payment, as illustrated in the following Figure 4.[22]

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[21] Dematerialisation refers to a quantitative reduction in the material throughput of the economic system. This is based on the assumption that reducing the material throughput will automatically reduce material output (pollutants, waste etc.) as well as harmful resource extraction. Dematerialisation implies a more efficient use of those natural resources which are fed into the economic system (re-use, recycling).

[22] Kuhndt, M., von Geibler, J., Türk, V., Moll, S., Steeger, S., Schallaböck, K.O., Utzmann, I. (2002). Virtual Dematerialisation: Ebusiness and Factor X. Interim Report to the European Commsion. Wuppertal Institute. Wuppertal, Germany.

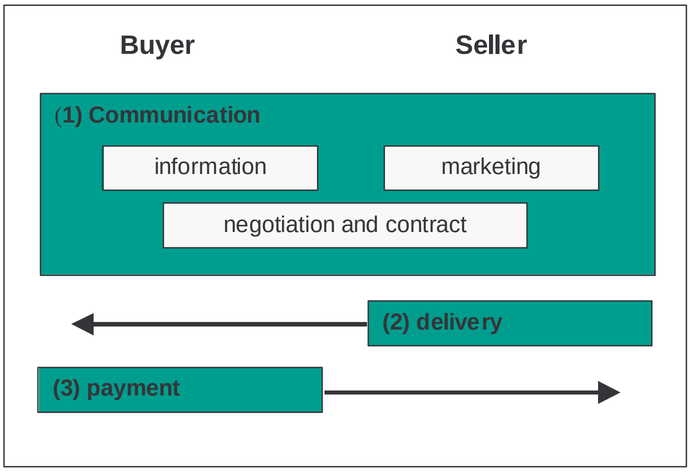


Figure 4: Phases of commerce. (Source Wuppertal Institute)

Regarding the delivery phase, the product intensity of the object of the transaction determines the influence that ecommerce has on resource efficiency.[23] Thus, ecommerce activities can be divided between **product-based ecommerce** and **information-based ecommerce** depending on the degree of physical material used to provide the service associated to the transaction object.[24]

**Product-based ecommerce** draws on a physical product as the mode for delivering services related to the product for the customer. An example of product-based ecommerce would be the online purchasing of CDs (Box 2).

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[23] Kuhndt, M., von Geibler, J., Türk, V., Moll, S., Steeger, S., Schallaböck, K.O., Utzmann, I. (2002). Virtual Dematerialisation: Ebusiness and Factor X. Interim Report to the European Commsion. Wuppertal Institute. Wuppertal, Germany.
[24] This approach is in accordance with the classification of services e.g. by White et al. (1999). Servicising: A quiet transition to Extended producer responsibility, In: Mont, O. (1999). Product service systems. IIIEE, Lund University

**Box 2**: Preliminary conclusions from a case study in the music sector[25]

Both product-based scenarios, i.e. the physical retailing and the CD online-shopping scenario, necessarily include the physical production of the CD and its distribution.

The infrastructure's (production site building) contribution to the overall material intensity is rather low, as enormous quantities of CDs (and herewith service units) are produced. For buildings with a far lower turn-over of CDs (such as e.g. a CD shop), the building infrastructure turns out to be of more importance for the overall material intensity. This explains the slight difference between the two scenarios as online shopping does not require a CD shop.

The consumer's transport stage is of importance to the overall material intensity. Here, the material use for travelling refers to an individual CD. This transport is more material intensive per service unit than transport to the retailer as the latter covers a larger number of CDs. The high importance of the consumer's physical transport is also highlighted in the banking case study (see below) and in other studies of product-based ecommerce.[26,27] Also in these cases the transport to the retailer is of less environmental relevance, with one reported and unsurprising exception: the transportation of the product to the retailer including product packaging is of high environmental relevance if air transportation is induced by ecommerce.[28]

In the case of product based ecommerce, the physical production and delivery of a product is taking place similarly to the traditional commerce scenario. Thus, the related resource consumption can be influenced by ICT only marginally, as the production of the product and the logistical efforts to deliver the product remain. In addition, the product handed over to the customer is likely to provide the same number of service units when compared to the traditional product, i.e. the product is likely not to be shared with others.

**Information-based ecommerce or eservices** refers to services that are delivered to the customer via an ICT infrastructure. This type of ecommerce is information-based, i.e. they are not based on a physical product which is handed over to the customer. Online banking and online music downloads are popular examples of such digital services (Box 3).[29]

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[25] Kuhndt, M., von Geibler, J., Türk, V., Moll, S., Steeger, S., Schallaböck, K.O., Utzmann, I. (2002). Virtual Dematerialisation: Ebusiness and Factor X. Interim Report to the European Commsion. Wuppertal Institute. Wuppertal, Germany.

[26] Swedish EPA*, Home shopping will save energy*, 2000. Available online at: http://www.swedenvironment.environ.se/no0001/0001.html#art13.

[27] Reichling, M., Otto, T., Environmental Impact of the New Economy, In: Park, J., Roome, N. (Eds.), (2002). Ecology of the New Economy, Greenleaf.

[28] Hendrickson, C. T., Matthews, H. S., Soh, D. L. (2000). *The Net Effect: Environmental Implications of E-commerce and the Logistics*, Pittsburgh: Carnegie Mellon University, 2000.

[29] GfK-Onlinemonitor (1999). In: Bundesministerium für Wirtschaft und Technologie. E-f@cts: Informationen zum Ecommerce. Ausgabe 01/2001.

**Box 3**: Preliminary conclusions from a case study with the music sector on online music[30]

Purely digital distribution of music, where no product is involved in the economic transaction, is clearly beneficial from a material intensity point of view, compared with the product-based scenarios. However this is only true under the assumption that the user does not burn the music on a CD and that a fast Internet connection is available.

If CD burning as well as a slow internet connection is assumed, digital distribution might be much more material intensive than the product-based scenarios. In addition, a fast Internet connection might change consumer behaviour and increase the overall material intensity on the macro level, as consumers with a fast Internet connection are more likely to stay online all the time or to download more music.

An initial conclusion from the research[31] is that ecommerce can – under specific circumstances - provide significant resource efficiency potentials. This seems especially true for physical products that are shifted to e-services. Hereby, the product is dematerialised, this means that the new ecommerce service is based on a highly dematerialised product per unit of service delivered. A music-server for example can provide a tremendous number of service units to many consumers and online music has therefore a low material intensity per service unit. Other examples of dematerialised products are centralised voice mailing servers,[32] or news servers.[33]

This shift from product-based commerce to e-service requires that the service provided by the product is purely informational. Groceries for example, cannot be supplied via the internet. Thus, product-based ecommerce appears to incorporate a lower dematerialisation potential.

The application of ICT for economic transactions will lead to economic advantages such as greater transparency or a larger geographical scope, reduced transaction costs and an increase in efficiency in the supply chain. With respect to the PCS, greater efficiency does not necessarily lead to favourable environmental outcomes, if more efficient use of some production factors also implies greater use of the environment as a production factor.[34] As long as environmental resources are not allocated efficiently or treated as a common good, or specific environmentally negative activities, such as certain modes of transport, are subsidised, the overall impact of ecommerce can be negative.

Further looking on PCS it has to be keep in mind that the rapid innovation pace in the ICT sector is not always matched by the consumer's response. ICT products and services are rarely used by consumers to their full potential. For example multi-functional ICT products (e.g. handhelds) are very often only used to fulfil one single function. This example shows the importance of understanding consumers' behaviour,

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[30] Kuhndt, M., von Geibler, J., Türk, V., Moll, S., Steeger, S., Schallaböck, K.O., Utzmann, I. (2002). Virtual Dematerialisation: Ebusiness and Factor X. Interim Report to the European Commsion. Wuppertal Institute. Wuppertal, Germany.
[31] Kuhndt, M., von Geibler, J., Türk, V., Moll, S., Steeger, S., Schallaböck, K.O., Utzmann, I. (2002). Virtual Dematerialisation: Ebusiness and Factor X. Interim Report to the European Commsion. Wuppertal Institute. Wuppertal, Germany.
[32] Reichling, M., Otto, T. (2002). Environmental Impact of the New Economy, In: Park, J., Roome, N. (Eds.) Ecology of the New Economy. Greenleaf.
[33] Reichart, I., Hischler, R., Schefer, H., and Zurkirch, M. (2000). Umweltbelastung durch Internet-Surfer, Fernsehzuschauer und Zeitungsleser [Environmental impacts of surfing the Internet, watching TV and reading a newspaper]. Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA), 2000.
[34] Stiller, H. (2002). In: Andretsch, D., Welfens, P. (2002). The New economy and economic growth in Europe and the U.S." Springer.

as well as assessing their needs, in order to ensure that the resource efficiency potential offered by new products and services is tapped by consumers (Figure 5).

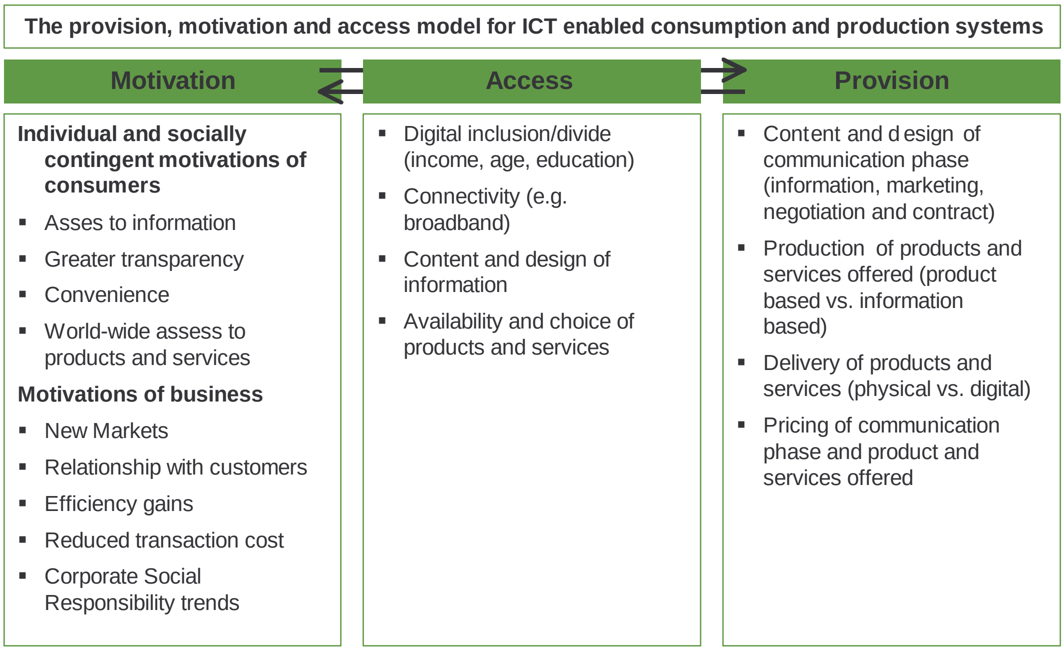


Figure 5: The ICT consumption and production system according to the PMA model

## Developing PCS indices

While the need for sustainable consumption and production is widely acknowledged, the means to achieve this aim are likely to vary for different economic sectors and regions. Consumption patterns are the consequences of choices that individuals make, which can vary between and within different countries and cultures, based on specific sets of value-systems.[35] If policies and strategies are to be effective, they must capture these differences. The PMA model can assist business in attuning product and service development to the entire PCS.

The three elements of the PMA model are potential intervention points for changing unsustainable CP patterns. Actions towards more sustainable patterns can also be grouped into three broad areas, targeted at different stakeholder groups, yet interlinked: information and awareness (targeted at consumers), production and product improvements (by business), and equity (targeted at governments and international agencies).[36] New approaches to Factor X strategies are suggested that address the two sides of the equation, production and consumption, and search for solutions in the PCS. While work on a PCS indices set is ongoing, this paper presents the initial ideas garnered, structured in three different phases[37].

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[35] UNEP 2002. Proposal for a Work Programme on promoting sustainable consumption and production patterns. Briefing note for distribution at WSSD. http://www.uneptie.org/outreach/wssd/

[36] Ryan C. 2002. Sustainable consumption – A global status report. Draft for comment, April 2002. UNEP.

[37] Examples of indicators draw on Wuppertal Insitute's work and on OECD 2001. Sustainable consumption: sector case study series. Household food consumption: trends, environmental impacts and policy responses. Paris, December 2001.

**1. Examining the potential for Factor X in the product/service life cycle**

The first phase addresses the impacts side, whereby the impacts of a product/service are identified along the life cycle, encompassing production and consumption. Indicators that measure resource efficiency, such as the material intensity per unit of service (MIPS) are useful in this phase.

**2. Assessing the current levels of consumers' demand and producers' provision**

The next phase is to assess the level to which the consumers are demanding and the producers are producing more sustainable products/services.

***Consumers****:* examples of indicators in the food sector include:

- Share of products from e.g. organic, integrated, conventional and greenhouse production
- Share and per capita consumption of food products with different degrees of processing (fresh, chilled, conserved, deep-frozen, pre-prepared, ready made, self-service and restaurant)

***Producers****:* examples of indicators in the food sector include:

- Share of fair trade products or organically grown produce on the market
- Number of information and education campaigns targeted at the consumer

**3. Understanding consumers' and producers' motivations and access to products/services**

The second phase aims to understand the motivations and potential of both consumers and producers to promote more sustainable solutions within the PCS.

***Consumers****:* new provision systems must reflect local cultures and values, to ensure that the products and services meet the motivations of consumers and can be accessed by them. Indicators in this area must capture *access* and *motivation*. Examples of indicators in the food sector include:

- Per capita availability of products from e.g. organic, integrated, conventional and greenhouse production *(access)*
- Per capita average distance and mode of transportation for food transports *(access)*
- Distribution and energy use of household appliances for food storage and preparation *(access)*
- Willingness to pay for organically grown produce, or fair trade products *(motivation)*

***Producers:*** drawing on the results from phase 1, product/service development and improvement must be based on life cycle thinking, to ensure that the most significant impacts are effectively addressed. Indicators in this are must capture *motivation* and *preparedness*. Examples include:

- Top management commitment to sustainability issues e.g. defined environmental goals, involvement with CSR issues *(motivation)*

- Innovative corporate culture e.g. number of new product entries to the market/year, number of life-cycle thinking applications/year *(preparedness)*

## Concluding remarks

The initial insights into provision, motivation and access aspects of the food and ICT sector highlight the importance and the benefits to business that can arise from addressing the entire PCS. Capturing life cycle issues and the consumers' potential response in product development helps guarantee the success of more sustainable products and hence contribute to more sustainable patterns of consumption and production. This paper sheds light into a number of issues and raises questions for further research:

**Differences between the food and ICT sectors**: Different sectors have varrying levels of preparedness and motivation for promoting more sustainable products/services, both from the consumer and the producer sides.

- In the ICT sector, intangible products can be of value for the consumer, whilst in the food sector only tangible products are delivered. In that regard, the physical form of the product becomes a major factor in the purchase decisions.
- While the infrastructure is a key determinant in the ICT sector, it is rather the primary production method, the transportation mode and packaging that are of strategic significance in the food sector.
- In the food sector, the scope for multi-functional products is quite limited compared to the ICT sector. Even though there are products that offer additional health benefits such as some diary products or diabetic products, such features do not bring in environmental benefits as in the ICT sector.
- As the food PCS is strongly linked to cultural and ethical concerns, Factor X solutions along the food supply chain hence need to be identified in the regional context. The ICT sector, in turn, is more prone to global solutions for sustainability, as production is organised internationally.[38]

**Need to address direct as well as indirect consumption:** business cannot limit product/service development considerations to direct consumption, but rather needs to include potential "indirect consumption" activities that may arise. Product/service development hence needs to capture motivation, access and consumption practices aspects.

- Product/service development and innovation in the ICT sector is often attached to considerable infrastructure requirements (rebound effect), which need to be balanced with the direct efficiency gains.
- Typical examples in the ICT sector are printing emails, and burning CDs with music provided online, which means that the initial efficiency gains are offset by increased consumption of other resources.

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[38] Friends of the Earth Netherlands 2002. Sustainable Produciton and Consumption - a global challenge. Pg.15

- In the food sector, examples such as the Odin initiative (Box 1) can also lead to "unnecessary consumption" in the cases when the provision levels exceed the expected needs.

**The need for information feedback to the consumers**: information to consumers can play a critical role in changing motivations.

- This is especially true in the food sector, where cultural and ethical values are paramount, and where the consumer is increasingly interested in knowing more about the products and their origin.
- Multi-functional ICT products may prove unsuccessful if the consumer lacks the information about the benefits it offers. An example is the measurement of the impacts resulting from the consumers' activities, through the incorporation in the product or the provision of feedback to the consumer.

**Need to involve relevant stakeholders**: while the hitherto work has focused on the consumer and the producer, all relevant stakeholders need to be addressed if unsustainable patterns of consumption and production are to be changed. This can be achieved through stakeholder involvement initiatives promoted by business, and through the extension of the PMA model to include other stakeholders, such as governmental agencies, civil society in general, and financial institutions. The PMA model may also be useful to understand regional differences within the same economic sector, facilitating the adaptation of product development to the regional context.

# Economic Modelling of Sustainable Consumption Patterns for Mobility and Heating

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## 1. Introduction

The past decades of environmental concern have been mainly associated with the negative impacts of production on the environment. The issue of sustainable consumption emerged as political and research topic after the Rio Earth Summit in 1992. Consumption processes are increasingly recognised as a prerequisite for sustainable development. Consumption processes influence production processes and imply the use of resources. Rising consumer demand on the one hand puts a strain on the environment as rising material and energy input is needed to satisfy demand. On the other hand rising material intensive consumption is accompanied by increasing amounts of waste.

The paper stems from a research project on modelling and quantification of changes in consumption behaviour in the areas of room heating and mobility in Austria[39]. The paper starts out with an overview of the international research on sustainable consumption and gives some examples of national and international initiatives to enhance changes in consumer behaviour. It then presents the results from an economic model aiming at quantifying the economic effects of changes in the structure of private household demand, which can be regarded as sustainable consumption patterns. This approach moves well beyond traditional economic theory, incorporating other than economic factors that influence consumer demand. The focus was laid on consumption services that generate economic welfare, and which are produced by a combination of stocks (e.g. housing with improved thermal quality) and flows (largely energy). Finally, some concluding remarks and policy options to bring about these changes in consumption behaviour are offered.

## 2. Measuring the Environment

In order to include aspects of sustainable development in economic modelling, adequate information systems that depict the flows and interactions between environment and economy are necessary. The following paragraphs give a short overview of such information systems, namely approaches for environmental accounting and sustainability indicators.

### *2.1 Environmental Accounting*

Several methods for capturing and assessing the environment and environmental services have been made available over the last few decades. These approaches attempt to achieve the most comprehensive integration possible of environmental factors in national accounting systems.

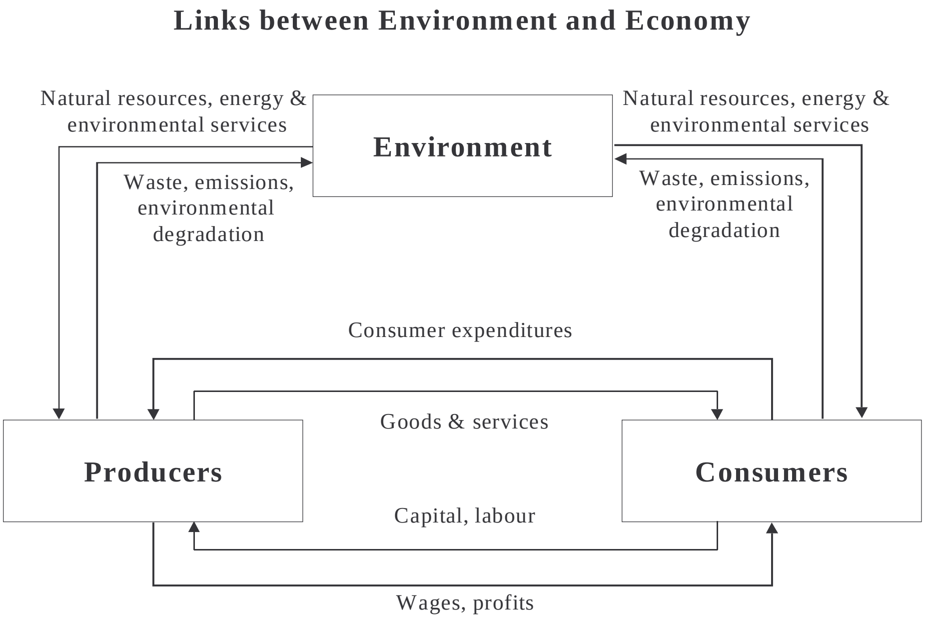
[39] The project results have been published in Kletzan et al. (2002).

As part of its revision of the System of National Accounts (SNA) in 1993, the United Nations devised and published the Integrated System of Environmental and Economic Accounting (SEEA) (http://www4.statcan.ca/citygrp/london/london.htm).

The underlying motives for producing a system capable of reflecting and securing internationally valid standards for environmental accounting derive to a large extent from the recognition that (environmental) problems arise as a result of interactions between economic and ecological systems. Fig.1 presents in simplified form the various interactions, which take place between the economic and environmental system. Included here are the normal transactions described in national accounts, as well as physical flows and environmental effects.

The flows of environmental inputs into the economic system in the form of raw materials, energy and environmental services are depicted. The cycle is then closed with the production of waste material and the deterioration of environmental quality resulting from economic activity.

Figure 1: Interactions between Environment and Economy




Source: http://www4.statcan.ca/citygrp/london/london.htm.

### 2.2 *Indicators for sustainable development*

To assess whether production and consumption patterns are compatible with sustainable development, indicators have to be developed. These illustrate the interdependencies and causalities between human activities and changes in the environment and make the progress towards or the distance from sustainability measurable. In order to serve as a basis for political or societal decision making, indicators ought to include all economic, social and environmental aspects of sustainable development. On the international level, different approaches are used to develop (sets of) indicators for sustainable development.

An approach that is frequently used is the "Pressure-State-Response" model that illustrates ecological-economic interdependencies and the environmental effects from economic activities, as well as from policy measures. Pressure indicators assess the causes of environmental problems (e.g. emissions from car traffic), state indicators describe the actual situation (e.g. concentration of air pollutants), whereas response indicators present policy instruments and measures to reduce pressures. The effectiveness of those instruments can in turn be measured by the change in pressure and state indicators[40].

A second approach is the development of indices, which aggregate several indicators with similar properties. Such indices are comparable to economic key data like the GDP. The advantage of this approach is to present one single figure, which measures a society's performance in terms of sustainability. The disadvantage is the necessity to weight heterogeneous factors (e.g. different air pollutants) and thus to judge their respective hazardousness.

Aggregated indices are inter alia the "Index of Sustainable Economic Welfare" (ISEW) developed as a reaction to the shortcomings of the GDP in measuring welfare (Daly – Cobb, 1994, Stockhammer et al., 1997). Another one-dimensional indicator is the "Ecological Footprint" (Wackernagel et al., 1999), which compares a society's demand for natural capital to sustain its production and consumption processes with the available supply, i.e. the countries' arable land, forest and water.

## 3. On the search for sustainable consumption patterns

In recent years economic research has shown a growing interest in the causes and consequences of material intensive consumer behaviour and its negative impacts on the environment. The research is driven by the search for more sustainable consumption patterns. Sustainable consumption refers to a rather new research area characterised by a great variety of theoretical and methodological approaches that go beyond neo-classical consumption theory. The research on sustainable consumption strives to integrate various disciplines in order to depict the driving forces of consumer behaviour and to derive policy instruments aiming at changing consumer behaviour.

Three main areas of research can be distinguished:

- Criticism and extension of the neo-classical "homo economicus". This research stems from an unease with the representative utility maximising consumer as explanation for consumer behaviour (Siebenhüner, 2000, Van den Bergh et al., 2000, Rabin, 1998, Duchin, 1998).
- Analysis of driving forces for material intensive consumption, focusing on economic, socio-psychological and socio-technical explanations (Røpke, 1999, Brown – Cameron, 2000, Douglas – Isherwood, 1980).
- Modelling of consumer behaviour within economic-ecological models. This research line focuses on modelling the heterogeneity of consumer behaviour and its impact on the environment e.g. within experimental economics (Gintis, 2000, Bossel, 2000, Jager et al., 2000).

Aside from the theoretical research on sustainable consumption, a number of research projects and initiatives have been carried out by international organisations or within

[40] See for example Jesinghaus (1999), Eurostat (2001), OECD (1998, 1999A, 2001), http://www.un.org/esa/sustdev/isd.htm.

countries[41]. The projects differ in the methodological approaches applied as well as in the consumption areas considered. The research is mainly focused on the empirical analysis and assessment of consumption patterns and the related environmental effects. The results should be used to develop policy recommendations for a move towards sustainability. Some of the projects also include direct action to change consumer behaviour and promote sustainable consumption patterns.

The surveyed research on sustainable consumption shows the need for further work on the integration of sustainability criteria in consumer demand modelling and the quantification of economic and environmental effects of changes in consumer behaviour. In the economic literature we find different approaches, which might be helpful for developing adequate consumer demand models for sustainability (see Wenke, 1993, Etzioni, 1985, Conrad – Schröder, 1991, Becker, 1965, Lancaster, 1966, Deaton – Muellbauer, 1980, Roth, 1998, Alston et al., 2001, Parsons, 1986). Important features in this respect are (i) an integration of sociological as well as psychological aspects into an economic model and (ii) a recognition of consumption expenditure as

## 4. Integrating new patterns of consumption into economic modelling

In order to illustrate sustainable patterns of consumption, conventional economic models have to be adapted and extended. The approaches described above provide essential guidelines on the changes needed. From these various approaches we derive a model of sustainable consumption for Austria in two areas of relevance to energy demand: heating and transport. The specific model elements are:

- Consideration of stock-flow relations.

Heating and transport can be provided by various combinations of energy flows and real capital (substitutive relation), as is also emphasised in the household production function approach. A model representing sustainable consumption patterns should therefore focus on the mix of stocks and flows. Moreover, consumption patterns are not only determined by relative prices: demand for stocks and for consumption services also depends on other economic and non-economic factors (e.g. the available infrastructure in a wider sense - road networks, public transport, settlement structure – has significant influence on the demand for services and (energy) flows). Depending on the general conditions different technologies with specific capital and energy requirements will be chosen (e.g. private vs. public transport). Our approach focuses – based on the household production function – on the transformation of energy flows into relevant consumption services.

- Adjustments costs in capital stock.

In our model of sustainable consumption various costs of adjustment in capital stock are taken into account: costs related directly to changes in the capital stock (e.g. purchase of fuel efficient cars, improvements of thermal quality of buildings) and changes in the

[41] For an the research on sustainable consumption carried out by the OECD see OECD (1999B, 2000A, 2000B, 2002), Payer et al., 2000. For various research project on national level see Vittersø – Strandbakken – Stø, (1999) Stø – Vittersø – Strandbakken (2000), Brand, (2000), Noorman – Schoot Uiterkamp (1998), Empacher et al. (2000).

demand for flows (e.g. modification of transport and travel behaviour, energy demand for heating). In this context the relation between (costs of) capital stock and expenditures for non-energy consumption are of relevance. The substitution of capital for energy flows reduces energy consumption but at the same time expenditure for capital has to be compensated by a reduction in non-energy consumption.

- ‘Demand shifts’ as possible (exogenous) changes in preferences.

The move towards sustainable patterns of consumption can also be brought about by an alteration of preferences that cause demand shifts. A specific module based on data from the Austrian consumer survey 1999/2000[42] incorporates these demand shifts in our model. Sustainable households are defined as those showing exemplary behaviour in relevant consumption areas. That is, given a certain level of income sustainable households have relatively low expenditure for energy and transport. The households covered by the consumer survey are subsequently divided into "sustainable" and "less sustainable" ones. In the resulting ascending ranking of the expenses for heating and fuel 50% of households are defined as showing sustainable consumption behaviour.

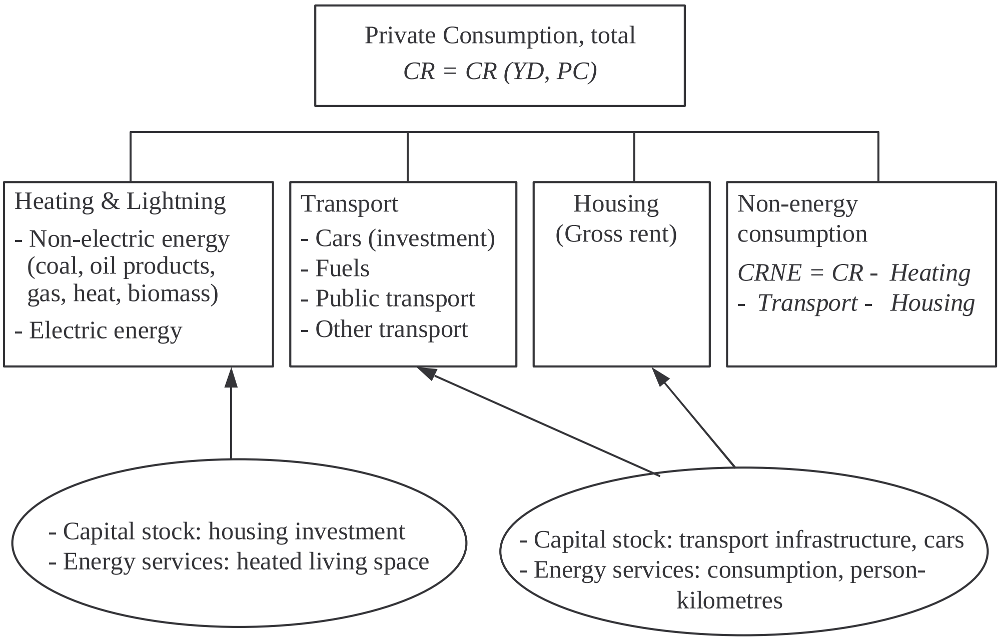
Using econometric functions on the consumer survey data set the preferences of the respective household types are derived, subject to their economic situation (level of income), their age, characteristics like size and composition, location (population density) and capital endowment (e.g. car ownership). Then, expenses for heating and transport are standardised for uniform household characteristics (income level, age, household composition, location). The resulting differences in expenditure between sustainable and less sustainable households are interpreted as demand shifts due to sustainable consumption patterns. On the average sustainable households spend 60% less for heating and 55% less for fuel than less sustainable households. These results indicate the magnitude of changes necessary to achieve a certain sustainability target: for example, a decline of 20% in expenditure for fuels would require an increase in the share of sustainable households from 50% to 76%.

Based on the above considerations (stock-flow relations, capital stock adjustments, demand shifts) a general consumption model (Figure 2) was developed. The model is based on econometric estimations of consumption expenditure from national accounts as well as on physical energy and transport data from various sources. All data are available from 1976 to 2000. The model can be characterised as a partial econometric model of microeconomic consumption. The major components of this model are: Production functions for energy services (e.g. heating, mobility), an equation to describe capital accumulation (e.g. investment in renovation and thermal insulation, purchase of vehicles), and demand functions for energy services. Demand functions for market goods are then derived from the production functions. Here, demand is not, as in the neo-classical approach, made solely dependent on relative prices, but adjusted in such a way as to reflect the stock of capital in infrastructure, which is treated as a quasi-fixed factor. The demand for energy services is modelled separately, where the effects of

[42] The consumer survey is carried out in order to derive a weighting scheme for the consumer price index. The survey does not only collect detailed data on consumer behaviour over a whole year, it facilitates its quantification with respect to demographic and socio-economic characteristics. The 1999/2000 survey covered a sample of 7098 Austrian households, and included data regarding consumer expenditure, income, the households' endowment as well as their living conditions and environmental awareness.

demand shifts are considered. Demand shifts represent changes in consumer demand towards more sustainable patterns of consumption.

Figure 2: Overall model of consumption




CR private consumption, total

YD household disposable income (nominal)

PC price index for private consumption, total

CRNE private consumption, non-energy

Total (real) private consumption is expressed as a function of real household disposable income. In order to allow for more differentiation within this aggregate, the following categories are considered separately: housing, heating/lighting, transport, and non-energy consumption. It is assumed that no explicit substitution takes place between these categories, but rather, for given levels of aggregate consumption and expenditures on housing, heating/lighting and transport, non-energy consumption is treated as a residual.

Subsequently, sustainability scenarios (in terms of $CO_2$ emissions) were formulated and 'ex post' simulations were carried out for the period 1990 to 1998. For defining the sustainability target a rather pragmatic approach was chosen. Consumption in the areas of heating and transport was said to be sustainable when over a ten year period it led to a reduction of households' $CO_2$ emissions of 13% compared to the level in 1990 (Austria's Kyoto target). The results of the ex post simulations reveal to what extent actual emissions diverge from the target set. The gap between the two time paths (actual vs. "sustainable" emissions) shows that substantial intervention would be needed in order to redirect consumption patterns and thus reduce consumption related $CO_2$ emissions.

While the use of such a one dimensional criterion for defining sustainability obviously cannot capture all aspects related to sustainable consumption, it still helps to clarify which structures need to be considered in economic modelling of sustainable consumption patterns.

The simulations indicate to what extent changes in specific consumption areas would have to be made, in order to induce, over approximately a decade, a move towards more sustainable consumption. Such changes result, e.g. from policy interventions or from alterations in social values. Technological innovation is likely to be just as much of help as is demand management policy.

To aid comparison, 'maximum settings' were used in the simulation runs, i.e. in each of the scenarios, and thus for every exogenous intervention, the sustainability target had to be reached (the above mentioned 13% reduction in $CO_2$ emissions). This facilitates direct comparison of the various simulation results and changes in technology, prices and behaviour are thus made visible. The results indicate that any attempt to achieve the 13% reduction in $CO_2$ emissions by concentrating on specific single measures would involve intense or excessive effort. It seems that moving prevailing consumption behaviour towards a more sustainable form is only likely to succeed when a bundle of policy instruments is used. This also includes non-quantifiable factors like awareness raising or education.

With respect to transport, the following sustainability scenarios were defined and calculated:

'Road Pricing': a kilometre fee for cars is introduced and then returned to households through a lump sum payment ('eco-bonus').

'Zero Charge in public transport': the price of public transport is reduced and financed through an increase in vehicle tax.

'Regional Planning': the density of city population increases.

'Demand shifts': the share of 'conventional' households decreases in favour of more sustainable households.

With respect to heating, the following sustainability scenarios were defined and calculated:

'Building Regulations': minimum standards for thermal quality in housing induce investment in improving the building stock (buildings constructed between 1945 – 1980).

'Demand shifts': the share of 'conventional' households decreases in favour of more sustainable households.

Overview 1 summarises the changes in the respective variables in the various scenarios that are needed to achieve the Kyoto target in the period 1990 to 1998.

Overview 1: Policy Instruments for Sustainability Scenarios (Average 1990 - 1998)

| **Simulation Scenarios Transport** | | | | |
|---|---|---|---|---|
| Changes in variables | Road pricing | Zero charge | Regional planning | "Demand shift" |
| Road toll revenues | 1.8 bn € | | | |
| Vehicle tax (fixed costs) | | 0.34 bn € | | |
| Price of public transport | | -29.6% | | |
| City population density | | | 41 inhabitants per km² | |
| Change in shares of household types | | | | 14%points |
| **Simulation Scenarios Heating** | | | | |
| | | | Regulations | "Demand shift" |
| Capital stock, dwellings | | | 8.7 bn € [1]) | |
| Change in shares of household types | | | | 12%points |

[1]) of which only 2.9 bn € per year are due to investment in thermal improvement.

### *4.1 Sustainability Scenario 'Road Pricing'*

This scenario comes closest to representing a neo-classical environmental policy approach as it targets emission prices. A tax on kilometres travelled is proposed. This tax could be implemented in the form of a toll, or in the form of a vehicle charge per kilometre. The crucial aspect in this scenario is revenue neutrality (i.e. in total, there are no new net revenues generated since tax revenues raised are returned lump sum to households). The recycling of the revenues should prevent any negative macroeconomic impact. Ex post, i.e. after the desired change in demand, the road pricing policy generates € 1.8bn for the approximately 45bn km driven (average 1990 – 1998). This represents an effective charge of about € 0.04 per kilometre.

The road charge raises consumer prices by about 1.7%, while the return of the revenue to households has an opposite effect so that the net impact is close to zero. As a result, there is hardly any change in real household disposable income. Thus, given the fall in real expenditure on individual motorised transport, we see a corresponding increase in expenditure on non-energy consumption. Further, not only has fuel consumption fallen by 11.3% necessary to achieve the targeted $CO_2$ levels, all forms of expenditure on individual motorised transport fall too. This includes car purchases (approx. -15%) and vehicle fixed costs (-7.5%) since, similar to an increase in fuel tax, the road charge raises the variable costs of car use. Since the decline in the demand for public transport is only 0.9%, we also see a change in the demand structure for transport, with an alteration in the modal split between private and public transport. Summing up, the 'road pricing' scenario, in correspondence with the many other studies on energy taxation, shows that with respect to the standard indicators employed in national accounts, sustainable development can indeed be combined with positive macroeconomic effects (double dividend).

## 4.2 Sustainability Scenario 'Zero Charge in Public Transport'

The underlying assumption in this scenario is that the acceptance of public transport by consumers will increase. The extent to which cost considerations affect such changes in acceptance is also tested here. Thus, this scenario can also be interpreted as an example of neo-classical price regulation of emissions being used as an environmental policy instrument. In this sustainability scenario, the price for public transport is reduced by 30% on average over the period 1990 to 1998, and the resulting revenue loss experienced by the public transport companies is offset by an increase in vehicle tax.

The required fall in fuel consumption of 11.3% (given the $CO_2$ target) is achieved through the shift from private to public transport (+6.1%), and also through the various effects of the increase in vehicle tax on fuel consumption. The increase in the vehicle tax, which (ex post) generates extra tax income of € 363 million, has an impact on the average fuel consumption of the car fleet, and influences the real fixed costs of private transport, which in turn dampens vehicle purchases. I.e. fewer, and at the same time, more fuel-efficient vehicles are purchased in an effort to offset, at least partly, the increase in vehicle tax. The combined price and income effects result in a real decline of car purchases by 15% and a real decline in fixed costs related to car ownership by 25%. In total, we see here a smaller increase in non-energy consumption (+1.3%) than in the 'road pricing' scenario. Thus, in this scenario too, positive effects on non-energy consumption and accompanying advantages for the macro-economy are to be expected (see Overview 2). This scenario differs from 'road pricing' with respect to the compensatory payments (lump sum transfer) to offset the increased tax and to achieve a double dividend effect. Here, a double steering effect is achieved by targeting compensation specifically at a lowering of public transport prices.

In order to raise the attractiveness of public transport and to increase the steering effect still further, additional measures should be used at the same time (e.g. schemes to promote co-operation with taxi operators). It is also possible to make the idea of cost redistribution even more transparent for households by providing a direct link between the two cost elements. For example, the annual payment of vehicle tax could be automatically coupled with the provision of a public transport pass.

In this scenario, an increase in the average fuel efficiency of the car fleet and a decline in the distances travelled, both factors being a result of the increase in vehicle tax, lead to a fall in fuel consumption. The reduction in car fuel consumption as a result of the rise in vehicle tax, is at least as great as that arising from the changes in the modal split due to the decline in public transport prices.

## 4.3 Sustainability Scenario 'Regional Planning'

This scenario is based on the changes in lifestyles that occurred between 1990 and 1998 and which led to an increase in traffic volume. The central variable in the model is the ratio of the population density in rural areas (surrounding cities) to that in the cities. This ratio rose continuously throughout the period 1990–1998, reflecting a lifestyle of 'work in the city - live in the country'. In contrast to this consumer lifestyle, this scenario assumes that population movement would have led to increased concentration of residential and work areas within cities. This leads to a significant increase in city population density, with the respective figures going up by 40 persons per square kilometer (+29%). From our point of view, this sustainability scenario illustrates the interface between transport and housing. Regional shifts in the population have no impact on the total level of private consumption. This scenario reflects the idea of reducing redundant energy services without a decrease in the level of economic welfare. Since, however, only the expenditure on fuel consumption falls and other transport related expenses remain almost constant, we witness merely a slight shift between energy and non-energy consumption.

### 4.4 Sustainability Scenario 'Demand Shifts' in Transport

This scenario analyses the effects of an increased share of more sustainable households. The distinguishing characteristics are changes in transport behaviour. In order to achieve the $CO_2$ target in this scenario, the two household types – as described above - are no longer grouped by the median value. An emission reduction of 13% would call for a share of 64% of households to engage in more sustainable consumption, and only 36% could maintain their conventional consumption behaviour. This assumption leads to an expenditure shift between private and public transport with transport costs remaining constant. In total, this leads to a slight increase (+3%) in kilometres travelled. The analysis of consumption expenditure for each household type showed that 'sustainable' households tend to have lower total consumption expenditure than 'normal' households (given the same income). The shift in the household structure thus leads to a decline in total real private consumption by about 2%, whereby non-energy consumption falls by 2.6% (see Overview 2).

### 4.5 Sustainability Scenario 'Building Regulations'

This scenario assumes an improvement in the thermal quality of the building stock constructed in the period 1945 to 1980 in order to achieve the targeted emission level. For the simulation it is assumed that certificates to proof minimum standards of energy efficiency are demanded in building regulations. This would then trigger the necessary investment in renovation and improvement (a sum of € 2.9bn). In the model, household investment in the necessary improvements is financed by an increase in expenditure on housing.

To achieve the emission target, consumer expenditure on heating/lighting has to decline by 11.7% (in real terms) and the capital stock of housing in terms of thermal quality would have to increase by € 8.7bn on average for the period 1990 to 1998. In the simulation the least favourable case for households is used, i.e. it is assumed that households have to finance renovation themselves (without public subsidies) and that all renovation costs are ascribed to emission reduction[43]. It can be assumed that investment in renovation, by leading to an improvement in the quality of housing stock, will in fact also exert a positive effect on household welfare. Financing renovation, however, puts a considerable burden on households, leading to an increase in real expenditure on housing of 2.3%. With no change in total expenditure for private consumption, this in turn leads to a decline in non-energy consumption by 0.3%.

### 4.6 Sustainability Scenario 'Demand Shifts' in Heating

Corresponding to the simulation for transport, this scenario leads to a shift in household structure with respect to heating/lighting, such that 62% of households would have to

[43] In reality, the overall costs can be divided into "conventional" renovation costs and costs that arise through thermal improvement of the building.

consume more sustainably, while 38% remain ‘conventional' in their consumption habits. Simultaneously, the differences in total expenditures for the household types were also taken into account. The shift in household structure thus leads to a decline in total real private consumption by 1.9%, with non-energy consumption falling by 2.3%.

Overview 2: Simulation Results for the Sustainability Scenarios ‘Transport’ (Average 1990 - 1998)

| | Road pricing | Zero charge | Regional planning | "Demand shift" |
|---|---|---|---|---|
| | Difference to baseline in % | | | |
| Consumer prices | 1.7 | 1.3 | - | - |
| Private consumption, total | 0.1 | -1.1 | 0.0 | -1.9 |
| Non-energy consumption | 2.0 | 1.3 | 0.5 | -2.6 |
| Private consumption (P 95) | | | | |
| Transport | | | | |
| Cars | -14.6 | -15.0 | 0.0 | - |
| Fuels | -11.3 | -11.3 | -11.3 | -11.4 |
| Public transport | -0.9 | 6.1 | -0.4 | 20.0 |
| Other transport | -7.5 | -24.7 | 0.0 | - |
| Transport activities | | | | |
| Person-kilometres, total | -12.7 | -10.4 | -12.5 | 2.8 |
| Person-kilometres, cars | -17.9 | -15.6 | -17.9 | -17.9 |
| Person-kilometres, public transport | -1.7 | 0.7 | -0.6 | 45.8 |

Overview 3: Simulation Results for the Sustainability Scenarios ‘Heating’ (Average 1990-1998)

| | Regulations | "Demand shift" |
|---|---|---|
| | Difference to baseline in % | |
| Private consumption, total | 0.0 | -1.9 |
| Non-energy consumption | -0.3 | -2.3 |
| Gross rent | 2.3 | - |
| Private consumption (P 95) | | |
| Heating | | |
| Heating & lightning, total | -3.5 | -11.7 |
| Electricity | 0.0 | -11.7 |
| Coal | -11.7 | -11.7 |
| Oil products | -11.7 | -11.7 |
| Gas | -11.7 | -11.7 |

## 5. Conclusions

International research on sustainable development is mainly focused on conceptual analysis and/or project based work. A central point is the reorientation of prevailing demand structures. In contrast, the integration and depiction of sustainable demand structures in empirical economic modelling is more or less new territory. The study for Austria presented here, can be considered a major step towards the integration of sustainable consumption patterns (for heating and transport) in an empirical consumption model (a partial model in the aggregate economy). In this context, an analysis of demand shifts was presented for the first time, a subject of central importance in the literature, and their respective impact was calculated within the overall consumption model for Austria.

In the present project specific focal points in the field of consumption behaviour were chosen as a basis for analysis. The modelling approach included a new and extended method for the measurement of economic welfare. The generation of consumption services (housing, mobility), and thus of economic welfare, out of a combination of stocks (e.g. housing with improved thermal quality) and flows (largely energy), is the primary focus of analysis. The analysis reveals that calculations based on flows alone can be highly misleading, particularly in the field of (sustainable) consumption.

The economic analysis of sustainable consumption patterns or structures attempts to clarify the extent to which it might be both possible or commendable to promote the substitution of flows by stocks (e.g. improvements in thermal quality of buildings, or more energy efficient transport systems). Relevant too, in this respect, is the role that can be played by technological innovation (improvements in the existing building or vehicle fleet stock, or the potential for introducing specific incentives to promote new technologies). Two essential factors are crucial in the context of sustainable consumption: the demand shifts concerning the consumer services desired, and the composition of the stock-flow mix necessary for the service provision.

In accordance with the above considerations, the following adaptations were introduced to distinguish present analysis from that found in conventional models:

- Instead of an economic analysis of consumption flows, attention was focussed on the level of consumption services achieved through stock-flow combinations,

- Stock-flow relations were explicitly modelled,

- The integration of technological innovation into the interplay of stocks and flows and the respective impact on consumption services affecting welfare,

- Demand shifts as a result of changes in lifestyle were taken into account.

Thus, economic policy has three principal ways of affecting consumption patterns: by influencing shifts in demand (e.g. through campaigns to raise public awareness), by acting on relative prices (e.g. those of stocks and flows), and by creating incentives to promote suitable technological progress (e.g. investments in infrastructure, or specifically targeted R&D programs).

The empirical evidence produced by the model reveals that economic instruments – in this case taxes and road pricing – can generate positive macroeconomic effects. This result is consistent with the evidence of several other studies that have been undertaken to test the effects of incentive based instruments in environmental policy. What is new in the present research is the strong focus on consumption services. It was found that not only flows of consumption goods and services alone generate economic welfare. The crucial point is that it is a combination of those flows with a specific capital stock that leads to the achievement of the desired consumption service.

Although the results appear positive for the macro-economy, and despite theoretical confirmation of their potential efficiency, political realities show little use of such policy measures. A prerequisite for successful implementation of such measures is the willingness to accept major changes in the existing economic framework. Macroeconomic effects are clearly only one part in the total assessment process. Other data found in the simulations would appear to be more important for political decision making. This includes: information on the starting points chosen for the policy interventions and the extent of possible effects on prices, tax rates, capital stock etc.

For the first time, the model framework makes it possible to assess the economic impact of shifts in demand. In the concrete case, this means that as far as the demand for energy in the areas heating and transport is concerned, the model is capable of determining how high the shift in the share of Austrian households towards more sustainable consumption would have to be, in order to reach the target set. The explanatory and predictive power of the model are largely exhausted in answering how these shifts in demand are propagated or how large monetary incentives need to be in order to induce such changes in consumption behaviour (demand shifts). Looking at the issues in qualitative rather than quantitative terms, however, it can be assumed that apart from changes in consumption, the realisation of structural change on the supply side should also prove possible. The interactions between technology and changes in public awareness becomes clear. Such complexity makes it all the more necessary that political objectives are stated as explicitly as possible.

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# Life-cycle based methods for sustainable product development

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## Abstract

Sustainability - a term originating from silviculture, has been adopted by UNEP as the main political goal for the future development of humankind - is also the ultimate aim of product development. It comprises three components: environment, economy and social aspects, which have to be properly assessed and balanced if a new product is to be designed or an existing one is to be improved. The responsibility of the researchers involved in the assessment is to provide appropriate and reliable instruments. For the environmental part we have already an internationally standardized tool: Life Cycle Assessment (LCA). Life Cycle Costing (LCC) is the logical counterpart of LCA for the economic assessment. LCC surpasses the purely economic cost calculation by taking into account hidden costs and potentially external costs over the life cycle of the product. It is a very important point that different life-cycle based methods used for sustainability assessment (or life cycle management (LCM)) use the same system boundaries. This is not trivial since in economy the "life cycle" of a product is often defined in a different way compared to LCA. The social aspects of sustainability have not yet been adequately described in terms of sustainable life cycle management. This points to an important research gap, which has to be overcome in the near future. Finally, once the methods for economic and social assessment will be developed, the most promising ones should be standardized by ISO.

## Objective

Sustainability is a broad and not precisely defined term, a guiding principle or goal laid down by the United Nations Conference of Environment and Development (UNCED) in Rio de Janeiro, 1992. In order to fill this principle with life, all sectors of society in all countries have to redirect their activities, which presently nearly exclusively aim at (economic) growth. In this lecture, product development is in the focus of the analysis. It is hoped, however, that also other fields of economy and society can profit from ideas conceived for a rather narrow sector of human activities. It should be noted that similar concepts have been put forward, as Life Cycle Management, Ecoefficiency, Integrated Product Policy, and Industrial Ecology, which try to achieve sustainability or at least to move in the right direction. The problem for responsible decision makers consists in weighting different approaches, technologies, product lines, etc. within an increasingly global business world. It is the duty of researchers and experts of different fields to develop and improve methods that can be used to operationalize the guiding principle of sustainability. What is ultimately required are simple-to-use (but not necessarily simplistic!) methods which give reliable results as a basis for decisions at different levels of the society (industry, politics etc).

## Sustainability

The term "sustainability" (in German: "Nachhaltigkeit") originates from silviculture and means that only as much wood is removed from the forests as grows again in the long run [1]. Cultivation and care are the prerequisites of sustainable forestry. Hans Carl von Carlowitz, the founder of this practice recognized well the economic and social implications of his idea (in his main profession, he was the superintendent of the saxonien silver mines in the early 18th Century). He therefore may also be considered as the father of sustainability in the modern sense of the word. In the global political arena, the term sustainability became popular through the report "Our Common Future" by the World Commission on Environment and Development, better known as "The Brundtland Report" [2]. In this report, environmental protection is linked with global development and emphasizes the responsibility humankind has for the future generations. This can be recognized in the famous definition: "Sustainable development is development that meets the needs of present without compromising the ability of future generations to meet their own needs". There is a high moral claim in this principle and a lack of guidance, how this aim can be reached.

At the United Nations Conference of Environment and Development (UNCED) in Rio de Janeiro, 1992, sustainable development was laid down as the most important task of the 21st century. Moreover, in the Agenda 21 many political and industrial areas were analyzed with regard to sustainable development and possible improvements have been presented. From here on it has been clear that three aspects (the three "pillars" of sustainability) have to be considered and brought together: **Ecology** (Environment), **Economy**, and **Social aspects.**

There seems to be consensus about that the three pillars, but not about the relative weights of these aspects. Industrialized countries tend to emphasize the environmental aspect (at least the green movements, the environmental agencies, and some companies as well), whereas developing countries give highest priority to economic development. As understandable these different priorities may be, they undermine the spirit of Gro Harlem Brundtland´s and UNCED´s conception. What is needed from an methodological point of view - that´s the field where researchers can and should contribute - are assessment methods allowing to distinguish between developments which are more or less sustainable and those which are not at all. The results of studies based on such methods could be used by decision makers to make the right decisions. Concentrating on products (including services) in the following, I hope to show that we are not starting at zero, since several methods already exist, which have to be refined and combined.

## Life Cycle Methods

### *Why life-cycle based?*

Any environmental, economic, or social assessment method for products has to take into account the full life cycle from raw material extraction, production to use and recycling or waste disposal. In other words, a systems approach has to be taken. Only in this way, trade-offs can be recognized and avoided. Life cyle thinking is the prerequisite of any sound sustainability assessment. It does not make any sense at all to improve (environmentally, economically, or socially) one part of the system in one country, in one step of the life cycle, or in one environmental compartment, if this "improvement" has negative consequences for other parts of the system which may outweight the advantages achieved. Furthermore, the problems must not be shifted into the future [2]. The second point is that life cycle thinking is not enough, since in order to estimate the magnitude of the trade-offs, the instruments required have to be as quantitative as possible. Since we are living in a global economy (which from the European perspective started in the 15$^{th}$ century, not as recently as often claimed), the system boundaries used in the methods have to be global as well. In this context, the life cycle initiative jointly launched by UNEP and SETAC deserves high attention and support [3].

### *Environmental Life Cycle Assessment (LCA)*

Product-related life cycle assessment with an emphasis on energy, resources, and waste started around 1970 [4-6]. It was the time of "The Limits to Growth, a report to the club of Rome" [7] and the first oil crisis soon afterwards showed, if not the shortage of oil, but the vulnerability of the global economic system. Twenty years later, LCA (now officially under this name) was developed by SETAC [8,9] and later on standardized by the International Standardisation Organisation (ISO 14040-43; TR 14047,49; TS 14048). The first round has been finished [10] and LCA can now be considered to be the first and only internationally standardized environmental assessment method.

The basic principles of LCA, which together distinguish this method from other environmental assessment methods, are:

- The analysis is conducted "from cradle to grave"
- All mass- and energy flows, resource- and land-use, etc. and the potential impacts connected with these "interventions" are set in relation to a "functional unit" as a quantitative measure of the benefit of the system(s)
- LCA is essentially a comparative method (also improvements of one system are compared to the status quo).

In short: two or more **systems** are compared on the basis of a common benefit in a "holistic" way. The advantage of (at least theoretical) completeness is partly set off by the uncertainty where and when exactly some of the processes, emissions, etc. occur and which ecosystems or how many humans may be harmed and whether or not thresholds of effects are really surpassed. Furthermore, the magnitude of the functional unit is usually fixed arbitrarily in wide margins; for instance, the functional unit for comparing different containers for beverages may be the filling of 1, 100 or 1000 liters (but not 1 bottle or barrel!). As a consequence, the absolute amounts of the "interventions" have no meaning and concentrations of emitted substances cannot be calculated. The additional use of other, often complimentary - albeit not standardized - methods (e.g. risk assessment, material- and substance flow analysis) has therefore been recommended for the sake of decision-making [11].

One advantage of standardization is that LCA has a clear structure, which essentially goes back to SETAC [9], and now consists of the following four components (ISO 14040): **Goal and scope definition, Inventory analysis, Impact assessment, and Interpretation** (formerly Improvement assessment [9]). If comparative assertions (system A better than or equal to system B) are made available to the public, a "critical review" is mandatory (ISO 14040 § 7.3.3) [12]. This and many other "obstacles" were built in the ISO-series of LCA standards in order to prevent the misuse, especially by false claims based on sloppy LCAs. As a consequence of these preventive measures, a full LCA to be used publicly has become a somewhat lengthy procedure. Of course, the learning process, which is perhaps more important than the numerical results, is more rewarding in a long and carefully conducted LCA study compared to a "quick and dirty" one. On the other hand, during the design phase, there is not much time and therefore simplified methods were proposed and also compared with each other [13]. In "Design for Environment", a compromise has to be found between a reasonably comprehensive coverage of the life cycle and the time needed for data collection and modeling. The actual calculation process is fast due to the elaborate LCA software, which is available nowadays.

### *Economic Life Cycle Assessment (LCC)*

The economic counterpart of LCA is known under several names, as Life Cycle Costing (LCC), Full Cost Accounting (FCA), Total Cost Assessment (or Accounting) (TCA) [14-16]. Also conventional cost accounting of products includes life cycle aspects, since the costs of raw- and intermediate materials enter into the calculation. Costs involved in the use of products and in waste removal, or recycling generally do not show up (with the exception that in special cases the producer may have to take-back the product or pay for the waste collection, as in the case of the German "Green Dot" system). The main difference between conventional cost accounting and LCC or TCA consists in accounting for "hidden" or "less tangible" costs, including costs for environmental protection [14,17]. Of course, also these costs are included in conventional cost accounting, mostly in the form of overheads, but they are not attributed clearly to a specific product system. As in LCA, this clear attribution to a product system is important for assessment in order to estimate the true costs (LCC) or true environmental interventions (LCA) of the product (system) to be compared with another one which fulfills the same function or has the same benefit.

White et al. define Total Cost Assessment as the "long-term, comprehensive analysis of the full range of internal costs and savings resulting from pollution prevention projects and other environmental projects undertaken by a firm" [14]. In this method, also the **economic benefits** of pollution control measures are included, whereas in conventional accounting only the costs of pollution prevention would be taken into account. This inclusion of positive trade-offs clearly indicates life cycle thinking. The term "life cycle", however, is often defined in another way in the economic sciences, namely as the sequence product development - production - marketing/sale - end of economic product live; as noted by Norris [15], this economic "life cycle" may be even shorter in some products than the physical life cycle ("cradle-to-grave") used in LCA. In a further step, even the external costs due to environmental damages connected with the products may be included [14,17]. These costs are not incurred to the company, but rather to society or even to future generations. The quantification of these costs is difficult, since it is often not clear, which damages are - or will be in future - connected to the interventions caused by a product system. Furthermore, some damages (e.g. ethical and esthetical ones) cannot be expressed in monetary terms or even the attempt to monetarize sounds clearly repulsive (what is the monetary value of a human?). There is also the problem of double counting if LCA and LCC is applied and LCC includes external effects. In this case, the external costs are expressed in monetary units **and** in "environmental units", i.e. in impact category indicator results according to ISO 14042 or in "ecopoints" etc.

### *Social Life Cycle Assessment (SLCA)*

SLCA is the least developed life cycle method, indicating a research gap. O`Brian et al. described an attempt to combine SLCA with (E)LCA to a method called "Social and Environmental Life Cycle Assessment" (SELCA) [18]. It is interesting to note that the purpose of this integration was quantifying sustainability. SLCA, according to these authors, consists of the components "Problem definition scoping", "Data analysis", "Process assessment", "Evaluation", and "Action". Data analysis is equivalent to Inventory analysis, Process assessment to Impact assessment. Although it seems difficult to combine concepts and data from so different fields as sociology and technology, it is clearly worth trying. It should be mentioned that also the German "Product Line Analysis", basically an early LCA, includes economic and social assessment components [19].

## Conclusions

I hope to have shown that only life cycle based methods have the potential for sustainability assessments. The methodological problem consists in combining the existing and new methods into one suitable instrument. It should be noted that **equal and consistent system boundaries** have to be used for environmental, economic, and social life cycle assessment. It is suggested that the physical rather than the economic life cycle definition is used throughout. A lucid analysis of LCA and LCC with the aim of combining them to create an assessment tool for supply chain management has been presented by Rebitzer [20]. Including social assessment, as proposed by O`Brian et al. [18], could pave the way to a true sustainability assessment including the three main aspects of sustainable development.

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## Indicators for Environmentally Sound Household Consumption

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### 1. Introduction

Households, through their demand side influence on the economy are a major actor to reduce environmental burdens. However, the ability to make a relevant contribution towards a more sustainable consumption and production system depends on

- Information where they can make a difference and
- An appropriate framework setting of other relevant actors.

The involvement of all "major groups" of society is one of the main institutional innovations the sustainability discourse and Agenda 21 have brought about. Another is the development of indicators for sustainable development as concrete, issue-related guidance for taking and evaluating action.

So the issues of sustainable consumption and the appropriate indicators have been high on the political agenda ever since Rio 1992 (see e.g. VROM 1993, Miljoverndepartementet 1995, UN DESA 1998, OECD 1998a)

But so far no methodologies for a coherent set of indicators have been developed. Since most current sets of indicators for the environmental impacts of household consumption cover eclectically selected and widely differing aspects of the issue (UN DESA 1998, OECD 1998a).

The indicators presented in this paper are based upon

- calculations of resource consumption as key driving force of current environmental problems,
- relevance of consumption clusters and
- an estimate of actors' influence.

The limited and thus easily communicatable number of indicators results from the identification of dominating factors of resource consumption, which are covered by one or few indicators each. With these methodological innovations, weighting and aggregation problems prevalent in much of the current work can be overcome.[44]

The suggested indicators are based on significance analysis based on German data. However, given the similarities in economic patterns and consumption styles, they should be applicable to the majority of industrialised countries without major readjustments. It is possible, however, to adapt the system of indicators to the diversity of countries' size, their infrastructure, climate, heating requirements etc. by "tailor-made" modification of some of the existing ones, or by suggesting additional indicators.

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[44] For a detailed description of the methodology see: Spangenberg, J. H.: "An environmental based approach to assessing the environmental impact of household consumption" in the proceedings of this conference

These could be developed along the same line of thought (prioritising derived from consumption statistic) used in the study presented here. Some further modification of the selection criteria for consumption cluster indicators might be needed for developing countries due to global differences in wealth, preferences, consumption patterns, culture etc.

When analysing consumption clusters regarding their share in key resource consumption, it turns out that the total requirement of construction and housing, food and transport adds up to about 70% of material extraction, energy consumption and land use. Each single cluster represents more than 15% of energy and material consumption.

The indicator development will therefore concentrate on the three environmentally dominant areas identified as *priority fields of action*: construction and housing, food and nutrition, transport and mobility.

Based on existing data, for each priority field a few consumption issues are identified offering the most significant potentials for reducing resource consumption. These will be presented as “why households can make a difference“ and characterised by indicators. The relative influence of the different actors including private households is presented titled “actors involved“, with 0 = little influence, + = significant influence, and ++ = strong/dominating influence). These results are based on common sense; for a validation of these estimates or even for their quantification detailed social science studies would be required. All relevant numbers are for Germany.

## 2. Construction and Housing

### *2.1 Why households can make a difference*

In Germany, energy consumption of housing accounts for 32% of the total demand, with heating representing 49% of the total households’ energy consumption including passenger transport (GRE 1997). A reduction in the energy demand for heating would thus significantly contribute to sustainable household consumption. It has the highest technical potential for CO2 reduction (Federal Ministry of Environment 2002)

Construction and housing causes 29% of the total material consumption. This includes all raw materials and resources needed for the construction, extension and maintenance of apartments and houses including heating as well as materials that become necessary at the end of the life cycle in order to demolish the building. In 1998 construction waste summed up to 231 Mio. t. That is 58% of the total waste (Federal Statistical Office 2002).

The construction sector is the main contributor to the increasing sealing of soil, with 85% of the approved building projects in 1994 dedicated to housing. Settlement area increased from 18.785 to 42.495 km2 between 1960 and 1998 (Federal Environmental Agency 2002). This equals 124 ha per day (Federal Statistical Office 2002a). 84% of this area will be used for single family houses (Enquete Kommission 1998).

Thus the housing sector offers significant opportunities for savings regarding land use, material flows and energy consumption.

## 2.2 Indicators

*Indicator 1: Heating energy consumption (kWh / $m^2$ a)*

This indicator is already established in expert discussions and is an essential part of an “energy passport“ for real estate that was introduced in the year 2000 (GRE 1997). Quality benchmarks already exist for different types of buildings.

In practice the indicator can be used by architects and investors to check their investments and plans and by households as a selection criterion for the new flat or house when a household has to move.

During the phase of use, however, it does not indicate specific action to be taken but can be a means to monitor whether thermal insulation work undertaken has been successful.

*Indicator 2: Settlement area ($m^2$ / cap)*

Settlement area is one of the main contributors to sealing off land, together with transport and production infrastructure. Measuring the development of land use for settlement purposes will therefore serve to indicate the sustainability of our settlement patterns.

The indicator measures the long term trends in housing; although only to a limited degree attributable to day to day consumption decisions it is driven by consumer choices as regards the flat or house rented, bought or built. It thus characterises one important aspect of our overall lifestyles and consumption patterns.

*Indicator 3: Relation of private investment in existing houses to the erection of new buildings (dimensionless)*

Modernising existing flats and houses to the standard of modern housing equivalent to that of new constructions reduces material flows and land use per unit of functionally identical output significantly (Enquete-Kommission 1998). The indicator monitors the trend in private household expenditure relevant regarding this alternative.

Currently the German government subsidises new private house constructions heavily, but still the future owner has to contribute significant matching funds. Thus the indicator also reflects the flow of subsidies, and in case their priority should be changed from erecting new buildings to maintaining existing ones as suggested by the Federal Parliament’s Enquete (Enquete-Kommission 1998), it monitors the degree to which households react to such changes in financial incentives.

*Indicator 4: Resource intensity (kg / $m^2$ a)*

The total material flows can be diminished considerably through reduced resource intensity in the sector of housing construction by using recycled materials and those which can be easily rebuilt or demolished. Technological achievements like the ultrasonic recycling of concrete by decomposing it into the re-usable single materials sand, gravel and cement for instance will hopefully lead to even more significant reduction potentials in future.

*Indicator 5: Living space ($m^2$ / cap)*

A valid calculation of individual resource consumption cannot be achieved by means of heating energy consumption and resource intensity measured in kg/$m^2$. A single person will presumably consume less energy than a 4-person household in an equally sized flat. The living space per person provides additional information necessary in order to avoid misinterpretations.

Empirically, energy and material consumption is correlated to the living space area per capita (Enquete Kommission 1998). Currently, the living space per capita tends to increase with the age and income of a person and in each age group grows over time. In 1950 4,7 persons shared one flat, in 1968 it decreased to 3,0 persons and 1998 the average household size was 2,2 persons only (Federal Statistical Office 2002) This is a reason for environmental concern regarding future resource consumption, in particular when taking demographic change into account.

## 2.3 Actors involved

Housing is characterised by a high diversity of actor-specific, but frequently overlapping potentials for influencing energy consumption and material flows as well as land use. Private households are important actors for a number of reasons:

- Nearly all housing expenditures (monetary and physical) can be attributed to private households, either as users or as property owners. In Germany, 38.7% of all flats are owner-occupied; in houses consisting of one or two flats, the share of owner-occupied property is 71%. In these cases, the households are owners as well as residents, with the influence increased accordingly.
- Private households play an important role with respect to decisions on sustainable housing modernisation. They influence to a considerable extent the amount of material, energy and water needed for construction and residence, in particular by deciding about the apartment size (even if socio-economic constraints are taken into account).
- As owners, they determine heating energy consumption by deciding about thermal insulation, the choice of more or less efficient heating systems and the like.
- The patterns of airing and heating, and the preferred room temperature influence household energy consumption significantly, at an equivalent level of living comfort (up to a factor 2 due to different consumption behaviour). This way, residents can determine the amount of heating energy consumed by their consumption behaviour (and through minor renovations, e.g. for the sealing of joints).

A similar pattern of influence like for private owners is attributable to public or corporate owners of rentable flats. One important difference, however, is the investor-user-dilemma that occurs if the house owners’ investments e.g. in energy saving benefit the resident through her energy bill, but not the investor. In these cases, energy service providers can help through contracting arrangements, i.e. by paying for and managing the investment and in return reaping the benefits by charging the consumer a stable price, although the cost are decreasing. Whereas the resulting surplus makes up for the profit of the contractor, the owner has a modernised (and thus value increased) property, and the households benefit from stable energy payments below market prices.

Local authorities significantly influence land use by dedicating specific areas for housing purposes and defining standards associated with building permits. Regional planners and architects influence settlement structures (living area) as well as the standards of construction (resource intensity). They do so by providing low energy consumption and resource efficient housing, and they could help offering flats of flexible size which permit a regular adaptation of living area to the changing size of a family.

Banks define lending criteria and thus influence the standard of housing – a capacity that could easily be extended to energy and material efficiency standards.

Political regulation frameworks and subsidies strongly influence if not determine the households' decisions whether to invest in the construction of new houses or whether to renovate old ones. Taxation of living area, material input and energy taxation, energy consumption standards play a significant role, as do criteria for granting subsidies. In Germany, public support for new developments was 27.1 bio DM (about 13,5 bio €) in 1996, compared to 8.4 bio for upgrading existing houses.

Table 1 illustrates the diversity of actors involved as well as their different but overlapping spheres of influence, according to the reasoning above.

Table 1: Indicators for Construction and Housing

| | **Residents** | **Poverty owners** | **Public owners** | **Corporate owners** | **Local authorities** | **Planers** | **Service Providers** |
|---|---|---|---|---|---|---|---|
| Heating energy consumption | + | + | **O** | + | + | + | + |
| Settlement area | **O** | + | ++ | + | ++ | **O** | + |
| Private investment on existing/ erection of new houses | **O** | ++ | + | **O** | + | **O** | **O** |
| Resource intensity | **O** | + | **O** | + | + | + | + |
| Living space | ++ | + | + | + | + | + | **o** |

O = less influence; + = average influence; ++ = significant influence

## 3. Food

### *3. 1 Why households can make a difference*

In Germany the food chain's share in energy and material consumption is 20%. Agricultural area, 97.9% of which were intensively farmed in 1999 (SÖL 1999) covers 56% of Germany's total land area. It furthermore has a considerable water pollutant and eutrophication impact as 38% of the total nitrogen input and nearly 40% of the phosphorus input originate from agriculture, mostly from the conventional (Burdick 1998). Further impacts on the soil are caused by erosion and pesticides. (Federal Environmental Agency 2002)

The output of greenhouse gases, measured as $CO_2$ equivalents, is significant. In order to feed Germany's 80 million citizens, 260 million tons of $CO_2$ equivalents are emitted per year, i.e. 3.2 tons per inhabitant (Enquete Kommission 1994).

Households could influence environmental resource consumption in the production phase significantly by selecting a particular diet, e.g. less meat intensive or organic food.

### *3.2. Indicators*

*Indicator 6: Meat consumption (kg / cap a)*

From a health care point of view a reduction in meat consumption has a number of positive effects, but these will not be dealt with in this paper. Here we refer to the environmental significance of meat production:

- The emissions of the livestock production sector of 115 Mio tons $CO_2$ equivalents are six times higher than those of the crops sector (20 Mio tons $CO_2$ equivalents).
- To produce meat large areas of land are needed. In Germany 60% of the farmland is used for the cultivation of feedstock, and additional feed is imported from the EU and from overseas.
- Ammonia emissions caused by pork breeding contribute significantly to regional acidification and eutrophication.
- Dung water contributes to ground water pollution (in some areas, the majority of natural wells is no longer suitable for drinking water purposes due to high nitrate concentrations), and it contributes to the nitrogen input to fragile ecosystems via water and air.

This indicator is also used in the draft set of OECD sustainable consumption indicators (OECD 1998a).

*Indicator 7: Organic products (% market share of food products)*

Organic agriculture leads to a considerable reduction in pollution as no pesticides and less fertilisers are used. Thus the pesticide and nitrate leakage into the ground water are diminished and the biodiversity of accompanying plant and neighbouring ecosystems is significantly higher than on intensively farmed land. Adequate animal breeding is not only an ethical issue, it lowers the amount of pollutant substances released as well.

Furthermore, the volume of erosion caused by organic agriculture is significantly smaller than in intensive farming.

The energy consumption of organic farming is slightly less than of conventional farming (Haas/Köpke 1994). The advantage of not using synthetic fertilisers is reduced by the lower output (Jungbluth 2000). Organic livestock production needs about 15 % less energy than conventional produced meat depending on the kind of animal (Kramer/Moll 1995).

*Indicator 8: Food transportation (km / kg)*

The distribution of food is after livestock production and consumption activities the third biggest factor contributing to the resource consumption of the food sector, with increasing tendency. The growing average transport distances are furthermore increasing the demand for transport infrastructure, in particular through increasing road transport (here only transport to the retailer is accounted for; the transport from the shop to the home is covered by the mobility indicators).

The preferable indicator would thus be based on product specific transport analysis, including domestic and foreign intermediate products and services, packaging etc. Given the existing restrictions in data availability, the total domestic transport efforts for food and feed is taken as an approximation, since these data are available in the German national statistics. For other countries, similar proxy indicators may be suitable.

### 3. 3 Actors involved

By expressing their preferences at the shopping counter, households have a significant influence on the kind of food produced, the mode of production and thus the environmental impacts. Their influence is limited, however, as regards the transport intensity of the food purchased, partly due to the lack of information (labelling), partly due to the absence of substitutes.

For this aspect, traders and retail companies are more influential, but the supply structures (e.g. limitations in regional organic food provision) are equally important. They can be improved by the farming sector, but this is at least partly dependant on the market conditions and cost structures determined by politics, in this case particularly by the European Union’s Common Agricultural Policy CAP. Food industry and restaurants are additional actors on the supply side, with the latter having similar choices than the private households regarding the menus they offer, but restricted by market demand (see table 2).

Table 2: Indicators Nutrition

| | **Private Households** | Retailers | Farmers | Food Industry | Politics | Restaurants & Canteens |
|---|---|---|---|---|---|---|
| Meat consumption | ++ | + | + | + | + | + |
| Organic products | ++ | + | ++ | + | + | ++ |
| Food transportation | + | + | O | + | + | + |

O = less influence; + = average influence; ++ = significant influence

## 4. Transport

### *4.1 Why households can make a difference*

The growth of transport volumes and distances is still closely linked to economic development, and the trend in modal split goes towards more environmentally unsustainable modes like road or air transport. While the transport volumes are reaching the limits of capacity of the road system, transport infrastructure has become a major driving force in land use and ecosystem fragmentation (a UK headline indicator for sustainable development, DETR 1997). Although not yet the sector with the highest greenhouse gas emissions in Germany (unlike e.g. New Zealand), transport is the sector with the highest annual emission growth rates. 50% of the global mineral oil consumption is for gasoline, making up for one fourth of the total greenhouse effect. In Germany this rate is 30% (Petersen/Schallaböck 1995). 32% of the OECD member countries' primary energy consumption occurs in the transport sector, with the United States at 37.4% and the European OECD states at 27.2% (OECD 1998b). Not included in these numbers are the $CO_2$ amounts (including $CO_2$ equivalents of other greenhouse gases) caused by the production and maintenance of vehicles and infrastructure. So far all concepts to curb transport growth have failed (Akademie 1997).

In Germany, private households contribute 96.4 million tons $CO_2$ (directly) and 68.3 Mio tons $CO_2$ (indirectly) to the emissions from transport (Federal Statistical Office 1997).

Regarding land use, 4.6% of the total area of Germany is occupied by transport infrastructure (Federal Statistical Office 1997), more area than for housing. This figure neither includes non-road infrastructure like petrol stations, repair shops and private parking areas, not the indirect land occupation by noise corridors etc.

About 83% of emissions can be attributed to passenger transport and 17% to freight. Still the amount of hazardous substances released from diesel trucks should not be underestimated. Compared to the total volume of transport, truck transport has a share of "only" 15% to 20% but it causes approximately half of all nitrogen emissions of the total transport sector and an even higher percentage of soot emissions (the contributions to road damage and maintenance as well as all other non-environmental impacts are not discussed here). Between 1990 and 1995 an increase in goods transport by 15% could be observed as result of a strong increase in goods transport by road (+ 50%) and the simultaneously diminishing importance of goods transport by rail (- 32%)(Akademie 1997).

### 4.2 Indicators

*Indicator 9: Shopping and recreation transport distances (km / cap a)*

Transport activities for shopping and recreation purposes are not only strongly dominated by passenger car use, they also account for more than half of the kilometres covered per person. Even if these transport activities are not “voluntary“, private households have at their disposal significant potentials for choosing more sustainable means of transport.

Changing framework conditions, like increasing individualisation of life styles, the growing number of single person households, suburban shopping centers and transport intensive leisure time activities all contribute to growing transport distances covered by private households, while commuting is decreasing in its relative importance. Settlement structures induce transport activities by increasing or diminishing the distances. So do the means of transport available, while the mobility rate (the number of trips) as well as the time used for commuting has remained quite constant in Germany for more than fifty years (Petersen/Schallaböck 1995).

The category of “leisure mobility“, however, is problematic as far as it is a residual entity in transport statistics for mobility not induced by paid labour. It includes transport from reproduction and voluntary work (Spitzner/Aumann 1995). This kind of transport, however, is characterised by quite low levels of elasticity regarding the mode of transport (Spitzner/Beik 1996).

The indicator proposed focuses on the distance covered, since societal trends like shorter job duration, longer educational or unemployment phases or the trend towards higher female employment participation resulting increasing numbers of working couples with two distant work places lower the private households’ possibilities to avoid transport. However, as regards occupational and educational transport activities, private households are free to select the means of transport they use, at least as long as sufficiently convenient choices are available.

*Indicator 10: Modes of transport for vocational purposes (share of cars, rail and other public transport, non motorised transport)*

In recent years the functional separation into inner-city working and outer-city living areas has led to an ever increasing number of commuters. Their mode of transport has a significant influence on the resource consumption for transport. For commuting, this is to a significant degree open to consumer decisions, whereas the frequency and distance of trips is overwhelmingly beyond their influence. Vocational purpose transport is dominated by cars, with still increasing shares (in Germany except for educational purposes).

As the frequency of transport activities for occupational, educational/training and business purposes by and large cannot be influenced by private households, the indicator refers to the transport activities for shopping and recreation purposes. Indicators like “commuter rate“ and “commuting distances“ are regarded good indicators for planning purposes, but are less suitable for indicating consumer behaviour.

### *Indicator 11: Modes of transport for shopping and recreation purposes (share of cars, rail and other public transport, non motorised transport)*

Factors which decisively influence the selection of transport means are: subjective needs, individual preferences and values. Sustainable consumption behaviour at the present state of the art can be predominantly expected in those consumption clusters that require the least personal efforts (low cost hypothesis). However, some studies indicate that individuals regard the transport sector as a high cost one, resulting in a comparably low elasticity as regards car use.

As pointed out already, the environmental impact of transport is determined by the frequency of trips, the distance per trip and the mode of transport. Since the transport distance for recreation and shopping is already covered by another indicator, this one monitors the modes of transport. Thus the environmental sustainability of consumption is strongly influenced the modes of transport chosen.

### *Indicator 12: Number of passenger cars (dimensionless)*

Empirical studies show that even proven environmental awareness does not significantly influence the mobility behaviour of car owners. Once a car is available, it is used as frequently as in other car owner households.

On the other hand, environmental concerns are instrumental in the decision whether to buy a car not, opting e.g. for a combination of car sharing, rental cars and public transport.

### *Indicator 13: Holiday flights (km / cap a)*

Despite the still relatively small environmental resource consumption of aviation, it needs to be monitored due to the current trends that more people use air transport to fly more frequent flights to ever more distant destinations.

This corresponds to a steep in crease in energy and resource consumption, which is not sustainable in the long run.

### *Indicator 14: Average energy consumption of new cars (l gasoline / 100 km)*

From the users’ point of view the use of the private passenger car is actually the quickest, most comfortable and economically attractive means of transport, especially as the costs for the railway network are included in the ticket price whereas the costs for the road network are independent of distance travelled. The car will remain a predominant means of transportation unless there is a change of circumstances.

24% of the energy consumption by household is caused by transport, 60% of this by gasoline consumption (Federal Statistical Office 1999). Besides the transport distances, frequencies and the mode of transport, the efficiency of the cars used has a major impact on energy consumption. This efficiency is determined by two factors: the technical efficiency of the car itself, and the style of driving. This indicator focuses on the former, which can be influenced mainly in the phase of buying a new car. Decreasing energy consumption of new cars (and thus a decrease for the next decade) can only be achieved, if the current trends towards bigger, faster, more comfortable and thus heavier cars is either overcome or at least overcompensated by efficiency gains.

### 4.3 Actors involved

In Germany, 58% of all households own a private car; additional 23% own two or more, but 56% of all West German and 66% of all East German citizens have not used railways in the last year (Federal Ministry of Environment 1998). 44.3 Mio cars are registered in Germany (Federal Statistical Office, 1997). Aviation shows the highest annual increases (7.5%) of all transport activities, with holiday flights playing an important role. Regardless of external constraints, households dominate the decision on the mode of transport, but the availability of suitable and convenient alternatives is important as well. Local authorities and service providers can do a lot in this respect, by offering or reducing the supply of infrastructures for mobility (public transport, parking areas etc.) and by increasing or reducing the need for mobility through planning and more or less centralised service availability. Employers influence commuting behaviour by financial and administrative incentives.

Travel agencies and tourism companies influence holiday transports, car sharing providers do so for the rest of the year. Political decisions can increase or decrease the cost of mobility, thus setting incentives for more or less resource consumption for transport purposes. Thus the legislative and administrative authorities are important actors for the development and implementation of a new policy in this sector. Finally the efficiency of means of transport is determined by industry as well as by their customers. Table 3 illustrates the overlapping spheres of influence.

Table 3: Transport Indicators

| | **Private households** | Leisure mobility provider | Local authorities | Politics | Industry | Service provider | Employers |
|---|---|---|---|---|---|---|---|
| Shopping/recreation transport distances | + | + | + | + | O | + | + |
| Transport for vocational purposes | + | O | + | + | O | + | + |
| Transport for shopping/recreation purposes | ++ | + | + | + | O | + | O |
| Number of passenger cars | + | O | + | + | + | + | O |
| Average fuel consumption | + | O | O | + | + | + | O |
| Holiday flights | ++ | + | O | + | O | O | O |

O = less influence; + = average influence; ++ = significant influence

## 5. Discussion

The 14 indicators for environmentally sustainable household consumption suggested in this paper are based on consumption clusters that cover the vast majority of key resources consumption. The indicators themselves monitor the main driving forces inside the clusters. They can be used by consumer organisations (the project was conducted under the supervision of an advisory board including representatives from consumer organisations) to focus their advice on the environmentally most relevant issues. For example no quantifiable environmental difference could be found between deep frozen and fresh vegetables from comparable locations, synthetic fibres are not quantifiably better or worse than natural ones, and clothing and fashion in general are no reason for serious environmental concern (that may be different from a lifestyle point of view, where the symbolic function of consumption counts more than the direct environmental impact).

The identification of relevant actors should be useful for policy purposes, permitting to initiate joint activities for sustainable household consumption. These could include voluntary or mandatory labelling schemes, consumer information, but as well financial incentives like resource consumption taxes to make environmentally sustainable consumption economically reasonable.

So far only extremely limited information is available about the environmental impacts of wealth: does it result in high resource consumption levels due to affluence, or in low levels as a result of high quality, expensive but eco-efficient consumption (the Kuznets curve hypothesis). The indicators developed in this paper can be applied to such questions and illustrate the significantly higher environmental disturbance potential caused by affluence under the current consumption patterns (Lorek/Spangenberg 1999). Geographically, this applies to Europe in first instance: the indicators were developed based on German data, they can be applied all over Europe and probably in most OECD countries.

With the resource input based approach developed in the paper for monitoring trends in environmental pressures, impacts on humans' health caused for example by toxic chemicals are not addressed. These include above all chemicals with human-toxic effects, i. e. cancerous, teratogenic, mutative, allergic and endocrinological substances but also eco-toxically doubtful, hardly biodegradable or bio-accumulating substances. As long as goods and services contain such substances, their avoidance is an essential aspect of health conscious consumer behaviour. The protection of humans against toxic substances is, however, rather the task of national legislation in order to legally prohibit harmful goods and substances, than one of individual consumer choices. Thus toxicity concerns are a subject of sustainable production patterns rather than one of sustainable household consumption.

Whereas the importance of a specific good and service for sustainability is, in general, only minor, numerous goods and services have a symbolic function besides and above their utility function. Some of them indicate the membership in a certain social or lifestyle group, serve as a symbol of status or for compensatory consumption (Scherhorn 1991). The importance for environmental sustainability and the perceived symbolic value of the products or services consumed need not be matching at all. This lack of congruence, however, does not reduce the validity and importance of the communicative function. On this basis, selected goods and services can be singled out that might serve as *headline indicators*, which due to their communication and social distinguishing function play an important role in sociological and psychological consumption analysis, however less in the environmental one. From an environmental point of view, in these cases the results of this paper could still be used to check the relevance of the consumption clusters to be communicated by the *icon indicators*, thus avoiding a misallocation of political and communicative efforts.

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# Towards sustainable development at city level: evaluating and changing the household metabolism in five European cities

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## Abstract

We address the issue of sustainable development at the city level. Environmental loading associated with production and consumption activities within our present day cities is steadily increasing. Another reason for focussing on the role of cities is the fact that cities often are the economic, social-cultural and political heart of society. For many people the city is the place were they live, work and build up a social network. In many cases cities play a leading role in a broader regional, national and even international setting. While the issue of sustainable development clearly has a global dimension it is also generally accepted that there exists a strong mutual relationship between the global and local level. Cities and their urban surroundings are therefore regarded as open systems.

Sustainable management of natural resource use is therefore regarded as an essential aspect of planning processes aimed at making our cities of tomorrow more sustainable. Our main focus is on consumption, however this is not considered separately from other processes, both upstream (production of consumer goods) and downstream (waste collection/processing) in the production-consumption chain. At the city level individual consumers and household activities play an important role as far as sustainable development strategies are concerned.

We used the total (direct and indirect) energy demand of households as a proxy for environmental pressure related to household consumption in five European cities (Fredrikstad, Stockholm, Guilford, Padova and Groningen). The direct energy demand refers to the energy that is literally consumed by households (natural gas for heating and hot water production, electricity and motor fuels). The indirect energy demand refers to the energy embodied in consumer items. Accounting for the indirect energy demand brings in the production and distribution activities in the production-consumption chain.

Although the energy values can only be a rough estimate of the energy budgets of different household types it is shown that the household energy budgets in the five cities result in different sets of change options for more sustainable consumption patterns in these cities. Such change options can be operationalised both through direct steering of household behaviour and through indirect steering via other actors in the integral production-consumption chain (producers, retail, distributors etc.), or by influencing the

conditions under which consumption takes place (including purchase, use and disposal of consumer items).

## Introduction

The last decades have witnessed an enormous growth in consumption and production levels and related environmental decay, notably in industrialized countries. In this paper we address the issue of sustainable development at the city level. We analyzed and compared the energy requirements of households in four European cities: Stockholm, Fredrikstad, Guildford and Groningen. Our main focus is on consumers and household consumption. It is increasingly recognized that, when aiming at redirecting the present consumption and production patterns in a more sustainable direction cities play an important role. Urbanization rates show a steady increase all over the world whereas at the same time pollution, noise, poor environmental quality, and the increasing demand for energy endanger sustainable development of the cities and the quality of life of those living in today's cities. City planners, together with a wide variety of stakeholders, launch a lot of new initiatives to deal with the environmental problems that go along with urbanization.

Another reason for focusing on the role of cities is the fact that cities often are the economic, social-cultural, and political heart of society. For many people the city is the place where they live, work and build up a social network. In many cases, cities play a leading role in a broader regional, national, and even international setting. While the issue of sustainable development clearly has a global dimension, it is also clear that there is a strong mutual relationship between the global and local level. Events taking place at the city level have their impact on other local or regional systems and ultimately on the global system as a whole.

Modern cities face many challenges when it comes to balancing environmental (urban) quality and sustainability with modern city life. The idea of sustainable development refers to a well balanced use and management of the natural resource base of economic development. During the last years a large number of European cities have given priorities to environmental issues in the political planning process. In transition routes towards more sustainable cities, the role of consumption and the activities of households has been increasingly recognised (see Agenda 21).

One reason for this is the increasing rate in which consumers buy and use a complex and changing mix of goods and services. These fast growing consumption rates result in an increasing environmental load. After all, consumer goods need to be produced before consumption takes place. Following this line of reasoning, consumer activities can be linked to inputs and output of economic activity and thus to the associated environmental effects thereof. We might even argue that the total environmental load associated with our production-consumption chain can be, directly and indirectly, assigned to consumption. We do not want to go that far in this paper although strategies aimed at reducing the environmental impact of consumption activities should ultimately embrace the entire lifecycle of consumer goods and services. We draw the line at those aspects that directly determine the extent of environmental pressure that takes place during and as a result of the consumption itself. Since the major part of consumer activities take place within cities we draw the line at the city level. The household metabolism metaphor is introduced to study the natural resource consumption of households and the associated environmental aspects.

## The Metabolism Concept Applied to Households

Nowadays it is increasingly realised that, similar to the broad range of activities taking place at the production side of the economy, a society consists also of a large (and rapidly increasing) number of households characterised by different lifestyles. It is increasingly acknowledged that households and lifestyle are interesting concepts for assessing and exploring routes to the required reduction of the (long-term) environmental impacts of the combined effects of production and consumption activities that take place within the economy.

Consumer activities, centred on households, can be linked to patterns of inputs and outputs of the economy and, thus, to the associated environmental effects of economic activities. Since the major part of consumer activities takes place within households, households rather than individual consumers determine a large part of resource consumption. The term “household metabolism" refers both to the demand for resources, i.e., the direct flows of resources through households, and to the supply of resources, i.e., the materials and energy indirectly required to realise these flows (e.g. in mining, production of materials, construction of houses, and manufacturing goods) as well as the generation of waste (Noorman and Schoot Uiterkamp [1]). This is shown in figure 1. By adopting the household metabolism metaphor, a picture is obtained that relates the use of natural resources to the very basis of economic activity: consumption in households. Measuring household consumption patterns as a means towards understanding how to direct them towards environmentally sustainable goals requires insight into the mechanisms of household metabolism.

In order to illustrate the changing rates of household metabolism in the four cities, we focussed on household energy requirements rather than taking into account the full range of natural resources used in production and consumption processes. Usually household energy consumption is taken to comprise that fraction of the national energy consumption that is literally consumed in (electricity, natural gas, etc.) or via (car fuels) households (i.e. direct energy consumption). However, households also use energy in an indirect way. They purchase goods and services delivered by the production sectors. The energy directly used for producing consumer items and services can be considered as the indirect energy consumption of households. We proceed from this perspective and assume that the economy is based on the production of goods and services on behalf of household consumption, and that the total energy consumption can be assigned to households (taking into account import and export). The total household energy requirements were calculated as a function of household expenditures. This generates insights into the relationships between household spending patterns and the effects thereof, counted as energy consumption. Furthermore, the approach reflects the interdependency between industrial metabolism and household metabolism as presented in figure 1: metabolic changes in the production processes of consumer items might have a significant impact on the indirect household energy use whereas changing consumption patterns has its effect on the structure of the production side of the economy.

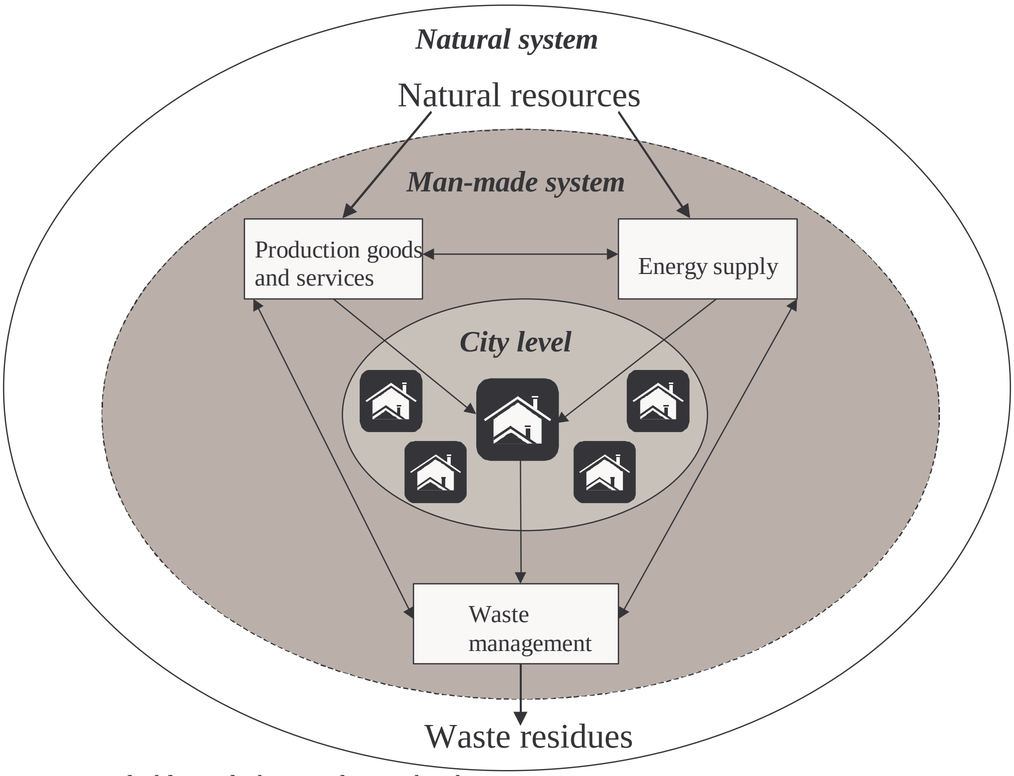

Figure 1: Household metabolism at the city level

## The Method

The essence of the methodology used in the Toolsust project is the projection of the total energy requirement (in production, distribution, consumption, and waste processing) on behalf of household consumption on desegregated household budget spending categories. This generates insights into the relationship of household spending patterns and the effects thereof (counted as energy requirements). The energy requirement of a specific household budget category thus contains a so-called direct part (energy consumed directly in the household for this purpose) and an indirect part (accounting for the energy consumption in production, transport and service sectors). The relationship of consumption of goods and services versus energy requirements can only be established indirectly. Household consumption must first be split into patterns of household consumption activities (e.g. vacation, private transport). Next, such activities need to be "translated" into energy terms, after which the direct and indirect energy requirements of these activities can be established.

The methodology for the assessment of energy requirements and intensities is outlined in figure 2. Rather than choosing for process analysis or input-output analysis we combined elements of both methods in a so-called hybrid analysis, which builds on the advantages of both methods. It requires reliable statistical data concerning energy production and consumption, economic input-output matrices, household budget surveys and goods and services price information (data that are only rarely available in a high-resolution, and compatible form).

In figure 2 it is shown that a combination of economic input-output data and energy statistics delivers, by means of input-output energy analysis techniques (Van Engelenburg et al.[2]; Wilting [3]; Wilting et al. [4]), data concerning the energy intensity of (66 in the case of the Netherlands) production sectors. In most cases, process analysis is used to determine the energy intensity of a range of (over 100) basic materials frequently used in the delivery and consumption of goods and services. Both data sets are used in a simplified Life Cycle Analysis of goods and services pertinent to the categories of the budget spending surveys. The LCA results are calculated by and stored in a software program EAP (Wilting et al. [5]). The EAP results lead to evaluation of the energy requirements of goods and services, using the base year 1996 (Kok et al.[6]).

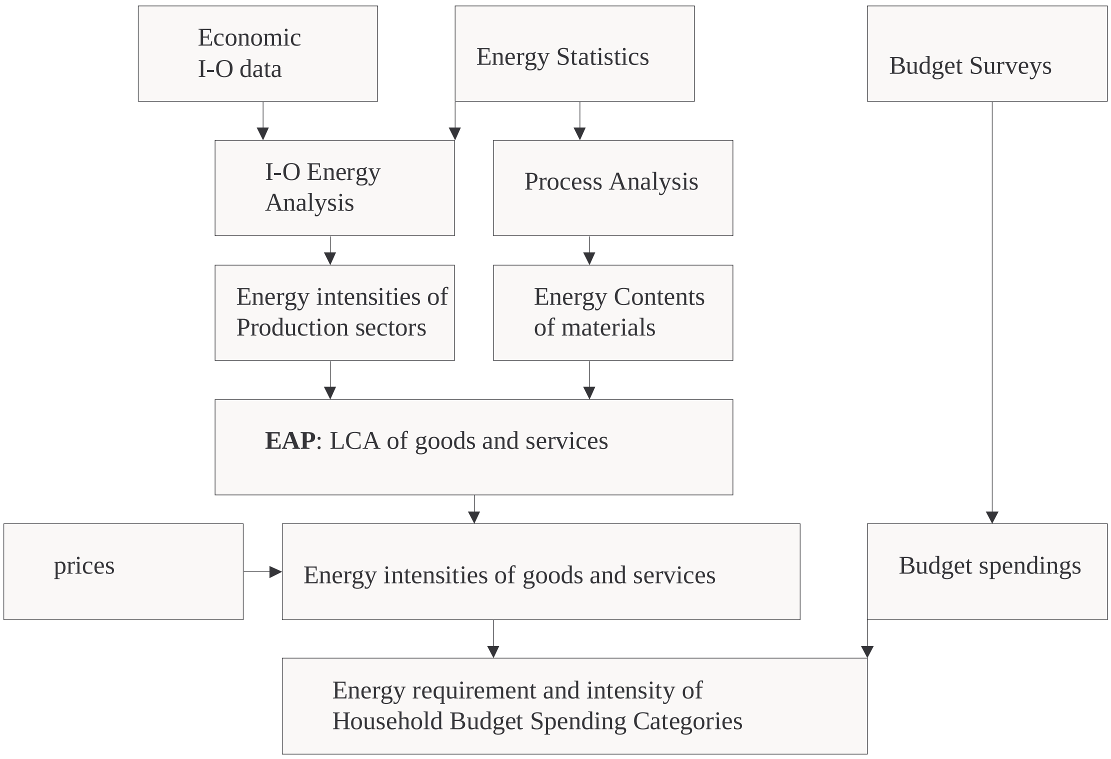


Figure 2: Flowchart of the methodology for calculating energy parameters of budget spending categories.

## The Energy Analysis Program (EAP) as a tool

To calculate the energy requirements of the consumer items consumed by households in the various cities, the original Dutch EAP model was used as a default, using 1996 data (Kok et al.[6]). It is beyond the scope of this paper to give a full description of the EAP model. For a detailed description the reader is referred to Wilting et al.[5]. In this section we only report on the adjustments of the original EAP model in order to make the method meaningful for the other European countries in the Toolsust project.

### *The EAP database*

The EAP model consists of a common database of basic data on the energy requirements of materials, economic sectors, forms of transport, trade and services, and waste processing. In order to make the original Dutch database meaningful for the other countries involved in the Toolsust project (Norway, Sweden, UK, and Italy) a number of adjustments were needed:

- It was assumed that the energy contents of most of the basic goods are the same in various countries. Therefore, except for Sweden, the Dutch database on basic goods was used with some modifications. For all countries energy data of food products were modified.
- Dutch recycling percentages of various materials were assumed
- Dutch trade margins (i.e. the purchase price as a percentage of the net turnover, excl. VAT) were used.
- Dutch data on the energy requirements of waste processing were used
- Except for Sweden, Dutch data on the energy intensities of transport were used.
- Furthermore, due to a lack of data, no correction for differences in annual fluctuations (temperature corrections) were included in the calculations.

For each country the energy intensities of the production sectors distinguished in the Input-output table were calculated using country specific energy data and economic data. It turned out that among countries data are available in different degrees of detail. The level of detail at which the energy intensities were calculated were merely determined by the availability of energy data. To calculate the energy intensities per country the following economic data were used:

- An input-output table with intermediate deliveries, in basic prices (for the UK we used a Use table, purchaser prices)
- An input-output table with competitive and (if available) non-competitive imports (competitive imports are imported commodities that are also produced domestically whereas non-competitive imports are not produced domestically).
- Per sector: total domestic production value
- Per sector: net value added
- Per sector: energy prices paid by the producers. In some cases due to lack of data the energy price per group of sectors was used.
- Per sector or per group of sectors: consumption of fixed capital (depreciation of capital goods)

In addition to economic data, information on energy consumption per sector, divided per fuel type was required to calculate the energy intensities of the input-output sectors. The energy intensities were calculated using primary energy terms. The energy required to produce primary energy and process it into useful fuels or electricity is included in the so called ERE (Energy Requirement for Energy) value. Except for electricity it was assumed that the ERE values for fuels were the same in the various countries. This assumption was not valid for electricity production since in the different countries electricity is produced in different ways using a variable mix of fossil energy, nuclear fuels, and renewable sources.

Due to restrictions related to data availability it was not possible to carry out the country analyses for the same year. For The Netherlands, the analysis was carried out for 1996, for Sweden 1995, for Norway 1997, and for England 1998.

### *EAP analyses*

Once the national databases were available, EAP was used to calculate the energy intensities of consumer items. The selection of relevant consumer goods was merely based on the available household budget surveys. Per country two important sets of data were needed:

- Consumer prices
- Budget surveys

The format of the various data sets differ per country . Per consumer item a separate EAP analysis has to be carried out to calculate the energy requirement of that item.

- Per EAP analysis different types of information are needed:
- Price information (i.e. consumer price of the product, incl. VAT)
- Composition of the product (i.e. type and amount of the basic goods and type and amount of packaging materials)
- The origin of the product (i.e. name of the manufacturer, names of the wholesale and retail trade and transport distances)
- How the consumer product is treated after being used (i.e. waste processing including recycling)

With help of these data the energy intensities per consumer item were calculated. When combining this information on energy intensities of consumption goods and services with the household budget survey information, we gained insight in the total energy requirements of the households in the cities. Rather than using the total national budget survey, we used data on budget spendings at the city level or at the regional level.

## Results

In this section we present the first results of the comparison between four cities: Groningen (The Netherlands), Stockholm (Sweden), Fredrikstad (Norway), and Guildford (UK). These first results are derived from the draft country reports, Falkena et al. [7], Carlsson-Kanyama [8], Throne-Holst et al. [9], and Clark et al. [10]. Except for Stockholm, due to constraints in the availability of budget spending data at the city level, the results related to indirect energy requirements refer to the region within which the cities are situated rather than to the individual cities. In this paper we present average figures. In the separate city reports to be available this fall as well as the intercountry comparison report to be available end of this year, also information per household type (size, income levels, composition), type of house, and different consumption categories will be presented.

## Direct energy use

Table 1: Average direct energy requirements in GJ per household for four cities

| | Groningen | | Stockholm | | Guildford | | Fredrikstad | |
|---|---|---|---|---|---|---|---|---|
| | Primary energy | Final* demand | Primary energy | Final demand | Primary energy | Final demand | Primary energy | Final demand |
| Natural gas | 71 | 70 | 0 | 0 | 55 | 54 | 0 | 0 |
| Oil/kerosene | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 7 |
| Solid fuels | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 |
| District heating | 0 | 0 | 62 | 53 | 0 | 0 | 0 | 0 |
| Electricity | 26 | 10 | 15 | 6 | 42 | 13 | 64 | 58 |
| Motor fuel | 22 | 20 | 18 | 16 | 43 | 39 | 44 | 40 |
| Total | 119 | 100 | 95 | 75 | 140 | 106 | 126 | 115 |

*ERE values used to calculate the final demand data: natural gas: 1.01, district heating: 1.18, motor fuels: 1.11. Conversion factors for electricity differ per country: The Netherlands: 2.65, Sweden: 2.42, UK: 3.21, Norway: 1.11. For Sweden and Norway, we also used average figures of the residential sector (IEA [11]).

When analysing the total energy requirements of households, we start with the direct energy requirements. Table 1 shows the average direct household energy requirements per city. Both the primary energy data and the final demand data are presented. When looking at the primary energy requirements, data for households in Stockholm are relatively low, whereas in Guildford the direct energy requirements are the highest. The picture changes when looking at the final demand figures. Due to low ERE values of hydro electricity, direct final energy demand in Fredrikstad turns out to be high.

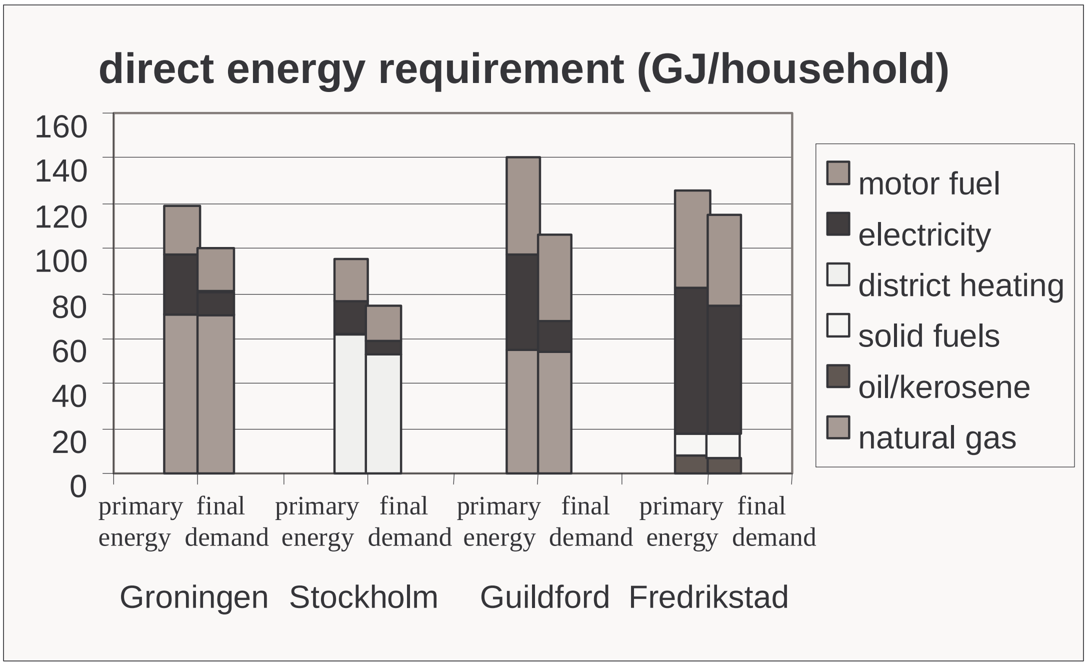


Figure 3: Average direct energy demand per household per energy carrier

Figure 3 clearly shows that the average direct energy requirements of a household in Guildford are almost 50 % higher than in Stockholm (in primary energy terms). Another interesting difference between the cities is the share of electricity in the total direct energy demand. Electricity counts for more than 50% of the direct energy use in Fredrikstad where it is used for heating purposes, whereas in the other cities the share of electricity varies from 16% to 30% of the direct energy use. In Fredrikstad and Guildford, the share of motor fuels is between 30 and 35%, indicating an intensive car use, whereas in Groningen and Stockholm motor fuels account for 18 to 19 % of the direct energy use. Indeed, car possession and car use in the latter two cities are much lower.

Direct energy use is mainly determined by space heating, hot water production, possession and use of electrical appliances, and transport. These functions, in turn, are associated with household characteristics (household size, composition, and income), size and quality of the house, and car possession. In our study, we differentiated between these characteristics. We found that the deviation of the direct energy use data is significant. In Stockholm, direct energy use of various household types varies from 34 GJ to 208 GJ, whereas in Groningen, direct energy use varies from 43 GJ for a student household to 175 GJ for households living in a detached house.

### *Indirect energy use*

In order to calculate the indirect energy requirements of households, two types of data are needed. Data on the energy requirements of consumers items, and information on how households spend their budget (see also figure 2).

Table 2: Budget spendings related to indirect energy use in the various cities/regions (%)

<table>
<tr><th></th><th>Groningen</th><th>Stockholm</th><th>Fredrikstad</th><th>South East UK*</th></tr>
<tr><td>Food</td><td>19</td><td>23</td><td>20</td><td>24</td></tr>
<tr><td>House</td><td>26</td><td>24</td><td>16</td><td>18</td></tr>
<tr><td>Household effects</td><td>11</td><td>6</td><td>9</td><td>14</td></tr>
<tr><td>Clothing & footwear</td><td>7</td><td>9</td><td>7</td><td>6</td></tr>
<tr><td>Hygiene</td><td>4</td><td>6</td><td>9</td><td>4</td></tr>
<tr><td>Education</td><td>5</td><td>5</td><td>5</td><td rowspan="2">20</td></tr>
<tr><td>Recreation</td><td>12</td><td>12</td><td>12</td></tr>
<tr><td>Transport</td><td>13</td><td>9</td><td>21</td><td>15</td></tr>
<tr><td>Other consumption</td><td>3</td><td>6</td><td>1</td><td>0</td></tr>
</table>

* The consumption categories in the household budget survey of South East UK differ partly from the other regions. Apart from the categories given in table 3, households in South East UK spend 14% of their budget on Household goods and services, 4% on Personal goods and services, and 20% on Leisure.

The way in which households spend their budget is given in table 2. Expenditures on direct energy are not included in the data presented in table 2. (For instance, households in Groningen spend 8% of their budget on direct energy). In some cases, data on budget spendings were not available at the city level but at the regional level.

Combining the EAP results with budget spending data yields the average indirect energy requirements of households in the various cities. The aggregated results are shown in figure 4. The average indirect energy requirements of a household in Groningen are the lowest (just below 100 GJ per household). Households in Guildford require more than twice as much energy (234 GJ/household). These outcomes are in line with the absolute spending levels: the budget of a household in Groningen is much lower than in South East UK. However, these first results also show that not just the absolute income levels determine the indirect energy requirements of households. Households can spend their budgets in different ways. Obviously, the way in which households spend their budget (i.e. in an energy intensive or energy extensive way) significantly influences the energy budget of a household.

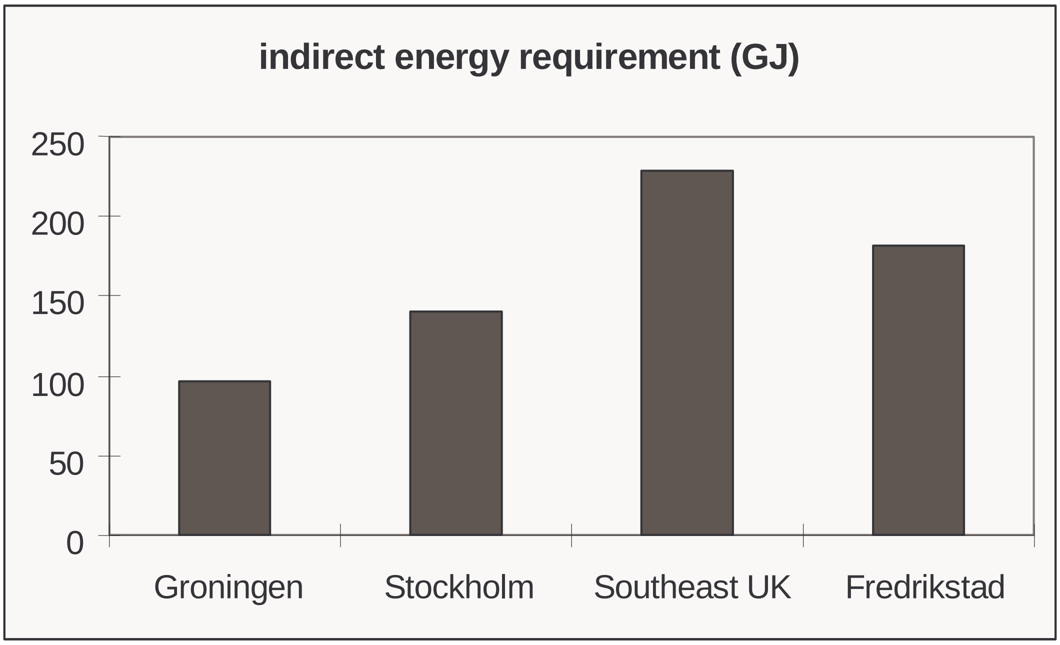


Figure 4: The average indirect energy requirements of households

The results presented in figure 4 show that large differences exist among the energy budgets of households in the various cities. Households can spend their budget in different ways.

The relative share of the various budget categories in the total spending budget gives a more detailed picture of the indirect household energy budget since different budget categories have different energy intensities.

In figure 5 a-d the average indirect energy requirements per budget category of households in the four cities are presented. The energy intensities of Euros spend on food (9-10 MJ/€) and recreation (8.5-10 MJ/€) are the highest in all four cities. Spendings in the category house (rent and mortgage) have a low energy intensity (2 MJ/€).

Table 3 shows the average spendings associated with the indirect household energy requirements and the average energy intensities of the households in the four cities. Households in Groningen spend their budget in a relative energy extensive way whereas households in the South East UK spend their income in a relative energy intensive way. The average energy expenditures of households in Stockholm and Fredrikstad are almost the same, and just in between the energy intensities of expenditures of households in Groningen and the South East UK.

Table 3: Average expenditures associated with indirect energy requirements

| | Spendings (€) | Indirect energy (GJ) | Energy intensity (MJ/€) |
|---|---|---|---|
| Groningen | 15,300 | 97 | 6.3 |
| Stockholm | 19,500 | 141 | 7.2 |
| South East UK | 29,000 | 234 | 8.1 |
| Fredrikstad | 24,400 | 182 | 7.1 |

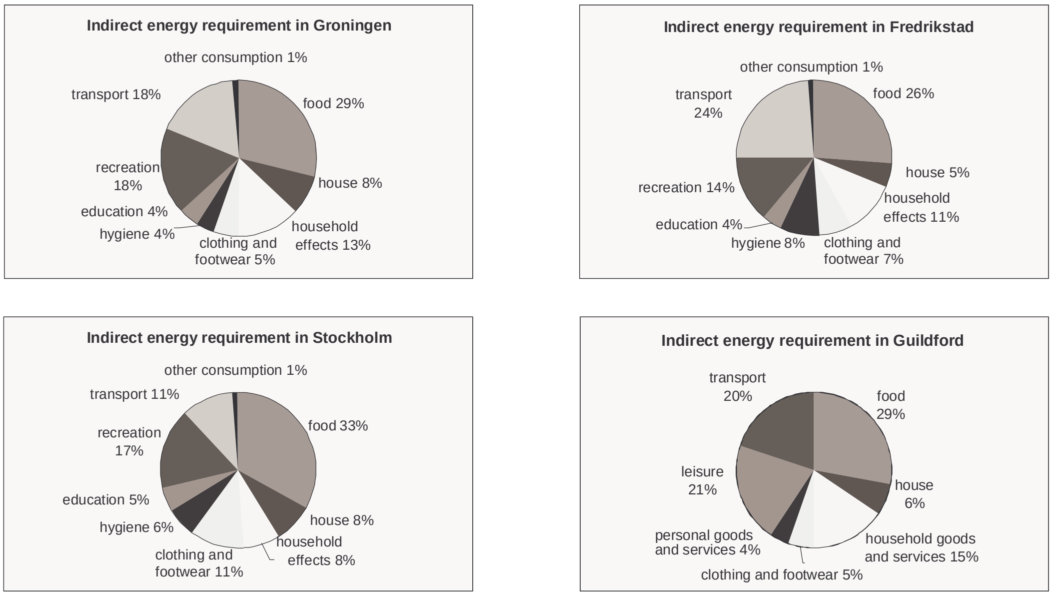


Figure 5 a-d: Breakdown of the indirect household energy requirements in the 4 cities

### *Total energy use*

Figure 6 shows the total energy requirements divided in direct and indirect energy use both per household and per person. The total energy requirements of a household in Groningen are the lowest (216 GJ per annum) whereas households in the UK require more than 40% more energy (374 GJ per annum) to run their daily life. Households in Fredrikstad also require more than 300 GJ per annum whereas households in Stockholm require 236 GJ per annum. When looking at the total energy requirements per person, it is interesting to see that the total energy requirements per person in Stockholm (141 GJ) and Fredrikstad (138 GJ) are almost the same. In Groningen, the total energy requirements are relatively low (116 GJ). Although the total primary energy requirements of households in the South East UK are the highest, due to a relative large household size, the total energy requirements per person (147 GJ) approaches the per person energy requirements in Stockholm.

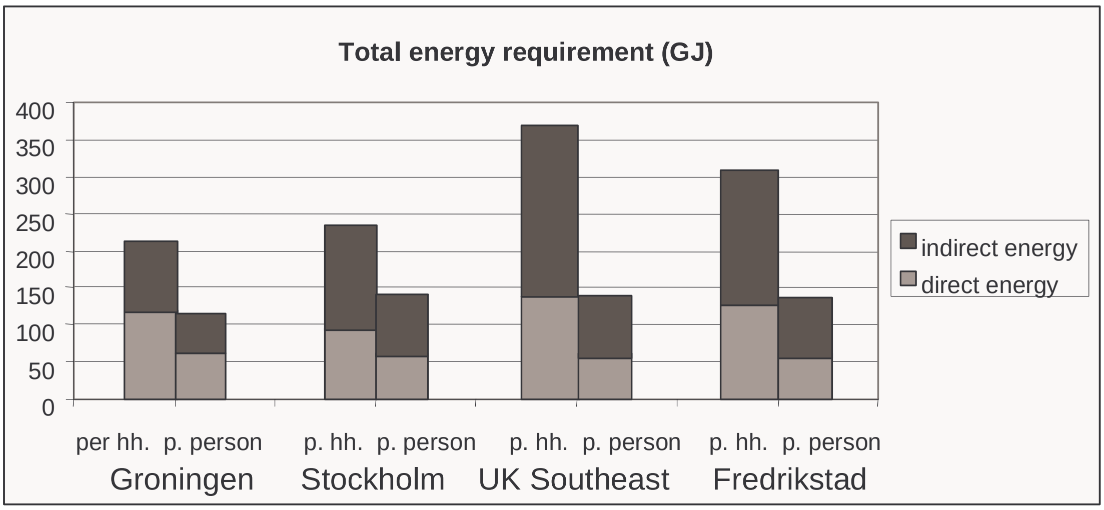


Figure 6: Total energy requirements per household and per person

Also interesting to notice is the share of indirect energy in the total household energy budget. Except for Groningen this share is about 60%. In Groningen, the indirect energy use accounts for 45% of the total household energy demand. Typical numbers for an average Dutch household for this ratio are 55% for indirect energy use and 45% for direct energy use.

When comparing the average spendings in Euros and the average total energy budgets of households in the cities with the national average of the country the city is part of, it turns out that except for the South East region of the UK, the total energy requirements of the city households are (well) below the national average. This is in line with the spending patterns: the spendings of households in the South East of the UK are higher than the national average whereas the spendings of households in Groningen are below the national average. Table 4 shows that this is not the case in Sweden and Norway. Spendings of households in Stockholm and Fredrikstad are (a little) above the national average household spendings whereas the total energy requirements of an average household in these cities is below the national average. Obviously, households in Stockholm and Fredrikstad spend their income in a more environmentally sound way, at least from an energy perspective.

Table 4: Average total spendings and total energy requirements per country and per city/region

| | The Netherlands | | Sweden | | UK | | Norway | |
|---|---|---|---|---|---|---|---|---|
| | Average NL | Groningen region | Average Sweden | Stockholm | Average UK | South East | Average Norway | Fredrik stad region |
| Spendings (€) | 21,302 | 16,625 | 20,290 | 20,850 | 25,750 | 30,190 | 25,519 | 26,955 |
| Total energy (GJ) | 249 | 216 | 263 | 236 | 340 | 374 | 312 | 308 |

## Change Options

In this paper we addressed the issue of sustainable consumption at the city level, taking into account the direct and indirect energy requirements of households in various European cities. By gaining insights in the energy budgets of households in these cities, we aimed at finding guidelines for reducing the environmental load, expressed in energy terms, associated with household consumption at the city level. Although we presented average figures in this paper, it is obvious that there is no such thing as an average household. Individual households are characterized by different features (size, income, type of house, quality of life standards, etc.). A broad range of characteristics determines the way an income is spent and thus the associated household energy budget. Rather than presenting a long range of possible options that can lead towards more sustainable household consumption patterns, we are interested in identifying system parameters influencing the energy budgets of households. Using energy analysis to portray household metabolism provides insight in how to search for change options at various system levels:

### *The macro level*

At this (inter)national level the structure of the economy or the structure and efficiency of the energy supply system are important factors that determine the energy requirements of households. Both the economic structure and the energy supply system are important determinants of prices of goods and services and the energy intensity of consumer items. The indirect energy requirements account for about half of the total energy budget. Households cannot change the energy intensities of goods and services. This kind of changes take place at the production side of the economy. It was also shown in our study that the efficiency of the energy system and the fuel mix used influences the household energy requirements significantly.

At this level, change options to reduce the household energy requirements are for instance:

- Changes in the subsidies/tax regime (i.e. higher taxes on resources and lower taxes on wages)
- Stimulation of locally produced open air grown food
- Measures to improve the energy efficiency of the industries

### *The meso level*

The meso level is the city level or the regional level. Cities show a great diversity and every city is characterized by its own specific features. In many cases the physical structure of a city such as the infrastructure, the presence of different types of industries, and the way buildings, houses and other facilities are located play a serious role in the way households organise their daily life. Also, qualitative aspects such as the quality of the public transport system, the environmental quality of the direct surroundings, and the quality of the dwelling are important determinants of household energy budgets. Poor quality houses, often occupied by lower income households, require more energy for heating purposes. Therefore, change strategies for lower income households might be more effective when focussing on direct energy use rather than on the indirect energy requirements. At this level, change options to reduce the household energy requirements are for instance:

- Facilitating public transport while discouraging car traffic and parking within the city
- Imposing energy saving measures for housing projects
- Facilitating local food shops for locally produced open air grown food

### *The micro level*

Micro level changes take place at the level of individual households. These are changes in the way households divide their budget over different consumption items and categories. The highest potential of energy reduction is at the micro level since households themselves have the biggest influence on their consumption patterns. There are many possible changes of very different kinds, for example:

- spending money in a different way (changing the composition of the consumption package)
- saving direct energy use (for example by energy insulation and using less electrical appliances)
- having vacations closer to home and using other transportation means than planes.

In the Toolsust project, the main focus is at the meso level. However, it has become clear that when searching for strategies to reduce the energy requirements of household consumption, change options at all three levels should be incorporated. Individual households can make choices in their daily life that result in a lower energy demand. But it should be realized that households are part of a complex system in which many actors play their role. The interrelationships between the various levels are crucial when composing strategies aimed at ‘greening’ our present day consumption patterns. Without a good public transport system, people are not likely to not use their car anymore. Buying locally produced, open air grown food requires the presence of locally-produced-food shops in the neighbourhood, and saving on the energy bill requires a good quality house. At various levels different stakeholders are involved.

Designing strategies aimed at reducing the energy requirements of households demands a fair understanding of the system at various levels, and a clear picture of the most important stakeholders playing a role in identifying and implementing the most promising change options.

## Discussion and conclusions

### *7.1 Discussion*

In this paper some general salient results are presented. Further analyses of the results will surely produce more detailed insights in the total energy requirements of different household types in the four cities. For the first time the Dutch EAP model was applied for other countries. For this purpose, most of the database of the original EAP model had to be modified. As much as possible, data of the country of origin were used in the analyses. However, we were not able to replace the complete Dutch data set with country specific data.

We experienced that collecting identical types of data in various countries is very difficult. National statistical bureau’s collect and present data in (slightly) different ways. The effects of using different types of data need to be studied further. We expect that in some cases the use of different statistical data might significantly influence the outcome of the analyses. This is true for both economic-financial data (budget surveys, Input-Output tables, energy prices etc.) and energy data (direct energy use of sectors and households). Completing the various data sets with better quality data is also a priority for further research.

With respect to the EAP model, Wilting [3] did an extensive study regarding the uncertainties of the Dutch EAP model and the outcomes of the model. According to Wilting uncertainties in the energy intensities of individual sectors are in most cases between 6 and 8% and uncertainties in price levels of products are around 10%. An example of an uncertainty analysis for an individual product (a wholemeal bread) is given. The maximum uncertainty of the product is calculated to be 20%. Since not all uncertainties lie in the same direction the 95% confidence interval will be less than 20%.

### *Concluding overview of the findings*

*About direct energy requirements:*

- Large differences exist in direct energy requirements among households in the four cities: expressed in primary energy terms the average direct energy requirements of a household in Guildford are almost 50 % higher than in Stockholm. When taking into laccount the efficiency of the electricity supply, final energy demand of households in Fredrikstad is the highest.
- Large differences exist in the share of electricity in the direct energy demand of households. Electricity counts for more than 50% of the direct energy use in Fredrikstad whereas in other cities this share varies from 16% to 30%.
- The share of motor fuels in Fredrikstad and Guildford (30%-35%) is much higher than in Groningen and Stockholm (18%-19%), indicating a more intensive car use.
- The direct energy requirement differs significantly per type of household: In Stockholm direct energy use of various household types varies from 34 GJ to 208 GJ whereas in Groningen direct energy use varies from 43 GJ for a student household to 175 GJ for households living in a detached house.

*About indirect energy requirements:*

- Large differences exist in the indirect energy requirements among households in the different cities. The average indirect energy requirements of households in Guildford are more than twice as high (234 GJ/household) as in Groningen (97 GJ/ household).
- Indirect energy requirements are strongly related to the absolute spending levels. However, also the energy intensity of expenditure patterns (i.e. the composition of the consumption package) should be taken into consideration. The energy intensities of Euros spend on food (9-10 MJ/€) and recreation (8.5-10 MJ/€) are the highest. Spendings in the category house (rent and mortgage) have a low energy intensity (2 MJ/€).
- The average energy intensity of households in Groningen are the lowest whereas the energy intensities of households South East UK are the highest. The average energy intensities of households in Stockholm and Fredrikstad do not differ much and are just in between the energy intensities of expenditures of households in Groningen and the South East UK.

*About total energy requirements:*

- Large differences exist in the total energy requirements among households in the different cities. Households in the South East UK require about 42% more energy to run their daily life than households in Groningen.
- The total energy requirements per person in Stockholm and Fredrikstad are almost the same, whereas in Groningen and the South East UK the total energy requirements are respectively the lowest and the highest.

- Except for households in Groningen the share of indirect energy is about 60% in the other cities. The share of indirect energy of the total energy budget of households in Groningen is 45%.

*About change:*

- Change options to reduce the total household energy budget can be found at the macro-, meso- and micro level.
- When searching for change options, trends in the household sector are also important. Current trends such as increasing income levels, household dilution, growing populations, and aging of the population are likely to head to an increase in the total household energy requirements.
- By changing their consumption patterns, individual households do have options to reduce their energy budget. The degrees of freedom of individual households to change their consumption pattern differ significantly and are determined by factors at all three levels. It is clear that changes at the macro level (i.e. changing the energy intensities of goods and services) are inevitable to significantly reduce the household energy requirements.

*Conclusions at a more general level:*

- The EAP model is a valuable tool to explore the relations between household consumption patterns and energy use.
- Indirect energy use accounts for (approximately) half of the household total energy use. Therefore, it needs to be considered in policy making.
- Information about the energy efficiency of spendings is valuable but cannot be presented and used without considering basic needs and quality of life.
- Energy profiles of different household types often differ a lot from the average picture. There is a need for individual consumer advice about more energy efficient consumption patterns.
- Large reductions in household energy use, such as a factor four or more, seem to require substantial changes in the energy intensity of the production system together with major shifts in expenditure patterns and possibly also reduced household expenditures.

## Acknowledgments

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# Indicators for the environmental pressure of consumption

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## Abstract

An integrated input-output model is a useful tool for tracing environmental impacts of consumption. By including impacts originating from production layers of infinite order, the methodology is highly relevant for studies operating in a life-cycle context. In this work we show how the input-output approach can be used to enumerate the problem of sustainable consumption. From our recent as well as ongoing research, we present examples of key indicators such as $CO_2$ emissions, and extend the analysis to a range of spatial scales, from the national to the household level. Finally, we discuss the policy relevance of the different indicators.

## 1. Introduction

Living means consuming, and consuming causes resource depletion and environmental degradation. Some contributions to environmental pressure arise from activities associated directly with households. These are, for example, the consumption of fuels and water in the house, or the consumption of petrol through driving a private vehicle. The resources needed and pollutants emitted by households are called *direct requirements*.

Households also cause environmental pressure indirectly through the consumption of goods and services. The corresponding resources and pollutants needed to satisfy consumer demand are called *indirect requirements*. These indirect requirements occur in the numerous industries situated in the countries in which the goods and services demanded by the consumers are produced. However, in accordance to Adam Smith's classical statement that "consumption is the sole end and purpose of all production" (Smith 1776 Volume II Book IV), they are ultimately being demanded by the households.

Indirect requirements must be understood as of "infinite order". This means that they, in the case of the provision of a train journey, for example, not only include environmental pressure caused by the very train journey, but also through assembling the train and running the stations, producing the steel for the train and the concrete for the station buildings, producing the materials for the respective steel and concrete factories, the machines to mine the iron ore, sand, etc, the steel to produce the mining equipment, and so on. This process of industrial interdependence proceeds infinitely in an upstream direction, through the whole life cycle of all products, like the branches of an infinite tree. The sum of these direct and indirect requirements of resources and pollutants is called *total requirements*. A technique used to calculate total requirements is input-output analysis.

The aim of the paper is to outline some analytical techniques for examining sustainable consumption. The paper is based on recent and ongoing research carried out by the authors. A common characteristic for the past and recent research projects is the use of an integrated, generalised input-output approach to analyse a range of policy issues. Another characteristic is that the environmental impact of consumption has been analysed at different scales: from national, state, city and household perspectives. The possibility of making studies of relevance at both the macro and micro levels is one of the benefits of input-output analysis.

The focus of this paper will be on empirical indicators of relevance to estimating the environmental impact of consumption. Without restricting the generality of our results and conclusions, the impact of $CO_2$ emissions will be considered as an example.

The paper is organised as follows: in Section 2 different methodological approaches for analysing sustainable consumption are introduced. Section 3 describes empirical indicators on a range of spatial scales for the $CO_2$ pressure of consumption. The policy relevance of these indicators is highlighted in Section 4. Finally, Section 5 concludes the paper.

## 2. What is the environmental pressure of consumption and how to estimate it?

*Energy analysis* was developed for the assessment of both direct and indirect (”embodied”) energy requirements for the provision of goods and services (International Federation of Institutes for Advanced Studies 1978). A bottom-up approach, *process analysis*, is usually employed where energy requirements of the main production processes and some important contributions from suppliers of inputs into the main processes are assessed in detail (for example by auditing or using disparate data sources), and where the system boundary is usually chosen with the understanding that the addition of successive upstream production stages has a small effect on the total inventory. The Institute for Energy Analysis, set up in Oak Ridge, Tennessee in 1974, established guidelines for the investigation of energy supply and conversion systems in terms of the net energy output (Perry *et al.* 1977b) or the energy service delivered to the consumer (Devine 1979).

Early studies already recognised that process analyses carry significant systematic errors due to the unavoidable truncation of the system boundary. Herendeen, Hannon, and others at the Center for Advanced Computation in Urbana, Illinois, therefore suggested to employ input-output analysis in order to account for energy requirements originating from inputs out of upstream supply chains of infinite order (Herendeen 1973). Since this statistical, top-down approach suffers from various shortcomings such as aggregation and allocation errors, Bullard and co-workers (Bullard *et al.* 1978) developed a hybrid analysis technique, combining the main advantages of process and input-output analysis, that is completeness and specificity.

With the increasing recognition of the threat of anthropogenic climate change, the emphasis in assessments of energy supply and conversion systems shifted from net energy to embodied greenhouse gas emissions. Nevertheless, greenhouse gas analyses were still carried out using process, input-output, and hybrid techniques (for a reference list, see Lenzen 1999).

## 3. Indicators for the $CO_2$ pressure of consumption

An integrated national input-output framework including the linkage of consumption and other categories of end use to production activities, and further to environmental effects, has many applications when combined with other data sources. The inclusion of foreign trade statistics makes it possible to analyse the embodied environmental burden in commodities traded between countries. This points to a national environmental accounting principle founded in consumer responsibility and to the concept of environmental balances between countries. Developing both these indicators within a multi-regional framework including foreign input-output and environmental statistics will form a basis for valid estimations of the environmental burden sharing between countries.

Combining input-output and detailed household expenditure data makes it possible to analyse the environmental pressure from household consumption. If household expenditure data and household characteristics can be linked, this opens up a wide range of studies in the field of "the socioeconomics of environmental pressure".

In the subsections below, different empirical indicators founded in an integrated input-output approach are described. The indicators cover a range of spatial applications from national down through city, commodity and household levels.

### *3.1 National indicators*

#### National $CO_2$ accounting and the influence of foreign trade

Especially for open economies such as Denmark, taking into account the greenhouse gases embodied in internationally traded commodities can have a considerable influence on the national balance of greenhouse gases. Increased export of commodities produced in Denmark, for example, increase Danish energy consumption and greenhouse gas emissions, while the opposite holds for imports into Denmark. Munksgaard and Pedersen (2000) report that a significant amount of electricity and other energy-intensive commodities are traded across Danish borders, and that between 1966 and 1994 the Danish foreign trade balance in terms of $CO_2$ developed from a 7 Mt deficit to a 7 Mt surplus, compared to total emissions of approximately 60 Mt. Emissions figures to be reported to the Intergovernmental Panel on Climate Change (IPCC) do not reflect national 'greenhouse gas responsibilities', but simply refer to territorial emissions. Consequently, meeting national emissions targets is becoming more difficult for Denmark, since an increasing part of greenhouse gas emissions from Danish territory is caused by foreign demand.

Similarly, Subak (1995) investigates methane ($CH_4$) embodiments in the most $CH_4$-intensive agricultural goods, and the possibility of $CH_4$ leakage. Subak points out that if greenhouse gases embodied in trade flows were more closely monitored, leakage would be avoided and moreover, trade could serve as a *de facto* abatement control, since countries with insufficient greenhouse gas credits from emissions trading schemes would import commodities from countries with more efficient industries.

These two examples highlight the relevance of a revision of greenhouse gas accounting practices for the Conferences of Parties (COP) under the UN Framework Convention on Climate Change. In Kyoto in 1998, differentiated emission reduction targets for industrialised nations were negotiated for the first time. However, these targets were set without consideration of international trade.

One way of dealing with international trade in regard to $CO_2$ emission is by applying input-output models. Some studies dealing with environmental factors in a generalised input-output framework assume closed economies. Most studies employ single-region models where imports are either treated as exogenous (that is to be determined externally, see Schaeffer and Leal de Sá 1996, Wyckoff and Roop 1994, and Common and Salma 1992a), or endogenous (that is an intrinsic element of the model, see Lenzen 1998b, Pedersen 1996, and Denton 1975). In both cases, however, factor embodiments in imported commodities are determined by applying the domestic production recipe and energy use structure.

Using a single-region input-output model and assuming that factor uses of foreign industries are identical to those of domestic industries can introduce an error into the $CO_2$ multipliers (the amount of $CO_2$ embodied in a value unit of commodities produced) and hence into $CO_2$ embodiments in internationally traded commodities. In order to arrive at more realistic estimates of the amount of $CO_2$ embodied in commodities traded internationally, one can employ a multi-region input-output model including multi-directional trade flows.

Combining Denmark, Germany, Sweden, Norway and the rest of the world, we have investigated three trade scenarios:

1. Five autonomous regions that are completely decoupled with regard to inter-regional trade: imports are treated as domestic production.
2. Unidirectional trade into Denmark: the introduction of foreign production, energy and $CO_2$ data relaxes the assumption inherent in Scenario I that foreign industries exhibit factor multipliers that are identical to those of Danish industries.
3. Multi-directional trade between Denmark, Germany, Sweden and Norway, and *from* the rest of the world[45]: inclusion of feedback loops and capture of direct, indirect, and induced effects of trade.

[45] The trade from Denmark, Germany, Sweden and Norway *to* the rest of the world was assumed to be negligible in terms of total imports of the rest of the world.

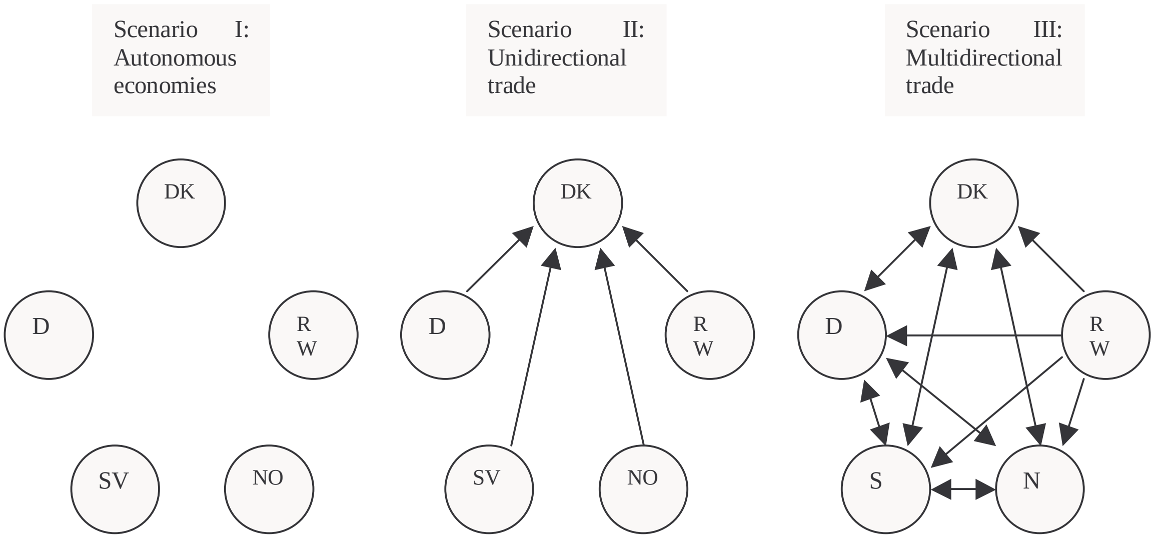


Figure 1: Schematic of three trade scenarios
(DK = Denmark, D = Germany, SV = Sweden, NO = Norway, RW = rest of the world).

Using the multi-region input-output approach, it is possible to determine Danish national $CO_2$ balances (see Tab.1 below). In contrast to conventional emissions accounts, these balances are expressed in terms of embodiments in final demand, and include $CO_2$ embodied in imports. They thus reflect consumer rather than producer responsibility for $CO_2$ emissions.

| Scenario | I: Auton. econ. | II: Unilat. trade | III: Multilat. trade |
|---|---|---|---|
| $CO_2$ responsibility | 63.0 | 74.2 | 73.1 |
| Exports | 34.2 | 43.4 | 43.2 |
| Imports | 38.9 | 59.3 | 58.0 |
| Trade balance | -4.7 | -15.9 | -14.8 |

Table 1: Comparison of 1997 Danish $CO_2$ trade balances obtained from input-output models with varying degrees of trade interaction.

In 1997, 58.3 Mt of $CO_2$ were emitted from industries operating on Danish territory, and reported to the IPCC (producer responsibility). The transition from producer to consumer responsibility (scenario I) increases the $CO_2$ emissions associated with Danish production by about 10% or 4.7 Mt to an overall 63.0 Mt. While 38.9 Mt are embodied in imports into Denmark (27.4 Mt into Danish industries, and 11.5 Mt directly imported by Danish households and governments), 34.2 Mt become embodied in exports, so that Denmark exhibits a negative trade balance of 4.7 Mt. In the transition from scenario I to

II the $CO_2$ responsibility of Danish final demand increases from 63.0 Mt to 74.2 Mt, because generally, foreign industries are more $CO_2$-intensive than Danish industries, thus increasing overall imports embodiments from 38.9 Mt to 59.3 Mt. As a result, the trade balance is negative at 15.9 Mt. Taking into account the multilateral trade structure of all regions changes the picture only slightly. Effects work towards the evening-out of regional differences: Relatively $CO_2$-intensive economies such as Denmark and Germany experience a general decrease, while the opposite holds for Sweden and Norway. The Danish $CO_2$ responsibility is now 73.1 Mt, while trade balance is –14.8 Mt.

These results demonstrate that it is important to explicitly consider the production recipe, energy use structure and $CO_2$ emissions of all trading partners, in order to arrive at realistic figures for $CO_2$ embodied in trade, and hence for the national contribution to emissions, based on consumer responsibility.

**Growth in national $CO_2$ emissions analysed by structural decomposition analysis**

Over the past decade, decomposition analysis has proved to be a useful tool for analysing changes in energy consumption, see e.g. Chen and Rose (1990), Li et al. (1990), Rose and Chen (1991), Boyd et al. (1988), Lin and Polenske (1995), Bruin et al. (1996) or Liu et al. (1992). A few studies have also decomposed changes in emissions, e.g. Common and Salma (1992b), Halvorsen et al. (1991), Ang (1997), Chang et al. (1998), Wier (1998) and Wier and Hasler (1999).

In their studies Munksgaard, Pedersen and Wier (2001, 2000), integrated input-output analysis has been combined with structural decomposition analysis. The aim of the studies were to analyse which factors influenced the change in $CO_2$ emissions from Danish household consumption over the period 1966 to 1992. Contrary to the multi-regional study described above, these studies have been founded in a single-regional approach only including Danish data. This implies the treatment of import as produced by Danish industries.

Decomposition analysis is carried out by changing the impact factors one by one in order to quantify the contribution of each factor to total change in emissions. The contribution of each factor is estimated as the change in the factor multiplied by the other factors. The impact factors considered in the studies include, among others: growth in total consumption, change in the composition of consumption, changes in energy intensities and changes in fuel mix in production sectors.

Total Danish household consumption increased by 58% in fixed prices over the period 1966 to 1992. We found, however, that total $CO_2$ emissions from Danish household consumption only increased by 7%. This points to the fact that overall $CO_2$ intensity has been reduced significantly (-35%) over this period.

Results from the studies show that overall growth in household consumption of energy and other commodities has been the main driving force behind growth in $CO_2$ emissions over the period 1966-92. This was partly offset by reduced energy intensity in consumption caused by substantial energy conservation in the households, the energy supply sector and other production sectors during the whole period plus changes in the commodity mix in private consumption. Over the period 1966-92 change in the composition of consumption has been insufficient to compensate for the overall growth in Danish consumption.

The highest growth rates in household consumption were observed in the consumption of services, transport, and recreation and entertainment. This indicates changing consumption patterns towards a life style with more telecommunication, more traveling and more leisure activities. From an environmental point of view this development is mainly beneficial since services and recreation and entertainment are characterised by lower than average $CO_2$ intensities. However, the increasing demand for transport services may constitute a severe problem in the future and considerable efforts should therefore be made to control $CO_2$ emissions from this activity.

Consumption of non-energy commodities in Danish households accounts for almost as much $CO_2$ emissions as consumption of energy commodities. In 1992, emissions from energy use accounted for 21 million tonnes whereas emissions from non-energy commodities accounted for 20 million tonnes.

Emissions from consumption of energy commodities increased by only 1% from 1966 to 1992 as direct household emissions have decreased continuously since the mid 1970s due to energy conservation and shifts towards less $CO_2$ intensive types of heating.

$CO_2$ emissions from non-energy commodities increased by 15% from 1966 to 1992, mainly due to overall growth in private consumption. Our decomposition analysis shows that, if all other factors were unchanged, increasing private consumption would have caused a 47% increase in $CO_2$ emissions between 1966 and 1992. However, this growth was partly offset by energy conservation in production. If energy intensity in production sectors had remained constant at the 1966 level, indirect $CO_2$ emissions would have been 31% higher than they actually were in 1992. Thus, if the behaviour of firms had remained unchanged, the environmental consequences of private consumption would have been much more critical.

### 3.2 City indicators

For cities, and regions within nations in general, the problem of assessing environmental performance is complicated by the need to establish a boundary and to deal with a much more specialised and open local economy. As an example for city assessments, direct (end-use) energy requirements were audited in the Urban $CO_2$ Reduction Project established by the International Council for Local Environmental Initiatives (Brugmann 1996; see also Bennett and Newborough 2001) with the intention of assessing greenhouse gas emissions. This project developed into what is now known as the *Cities for Climate Protection* (CCP) campaign which has more than 500 member municipalities (see www.iclei.org/co2). The basis of the assessment procedure, the establishment of the emissions inventory, is outlined in software developed by Torrie Smith Associates (2002) in Toronto, Canada. The Association of American Geographer's *Global Change in Local Places* project is another, independent effort to examine the causes and effects of climate change at a local level (Kates *et al.* 1998).

In assessing a local area, one has to distinguish between greenhouse gas emissions *occurring in* a local area, with emissions *resulting from* the activities required to support the local population. There are many important indirect emissions that are ignored in, for example, the CCP approach. While accounting for environmental pressure on a purely territorial basis may be appropriate for impacts such as localised urban pollution, or urban microclimate, an assessment of global impacts such as climate change needs to take into account indirect contributions. Kates *et al.* (1998) do identify indirect emissions as important. However, in the CCP approach "the marginal benefit of computing and applying full-cycle coefficients did not seem justified by the benefits" (presumably a more complete emissions inventory). Kates *et al.* (1998) admit that "all greenhouse gas emissions could be linked to final consumption behaviour, but the extent to which such a principle should be and can be applied is a central consideration in the methodology of local emissions inventories". This is a key philosophical point: a city exists fundamentally to support the lives of its inhabitants. The fact that for example a steel-making facility is located in one area, the output of which clearly supports populations elsewhere, does not mean it is appropriate to apportion all the emissions from the facility to the local inhabitants. This approach does not invalidate emissions reduction action taken within the steel making facility: it means that this action benefits all future users of the steel.

Indirect emissions and boundary issues become critical when comparisons are made between cities or local government regions. In CCP studies for example, very large differences, sometimes up to an order of magnitude, in the per capita $CO_2$ emissions of local government areas in the same country have been observed. These differences are primarily due to the nature of the accounting of indirect emissions. For example, people who happen to live in a central business district are largely not responsible for the large amount of electricity used by the businesses in that area.[46] A comparison on the basis of local per capita emissions is therefore of limited meaning.

A comprehensive and consistent assessment of cities and regions can be achieved by applying input-output analysis and multi-variate regression techniques. In a study of the Australian city of Sydney, Lenzen, Dey and Foran (2002) calculated households' energy requirement using input-output-based energy multipliers, and examined the correlation of these energy requirements with socio-economic-demographic variables such as expenditure, household size, age structure, number of children, house type, employment and education status.

### *3.3 Commodity indicators*

Several studies have investigated the amount of energy or environmental effects like $CO_2$ embodied in different kind of commodities, see e.g. Faist et al 2001, Wilting and Biesot 1998, Vringer and Blok 1995. Indicators for ranking the commodities have most often been specified in units of physical effects in e.g. kg per unit of commodity in value terms. The techniques used for analysis are most often input-output analysis, process analysis or hybrid analysis.

In the study done by Munksgaard et al 2001, $CO_2$ emissions from different non-energy commodities are estimated by the use of a single-region input-output model**.** Table 2 shows $CO_2$ emissions and $CO_2$ intensities in 1992 for eight aggregated groups of non-energy commodities.

[46] Larivière and Lafrance 1999), for example, exclude industrial electricity consumption from their regression analysis of Canadian cities, because it is not explained by any city characteristics.

Table 2: $CO_2$ emissions for aggregated commodity groups in 1992

| Commodity Group | $CO_2$ emission million tonnes $CO_2$ | $CO_2$ intensity kg/DKK |
|---|---|---|
| **Direct $CO_2$ emissions** | | |
| Electricity | 8.2 | - |
| Gasoline | 4.7 | - |
| Other heating | 3.5 | - |
| Oil | 3.2 | - |
| Gas | 1.6 | - |
| **Indirect $CO_2$ emissions** | | |
| Foods | 5.5 | 0.16 |
| Recreation and entertainment | 3.9 | 0.12 |
| Transport *) | 3.0 | 0.18 |
| Household appliances incl. operation | 2.8 | 0.05 |
| Clothing | 1.6 | 0.12 |
| Services | 1.1 | 0.07 |
| Beverages and tobacco | 1.0 | 0.16 |
| Health | 0.7 | 0.1 |

*) Includes vehicles and public transport services. Source: Munksgaard et al (2001:151)

Looking at total $CO_2$ emissions in 1992 the consumption of foods is the biggest non-energy contributor accounting for 5.5 million tonnes $CO_2$. Thereby, consumption of foods is responsible for more than 10% of total Danish $CO_2$ emissions from the household sector. Comparison of indirect and direct household emissions reveals that only emissions associated with electricity consumption (8 million tonnes $CO_2$) are greater than those associated with the consumption of foods. In comparison, gasoline consumption only accounts for 5 million tonnes $CO_2$.

Next to the consumption of food "recreation and entertainment", "transport" and "household appliances incl. operation" are the biggest $CO_2$ contributors. Not very surprisingly "transport" is the commodity group having the highest $CO_2$ intensity (0.18 kg/DKK). However, the production of "foods" and "beverages and tobacco" is also very $CO_2$ intensive, which is shown in table 2. The commodity group having the lowest $CO_2$ intensity is "household appliances incl. operation" (0.05 kg/DKK).

Analysis on a more detailed commodity level reveals even larger variations in $CO_2$ intensities. In 1992, the most $CO_2$ intensive commodity was public transport, followed by various kinds of food products. Commodities having the lowest $CO_2$ intensity include various types of services. This implies that greater demand for services together with reduced consumption of commodities such as transport, foods and beverages will be accompanied by major decreases in $CO_2$ emissions.

In fact our results show that policies directed towards household consumption of commodities other than energy offer considerable potential for reducing $CO_2$ emissions.

As the differences in the $CO_2$ intensity of the various commodities is sizable, changes in commodity mix towards less $CO_2$ intensive goods could be of significant importance.

The reduction potential of altering the commodity mix suggests policies should be directed towards this end. One possibility is eco-labelling, another is a green levy program in which the highest levies are imposed on the most polluting commodities. Such policies would encourage the consumers to spend more of their budget on commodities with low $CO_2$ intensity. However, the impact of a green levy program will depend on how price elastic demand for different commodities is.

### *3.4 Household indicators*

Indicators of the environmental pressure of households make it possible to compare households that are different with regard to socio-demographic household characteristics such as income, age, education, urbanity and number of children.

Different family types have different lifestyles and consumption patterns and hence affect the environment in different ways. Household indicators are useful for assessing the environmental effects of different household types, making it possible to identify family types representing high environmental pressure. Furthermore, household indicators reveal the environmental effects of changes in household characteristics, therefore informing the environmental consequences of future demographic and economic scenarios.

Household indicators can be specified in different units, e.g. per household or per capita. Corrections can be used to eliminate the positive influence of income and the influence of more household members. This leads to household comparisons based on the emission intensity of consumption measured as for example kg emission relative to household income, or kg emission relative to number of consumer units[47].

Studies linking input-output and household expenditure data for entire countries have been undertaken by a number of authors. The techniques was introduced by Herendeen in the early 1970's and first applied to the US economy of 1960-61 (Herendeen and Tanaka, 1976), the Norwegian economy of 1973 (Herendeen, 1978), and again the US economy of 1972-73 (Herendeen et al., 1981). The demographic factors considered in these early studies were total expenditure (related to income), number of household members, and regional population density. The main results of these early studies were that (1) a substantial part of a household's energy requirements is constituted by non-energy commodities, (2) total energy requirements increase less than proportional with income, that is, total energy intensity decreases with income, (3) per-capita energy requirements decrease with the number of household members, and (4) urban households exhibit a lower energy intensity than rural households.

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[47] When comparing various household types (e.g. urban and rural households), most studies make adjustments for differences in household size by applying per capita household energy requirement. However, there may be economies of scale in consumption, as commodities can be shared in larger families and as item prices may decrease with purchased amount. Therefore, each consecutive household member counts less than the previous one. Furthermore children count less than adults, as their consumption is lower. An approach to this problem is to apply a scale of *consumer units*, weighting household members according to their decreasing impact on household consumption. An example of this is consumer units defined by the *modified OECD scale*, where the first adult person in the household counts 1, other adults count 0.5 and children count 0.3.

These results were confirmed in similar studies on other countries, such as the Netherlands (Vringer and Blok 1995, and Biesiot and Noorman 1999), Germany (Weber and Fahl 1993), New Zealand (Peet et al. 1985), Japan (Aoyagi et al 1995: Kondo et al 1996), and Australia (Lenzen 1998).

### Recent Danish research

In a recent Danish study (Wier et al., 2000) on energy consumption and derived $CO_2$ emissions, more socio-demographic household characteristics were included. In addition to disposable household income, urbanity, and number of adults and children in the household, characteristics such as type of accommodation (flat/house), age, education and employment status of main income provider in the household were included. The Danish study suggested that in Denmark the above mentioned main results hold: household income is the main explanatory variable. This holds for direct as well as indirect energy consumption. Direct energy consumption increases with income, but less than proportionally, however, due to saturation. Besides expenditure, house type, urbanity and age are important too. This is due to increased transportation and heating needs for families living in houses and in rural areas, compared to for families living in flats and in urban areas. Furthermore, age has a small, but significant influence, as young households have lower direct energy requirements.

Indirect energy consumption turned out to be almost proportional to income, with the remaining explanatory variables having very little importance. Underlying the higher energy requirements for families in higher income brackets are, first, higher total consumption of all goods, and second, that consumption pattern changes with income. Thus, high income families have much higher indirect energy consumption due to a higher share of energy intensive goods like recreation activities and travelling. For more on this, see Wier et al, 2001.

Household size, which is highly positively correlated to household expenditure, has only minor, (negative) influence. Consequently, in Denmark sharing goods in larger households is not sufficient to decrease neither direct, nor indirect energy consumption significantly.

Level of education and employment status do not make any noteworthy difference. The fact that these variables, which in turn may be related to lifestyle and consumer values (see e.g. Bourdieu, 1989, 1990; Turner, 1988) have minor importance for direct energy consumption is supported by other studies (cf. Stokes et al. (1994), Pedersen (1997, 2000) and Jensen (1999)).

### Multivariate approaches

The input-output based approach has its limitations, however. In analysing the influence of more socioeconomic variables on household emissions of $CO_2$, the shortcoming of input-output analysis is that the method is not able to determine the significance of the relative impact of the different variables considered. Such kind of correlations analysis calls for multivariate regression analysis, which is able to estimate the effect on energy requirements (or derived emissions) from a change in each household variable, when controlling for the effects from other variables.

In an ongoing study (Lenzen et al., 2003) a multivariate analysis of energy requirements of households in Australia, Brazil, Denmark, India and Denmark is being carried out.

This analysis reveals that for all countries, except for Japan, expenditure is the main explanatory variable – for Japan this is urbanity. In all cases, the expenditure elasticity is lower than or equal to 1, indicating that energy demand is rather inelastic with regard to household expenditure in all countries. Urbanity has significant negative influence in all countries, except from India, where the effect is positive. Age has significant positive influence in all countries, except for Japan. More results on other household characteristics – and on the inter-dependencies between them – can be found in Lenzen et al. (2003).

### *3.5 Overall environmental performance indices – the DEA approach*

Most input-output based studies consider solely energy consumption and $CO_2$ emissions. However, consumption is related to a large number of different types of environmental degradation. As the commodity mix in consumption changes, this change will have different impacts on the different types of environmental pressure. The previous studies described in this paper, have not provided information on the effect on other types of environmental pressure than energy and $CO_2$ emissions.

The main reason for not including other types of emissions has been insufficient emission data. In the past decade however, several countries, among others Denmark, have improved their environmental statistics, and begun developing environmental satellite accounts, compatible with traditional economic national accounts meaning that economic flows, physical flows and emissions can be linked altogether. In the Danish environmental account system, various physical flows like energy, iron, wood etc are estimated. In addition, various emissions are included, e.g. energy related emissions of $CO_2$, $SO_2$, $NO_X$ and particulates, NMVOC, $NO_X$ and CO emissions from transportation and industry, and $CH_4$, $NH_3$ and $N_2O$ from agriculture.

Using this system, it is possible to estimate, not only $CO_2$ emission indicators for various goods, countries, or households, but now also emission profiles for each unit, including all types of relevant environmental effects. The advantage of emission profiles is that much more information is provided, compared to $CO_2$ indicators. The drawback, however, is that large amounts of information may be difficult to interpret. As a shift in commodity mix may imply multiple effects, e.g. increasing $CO_2$ emissions together with decreasing $NH_3$ emissions, it is complex to assess whether improved environmental performance in general occurs, or not. Consequently, to reduce complexity, there is a need for weighting different types of environmental pressures – due to their relative importance – together in a broad environmental performance index, aggregated across environmental pressure types.

From an economic point of view, the ideal environmental index would measure the reduction or increase in social welfare following the change in environmental pressure. The best way to aggregate across different types of environmental pressure, that is, to weight different types of environmental goods (or “bads”) together, would be to assign weights to each pressure type due to society’s preferences measured by marginal utility, which in turn equals prices. Environmental goods are, however, most often not supplied and demanded on any market and hence, have no observable prices. Estimating prices on environmental goods is in principle possible, but is, however, costly and entailed with large uncertainty.

## The DEA approach

One way to overcome this problem is to apply Data Envelopment Analysis (DEA). DEA was introduced by Charnes et al (1978) as an alternative approach to the measurement of productivity or efficiency in firms or enterprises, which are either using or producing goods not directly bought or sold in a market, and which consequently have no observable prices. Productivity is normally assessed as the value of output per unit value of input (output productivity) or the amount of inputs used per unit of output (input productivity). Without prices, the values cannot be estimated, but using the DEA method, another type of productivity or efficiency analysis may be carried out to compare different units (e.g. firms). In short, the DEA method optimises an artificial "price" or "weight" for each unit in the analysis, in terms of the value of output divided by value of input. The philosophy behind this approach is that as the DEA method has chosen exactly those "prices" (or "weights") that gave the best possible result for this unit (e.g. a particular firm), and it turns out to be less efficient than other units (other firms) even so, then we can conclude that this unit does not perform well.

Correspondingly, DEA can be used to compare units with regard to environmental performance. Environmental efficiency may be understood as the lowest possible environmental pressure per unit produced or consumed. The units may be different firms, plants, sectors, goods, countries or households. The DEA method weights various pressure types together estimating an aggregated environmental performance index. Previous DEA analysis on environmental performance of various countries have been made by Taskin and Zaim (2000, 2001) and Zofio and Prieto (2001), and of environmental management systems by Sarkis (1999) and Sarkis and Weinrach (2001).

## Recent Danish results

In an ongoing Danish study, we apply DEA on good and household level in order to compare the environmental performance across goods or household types. Until now, we have aggregated the emissions into three types of environmental effects according to their relative effect or contribution to a particular type of pressure. Greenhouse gasses like $CH_4$, $N_2O$ and $CO_2$ can be weighted together in a Global Warming Potential index, $CH_4$, NMVOC and CO can be weighted together in a Photochemical Ozone Creation Potential, and finally $SO_2$, $NO_X$ and $NH_3$ can be weighted together in a Potential Acidification index. On top of this, DEA is used across household types regarding the three types of environmental effects. Currently, we are adding effects indices on contributions to Ozone Depletion Potential index, natural resource depletion and groundwater contamination. The analysis shows that families living in urban flats have the most environment-friendly consumption pattern – and low and middle-income, elderly families have the least environment friendly consumption pattern. Until now, this is to some extent revealing the same pattern as energy requirements analysis due to the fact that several of the included emission types are energy related. Thus, as more pressure types are included, we expect these conclusions to change.

An aggregated environmental performance index is valuable to decision-makers as well as to citizens as they provide a simple way of revealing success or failure of policies. The development in the environmental performance index holds information on the environmental effects of a given policy. If the policy is directed towards households, firms or sectors, it is relevant to consider environmental performance indices for these units. If we consider national or international policies, the environmental indices should be estimated at national level. Together with economic indicators such as GDP, the environmental performance indicator provides a good foundation for policy making based on comprehensive information in aggregated terms.

## 4. Policy relevance of the indicators

For environmental policy-making the relevant question will always be if a certain change in the environment is good or bad and further, how good or how bad? To be able to guide political decision making environmental indicators must there fore have some normative implications. Environmental indicators must be able to provide information support to allow such a value judgement, ideally based on explicit value systems, (eg. Olsthoorn et al (2001)).

In this perspective we will highlight the policy relevance of the indicators described in Section 3.

- *National accounting of $CO_2$ and other environmental pressures.* Accounting based on the consumption approach makes it possible to monitor whether national consumption over time is putting a greater strain on the environment. Using the production approach makes it possible to verify if international agreements on reduction targets are fulfilled and further, if the link between economic growth and environmental impact can be broken.
- *Environmental trade balances* give information about the environmental pressure put on other countries by domestic consumption. One practical use of such an indicator is to judge the fairness of international agreements on $CO_2$ burden sharing mechanisms. The appropriate apportioning of national contributions to climate change entails the calculation of greenhouse gas emissions embodied in international trade. The latter can be carried out conveniently using a multi-region input-output model. The results from these models impact on concepts of equity, and on producer and consumer responsibility, and therefore hold implications for negotiations at the Conferences of Parties in the UN Framework Convention of Climate Change, the forum for international negotiations on greenhouse emissions policy.
- *Multi-regional input-output modelling* also serves as a tool to analyse the potential for minimising the global environmental impacts from consumption. By comparing national environmental multipliers, e.g. $CO_2$ multipliers, for comparable industries or commodities it is possible to point out which countries are most efficient to produce given types of commodities as seen from an environmental point of view. Such kind of analysis might be useful in order to estimate the environmental benefits from restructuring international trade.
- *Analysing growth in national $CO_2$ emissions by structural decomposition analysis* points to the importance of decoupling overall growth in consumption from growth in environmental impacts. This can be obtained by focusing on measures influencing household consumption habits. Shifts in commodity mix towards less $CO_2$ intensive goods could be of significant importance since energy intensity differs significantly among commodities. Together with *Commodity Indicators* showing the embodied amount of environmental pressure in a value unit of a commodity, these tools can be used to assess environmental effects of changing consumption patterns. To change consumption pattern in an

environment-friendly way, product related environmental information to consumers (e.g. eco-labelling) would be a relevant policy instrument. Another instrument is a green levy programme for consumer goods in which the most $CO_2$ polluting commodities bear the highest levies would encourage the consumers to spend even more of their budget on low-intensity goods and services. Finally, a third way of influencing demand for low $CO_2$ intensity products would be to increase environmental levies on the industry, but this has the drawback that imported commodities then become more competitive, giving the consumers an incentive to consume commodities produced in countries without any environmental levies.

- *Indicators of the environmental pressure of households* are useful to assess the environmental effects of different household types making it possible to identify family types representing high environmental pressure. Furthermore, household indicators reveal the environmental effects of changes in composition of family types, therefore assessing the environmental consequences of future demographic and economic scenarios.
- *General environmental index (DEA).* The development of the environmental performance index holds information on the environmental effects of a given policy. If the policy is directed towards households, firms or sectors, it is relevant to consider environmental performance indices for these units. If national or international policies are considered, the environmental indices should be estimated at a national level. In combination with economic indicators such as GDP, the environmental performance indicator provides a good foundation for policy making based on comprehensive information in aggregated terms.

## 5. Conclusions

Integrated input-output modeling serves a useful tool to link environmental effects to consumption. Such modelling considers consumption (final use) as the first step in a process leading to environmental impacts. Present and ongoing research carried out by the authors show a great variety in applicating the methodology, from national to household environmental indicators.

Using the example of $CO_2$ we demonstrated in this paper that an integrated national input-output framework has many applications when combined with other data sources. The inclusion of foreign trade statistics makes it possible to analyse the embodied environmental burden in commodities traded between countries. This point to a national environmental accounting principle founded in consumer responsibility and to the concept of environmental balances between countries. Developing both these indicators within a multi-regional framework including foreign input-output and environmental statistics forms a basis for valid estimations of the environmental burden sharing between countries.

Combining input-output and detailed household expenditure data makes it possible to analyse the environmental pressure from household consumption. If household expenditure data and household characteristics can be linked, this opens up a wide range of studies in the field of “the socioeconomics of environmental pressure”.

Within the field of environmental pressure of consumption we point to different indicators and applications:

- National accounts of environmental effects based on producer or consumer responsibility can add valuable information to assess whether the link between economic growth and environmental impact can be broken.
- Environmental foreign balances are indicators measuring the environmental pressure put on other countries. Applied for the emissions of $CO_2$ the indicator has impact on concepts of equity, e.g. the burden sharing principles discussed in the forum for international negotiation on greenhouse emissions policy.
- National environmental multipliers based on multi-regional input-output modeling make a basis for discussing trade policies directed towards minimising the global environmental impacts from consumption. By comparing the multipliers for comparable industries or commodities it is possible to point out which countries are most efficient to produce given types of commodities as seen from an environmental point of view.
- Assessment of the environmental pressure of changing consumption patterns over time can be founded in structural decomposition analysis focusing on the economic driving forces behind changes in environmental pressure. Such commodity indicators point to regulatory measures as eco-labeling and a green levy programme for consumer goods or for industries.
- Indicators for the environmental pressure of households make a basis for identifying family types representing high environmental pressure thereby pointing to the socioeconomics of environmental impacts.
- Finally, using an integrated input-output model within a DEA approach makes it possible to develop general environmental performance index including a weighting of the pressure of more than just one environmental effect. Such environmental indices provide a foundation for monitoring the overall impact of a given environmental policy over time.


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# Life Cycle Sustainable Development: An Extension of the Product Life Cycle Assessment Framework to Address Questions of Sustainable Consumption and Development

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## Abstract

Life Cycle Assessment (LCA) is the flagship analytical tool in the Industrial Ecology "toolbox", with a history of 30 years of practical application in both industry and government, and a global and growing body of practitioners in industry and academia. LCA points to opportunities for:

a) consumers to select products which are "greener" (that is, less environmentally damaging from an overall perspective), and

b) producers to manufacture greener products.

The LCA approach's initiation and development has been steered by the goal of avoiding "burden-shifting" from one environmental problem to another, or from one life cycle stage to another. Even with LCA's challenging breadth, LCA-based inquiries can miss burden shifting within the realm of sustainable development, and can also miss opportunities for greater progress on sustainable development goals. The first required expansion is to include outcomes of an economic and social nature in addition to the current environmentally-related "Areas of Protection" which are used in LCA. The second required expansion relates to the framing of the question itself: Rather than take product-based delivery of a function as the pivot point of the analysis, we propose to quantitatively examine alternative ways that decisions alter the levels of satisfaction of fundamental and rather universal human needs for target shares of populations within societies.

In this paper we summarize the need for such an expanded framework, which we term Life Cycle Sustainable Development (LCSD). Next, we explore the feasibility of establishing an expanded set of "Areas of Protection" which address the scope of sustainable development; we suggest that one solution to this challenge may lie in recently proposed frameworks of core economic needs. Then we articulate the concept of need-required income (NRI) and summarize the results of recent analyses of NRI and its evolution over time. Finally, we propose an analytical approach for LCSD: main data sources and modeling methods which, in combination, can provide a capability for identifying and evaluating choices, from the level of individual to society, in terms of their consequences for levels of core human need satisfaction in the present and future.

## Background: From Green Products to Sustainable Development

Life Cycle Assessment (LCA) is a quantitative and comparative method for supporting the identification of environmentally preferable product choices and design options. LCA has a history of 30 years of practical application in both industry and government, and a global and growing body of practitioners in industry and academia. At the core of

LCA is the concept of the "functional unit": a quantitative measure of the amount of function delivered by a product system or service. *LCA as currently practiced takes the delivery of a specified unit of function as a given*; it then informs inquiries about the total system-wide environmental consequences of delivering this function via alternative product systems, and it points to opportunities for:

a) Consumers to select products which are "greener" (that is, less environmentally damaging from an overall perspective); and

b) producers to manufacture greener products.

The primary advantage of the LCA scope lies in its ability to help decision makers avoid "burden-shifting" from one environmental problem to another, or from one life cycle stage to another.

LCA is increasingly cited as a tool that can help guide the search for patterns of "sustainable consumption," and in achieving movement towards sustainable development. In particular, proponents have begun to cite "life cycle management" (LCM) as becoming increasingly capable of serving these two goals. LCM has been defined many different ways. In general, it is seen to consist of the integration of life cycle concepts ("life cycle thinking") with other information systems and metrics for management decision making in firms.

In our view, while LCA has value and LCM has promise, neither as currently conceived is up to the task of promoting sustainable consumption or sustainable development except in a narrow and partial way. This is true for the following reasons:

- The focal point for LCA is a specified unit of product-delivered function; this is a limitation because purchased products are not the only nor always the best way to achieve a function, and because need satisfaction, rather than function delivery, is closer to the core objectives of sustainable development;
- The focal point for LCM is choices by and on behalf of firms, either among alternative products or (possibly) alternative operational choices; this is a limitation because while profit-seeking firms are an important segment of the partnership of actors who must work together for sustainable development, there are also other decision making perspectives which must be empowered with decision support;
- The scope of the impacts is generally environmental and resource impacts, as well as impacts on human health via environmental pathways; this is a limitation because there are also important socio-economic pathways to human health consequences, and because the perspective of sustainable development tends to embrace a wider set of "areas of protection" than human health, environmental health, and resource sufficiency.
- The model scope generally excludes consideration of dynamics and price adjustments in both product markets and labor markets; this is a limitation because market supply constraints and price responses can limit the power of income growth in the aggregate to provide for need satisfaction in the aggregate: while more money to an individual enables that individual to increase consumption and need satisfaction, more money to everyone may simply bid up the prices for need-satisfying commodities that are in short supply;

- The model scope generally includes processes that are connected by appreciable material or energy flows excluding processes connected by economic flows or other causal influences which are non-material in nature; this is a limitation if we are attempting to provide decision makers with best estimates of the consequences of possible decisions.

Important environmental gains can be achieved by substituting alternative product designs at the level of a fixed functional unit (and thus within fixed consumption patterns). However, it is becoming increasingly clear that progress on "eco-efficiency" (economic output per unit of environmental burden) alone will not achieve the goals of sustainable development. For one thing, if economic output escalates faster than eco-efficiency, net environmental impacts continue to increase. Secondly, the so-called "triple bottom line" of sustainable development includes economic and social objectives, in addition to environmental ones. Third, aggregate economic output and consumption are properly viewed not as ends in themselves, but only as means to real ends.

A life cycle framework that means to truly serve the quest for sustainable development can no longer neglect the "other" imperatives of sustainable development including poverty reduction, increasing life expectancy and opportunity. At a minimum such a framework must be expanded to ensure that measures for achieving environmental gains avoid burden shifting to the socio-economic aspects of sustainable development. More positively, an expanded life cycle-based framework will help decision makers innovate within a broader space of possible options, and to identify within this expanded space those options that provide environmental *and* social and economic benefits. Finally, sustainable innovations only have an impact to the extent that they become *adopted* by industry and consumers. Thus, an analytical framework for "sustainable consumption" must address alternative patterns of consumption in terms of consumer acceptability, environmental efficacy, and socio-economic feedback loops.

## Framing Sustainable Development

Sustainable development means more than escalation of economic activity within environmental limits. There are two frames for sustainable development. The original expression came in 1987, in terms of "meeting the needs of present generations without compromising the ability of future generations to meet their needs." During the 1990s sustainable development has more commonly come to be expressed in terms of the three "pillars" of economic, environmental, and social objectives or indicators.

In adopting life-cycle-based methods of analysis to assist sustainability analysis, which of these frames or conceptions of sustainable development is most suitable to employ? At first glance, it would seem that the more recent "three pillar" approach is the logical choice: LCA could simply expand its set of impact categories or "areas of protection" to include social and economic measures of product system performance. This expanded indicator scope is the general tack being taken by corporate performance measurement systems such as the Global Reporting Initiative (GRI 2002) as these systems move from an environmental focus to a sustainability scope.

There are two problems with this approach. First, there is the proliferation of indicators, with no easy means in sight for their integration into an overall score. This problem might eventually be solvable, but at present there is no clear means. Instead, movement continues to be in the direction of increasing indicators in each of the categories: environment, social and economic.

A second, deeper, yet much more subtle problem with the three pillars approach is an inherent conceptual rather than a solvable technical problem; this is its tendency to confound development with economic growth. From within the presently conventional mind-set, with "economic sustainability" as one of the three pillars, the term "sustainable development" is readily understood to mean "constrained economic growth," as if economic growth were an end in itself. In this view, sustainable development then brings to the development program a set of social and environmental limiting conditions or at least competing sets of indicators which must be grappled with and somehow weighed, traded-off, or balanced in evaluating alternative means for sustaining economic growth. But since we know that money is only an indirect and partial *means* to human ends, then we must remember that the same is true of aggregate affluence. Of course everyone acknowledges this fact when pressed, but at other times and in other analysis frames we lapse nonetheless into treating economic growth as an end in itself.

Both these limitations can be addressed by building upon the broader, more recent and more enlightened definitions of development. Streeten (1995) traces the evolution, within the development field, of the defined *end* of development as progressing economic growth, to employment, to redistribution and alleviation of economic poverty, to fostering human development. Rather than development meaning increasing aggregate affluence, or increasing industrialization, development is properly evaluated in human rather than economic or technological terms, as increasing success in meeting basic human needs (Streeten 1981, 1995). The evidence and fruit of development is not that business is booming nor that wheels are spinning, but rather that human beings are thriving. Development is sustainable when present day thriving simultaneously builds rather than erodes the basis for future generations to thrive.

This brings us back to the original definition of *sustainable* development: better meeting the needs of the present while preserving or enhancing the ability of future generations to meet their needs. We propose to construct a framework for sustainable development that is centered on present and future satisfaction of core human needs. As we show below, defining an operational set of need-based indicators, while a challenge calling for creative input and dialog from many perspectives and experts, appears practical and doable.

## Elements of a Sustainable Consumption Framework

A long-standing general conceptual framework in which to consider the environmental impacts of consumption is the so-called "IPAT" identity first introduced by Commoner, Ehrlich and Holdren in the early 1970s (e.g., Commoner 1972; Ehrlich and Holdren 1972). This identity casts total environmental impact as equal to the product of the influence of population, affluence, and technology:

$$I = PAT \quad (1)$$

where impact might be in units of tons of CO2 emitted per year, affluence is in units such as $ per capita, and technology is in units of tons CO2 per dollar of output.

Very recently, Waggoner and Ausubel (2002) proposed a "renovated IPAT identity" as a framework for sustainability science, which disaggregates the "technology" term into two distinct constituents: an intensity of use term, "C", in units such as gallons of fuel per $ GDP; and an efficiency term "T" in units such as emissions CO2 per gallon of fuel.[48] The affluence and population terms remain as in the original framework, so that

$$I = PACT \tag{2}$$

This framework has the obvious advantage that it separates the influence of decisions and trends in consumption from production efficiency. It is obviously tautologically correct. The integration with LCA might be accomplished in general by considering the intensity of use term, C, to reflect functional units per dollar GDP. And it provides a basis for structural decomposition of past trends in impact, as well as for estimating the impacts of technology and consumption changes on environmental impacts. What it misses, however, are the *purposes, drivers, and benefits* of consumption. Thus, it provides one way to decompose past consumption trends, but it only assists the purely technological efforts aimed at achieving progress on sustainable consumption.

We suggest that a framework for sustainable consumption analysis that has the goal of inspiring and informing the search for decisions, innovations, and policies that will be *both* technically effective *and* successfully and lastingly adopted by consumers must first break the *implicit identification or confusion of well-being with consumption*. It must do so for several reasons:

- First, product policy *evaluators* must bear in mind that consumption is only instrumental to meeting human needs; it is not properly seen as a term in the objective function for sustainable development;
- Second, product policy *formulators* must work within a framework that provides explanatory power regarding the motivators and drivers of personal consumption choices, which is the attempt to satisfy a variety of needs; feedback loops from today's to tomorrow's consumption drivers;
- Third, we will all benefit from recognizing the phenomenon of "consumption efficiency", a now-neglected (indeed, invisible) but highly influential driver of consumption aspiration levels and the extent of human need satisfaction.

We address this third point in more detail in the next section.

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[48] A similar proposal was made in 1990 by Y. Kaya ("Impact of carbon dioxide emission control on GNP growth: interpretation of proposed scenarios." Paper presented at the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris, France.) Thanks to Edgar Hertwich for this reference.

### Affluence vs. Need-Required Income

We propose to make explicit the facts that income and consumption are instrumental rather than final ends, by decomposing the "affluence" term into two constituents:

N, the level of need satisfaction per person; and

S, the service intensity of needs satisfaction.

In addition, we suggest decomposing "technology" into two terms:

T1, the output intensity of final demand; and

T2, the emissions intensity of output.

Thus, total (environmental) impacts can be expressed

$$I = PNSCT_1T_2 \quad (3)$$

The term N should be conceptualized as a matrix, whose rows correspond to different basic needs, with a column for every person in the society, or for segments of the population. A draft set of core needs is elaborated below. For the present discussion we consider the core need of mobility, which might be loosely defined as the ability to move between work, home, and the other loci of activity with reasonable safety and timeliness. We note in passing that equation (3) is a conceptual device rather than a "model"; the relationships between the terms in the equation will have important nonlinearities. For example, there are generally diminishing returns of need satisfaction from increasing levels of service.

The term S, the service intensity of need satisfaction, can be conceptualized as a matrix whose rows are the core needs and whose columns correspond to different dimensions of "service." In the transportation example the unit of service might be kilometers of travel per person per year. Note that societal factors (e.g., proximity of employment to housing) as well as individual choices influence the service intensity of needs satisfaction. Levels of service will generally correspond to functional units in LCA.

The term C is the consumption intensity of services, in units such as $ of commodity per unit of service. C can be conceptualized as a matrix whose rows are the different categories of service, and whose columns are the different commodities (economically traded goods and services) which may be used to deliver a service. In fact, a third dimension of this matrix would enumerate the alternative commodity bundles that can be used to provide the service set in question. P*N*S*C =y would equal the total amount of commodities being purchased in order to provide the population with its current level of need satisfaction. This vector y is termed "final demand" in national economic statistics. Note that societal factors (e.g., the availability of public transportation, the characteristics of the road network, the willingness of neighbors to carpool, etc.) will influence which consumption options are present in C and what quantities of commodities are required to achieve given levels of service.

The sum of the elements of the vector y = P*N*S*C is equal to total personal consumption expenditures, which in the US accounts for roughly 2/3 of total gross domestic product (GDP).[49] The sum of N*S*C over the commodities is equal to per capita consumption, which is analogous to the "affluence" term in the IPAT and ImPACT frameworks described above. A value of the IPNSCTT framework is that it makes clear the instrumental nature of consumption and affluence; it shows that the affluence term is a function of the given levels of need satisfaction and of the consumption required to achieve this level of need satisfaction. The inverse of the product S*C can be considered a measure of "consumption efficiency" – the amount of need satisfaction achieved by a given level of private consumption. The inverse of S provides a measure of the "service efficiency" of a society – the amount of need satisfaction achieved by a given level of service delivery.

As the work of Segal (1999, 1998a, 1998b) has helped clarify, the inverse of S*C, which we have here termed "consumption efficiency", and which Segal referred to as "the social efficiency of money") has both individual and social dimensions.

At the individual level, consideration of consumption efficiency reminds us that:

- To "live well" is an "art," and ideally one continues through life to improve one's understanding of, and skill at satisfying, the myriad human needs in a balanced way; and
- Levels of satisfaction for several basic human needs depend significantly upon attributes of work besides wages/income.

At the same time, consumption efficiency reminds us that, to make effective progress towards sustainable consumption is likely to require not only individual choices, but also action at the level of groups and society as a whole:

- An individual's ability to achieve needs satisfaction at a given level of income is partly dependent on the person's social, cultural, and physical environment (e.g., the availability and effectiveness of public transportation, and the distances between housing and work drive the cost of mobility);
- The motivations, choices and consequences of consumption choices of individuals influence those of other individuals;

Segal (1998a, 1999, 2002) explored the level of income required to meet basic economic needs in the US: housing, mobility, food, health care, clothing, education, and economic security. The analysis indicates that the US economy/society as a whole has evolved during the past half-century in a way that has involved major reductions in consumption efficiency – that is, major increases in the level of consumption required to meet basic levels of core need. This was especially true in the need categories of housing, mobility, health care and education.

The history of attempts to identify the basic needs required to live a "good life" is at least as old as Aristotle. Indeed, some of the prominent threads of work attempting to relate basic needs to economic development (Sen 1998, Nussbaum 1998) build explicitly upon the Aristotelian framework. Both of these authors propose to characterize basic needs as necessary "capabilities to function." Nussbaum (1998) proposes a set of basic capabilities to function which is intended to be universally

[49] Other components of GDP in the US accounts are gross private fixed investment (16%), exports les imports (net –1%), government consumption and gross investment (18%) and change in private inventories (1%). Figures are for 1997, based on Kubach and Planting, 2001.

applicable across cultures. Within the field of psychology, Maslow (1958) and more recently Max-Neef (1992) have proposed sets of basic human needs.

Segal (1998) critiqued Nussbaum's approach, noting how it might be quite contestable across cultures. He then proposed to resolve much if not all of this cultural relativism by focusing on a subset of the basic human needs, which he termed core *economic* needs. A slight modification of Segal's set of core economic needs is summarized below, where we have opted to differentiate education from the care of children not in school:

- Housing: safe, minimally attractive housing a reasonable distance from work
- Transportation: safe public or private transport allowing family members to travel quickly among the central points of everyday life (e.g., home to work, schools, stores, communal activity)
- Food: ample, healthy, reasonably diverse and enjoyable food
- Health care
- Clothing
- Education
- Economic security
- Child care (pre-school and not-in-school)

The intergenerational equity aspect of sustainable development also has, for at least some decision makers, contemporary corollaries at the individual and societal levels:

Individual: seeking to meet one's needs while leaving intact or improving the ability of others to meet their needs; and

Societal: seeking to raise (and perhaps attempting to universally achieve at least minimum) levels of need satisfaction.

Indeed, the impact term "I" in equation 3 is ultimately of interest to human decision-making because of its influence on levels of need satisfaction for humans alive today and in the future.[50] We could therefore reformulate equation 3 as $N = f(P, S, C, T)$. The sustainable development challenge is thus to seek levels of P, S, C, and T which achieve desired outcomes related to need satisfaction, today and in the future, for self and others. Thus, a need-based framework for LCD has a closed-loop property, as shown in Figure 1a. Methods to provide for present and future needs are evaluated in terms of

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[50] The needs set certainly includes sustaining environmental quality, carrying capacity, resource health, and environmental beauty. Because of our interdependence, an individual's needs are partly served by the satisfaction of the needs of family and friends; the same holds true for the environment. But human needs may also include the preservation of biodiversity and ecosystem health as ends in their own right, even where a relationship of "dependence" has not been demonstrated. Stating that human needs are the basis of evaluation of human decisions is not "anthropocentric" in the sense that it excludes the possibility that humans will feel and act upon the need to nurture all of life on earth. A related point is that some of our needs are met by the very act of *serving* other's needs. This discussion pertains to issues beyond the scope of the proposed research, but is an important reminder of the fiction inherent in the simplified model of humans as autonomous need-satisfiers.

their impact on the provision of present and future needs. This is in contrast to the linear, "open loop" nature of the more traditional frameworks (e.g., IPAT, IPACT, Life Cycle Assessment, and eco-efficiency) which is illustrated in Figure 1b.

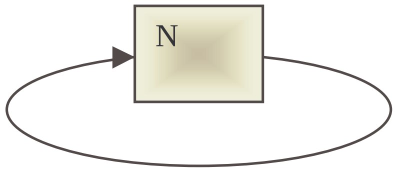



Figure 1a: Recursive nature of need-based framework

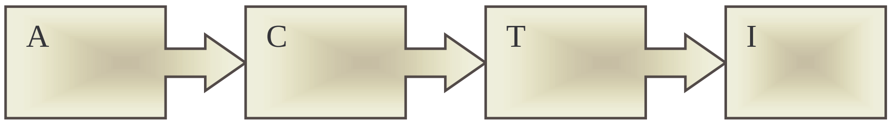



Figure 1b: Linear influence chain from affluence to consumer choice through technology to impacts

In a need-based framework for sustainable development and "sustainable consumption," the term N helps define a feasibility/acceptability constraint and possibly serves as part of an objective function, while the terms T, C and S all represent separate points of leverage to achieve progress. The approach must also attempt to identify and reflect the most important driving factors of individual consumption choice, and the most important feedback loops between individual choices and the evolution of the terms T, C, and N. This brings us to subjects of consumer theory and modeling, and economic + life cycle consequence assessment.

## Consumer theory and modeling

There are macro and micro-based approaches to modeling consumer behavior. We will address application of both in this project. Macro-based approaches work at the level of populations, and attempt to explain or predict market shares for different alternatives as a function of first cost, life cycle cost, other product attributes, as well as economic/demographic population characteristics. This type of modeling is often referred to as consumer choice theory or discrete choice analysis (e.g., Ben-Akiva and Lerman, 1985). Regression analysis is used to estimate parameters in models that forecast new purchase market share responses to product prices and other characteristics; multinomial logit and probit formulations have become a popular approach in models for integrated assessment and energy demand modeling by policy makers and electric utilities. As one among myriad examples, such a framework for modeling of consumer demand responses to policies was recently applied in a major study of $CO_2$ reduction potential and impacts for the Canadian government (Canadian Government 2002). These models *implicitly* capture the influence of realities such as variability in preferences and prices among consumers, limited/imperfect information, non-rational information processing, and the influence of non-price factors in consumer choice.

Regression-based models rely on the assumption that relationships among macro levels of demand and market shares among alternatives will continue to respond in the future to key driving variables (such as income, first cost, usage efficiency, etc.) as they have responded in the past. Such an assumption can be relevant in a world with only incremental changes in lifestyle, technology, costs, product characteristics, demographics, etc. However, for sustainable product policy, we may wish to identify options for new products that are revolutionary and novel rather than incremental. We may also wish to consider significant changes in life styles. Furthermore, as noted earlier, we would ideally like to work with a model that explicitly reflected levels of need satisfaction. And finally, we would prefer a modeling framework that explicitly characterized many different segments of the population, e.g., different levels of income, different demographic groups, etc.

For these reasons, it is advisable to build into the LCSD framework the newly emerging techniques for adaptive agent modeling of consumer behavior, as is being pioneered by Jager and his colleagues (e.g., Jager 2000). Adaptive agent modeling and simulation has become feasible in recent years with the revolutionary increases in computing power, and is being increasingly applied to study behavior in social systems; an overview is provided in (Liebrand et al. 1998). In these models, the behavior of individual decision-makers or “agents” is modeled explicitly, with the opportunity to study dynamics that evolve from the interaction of the agents over time. Agent interaction can be important for consumption, as it can explicitly reflect such important processes as information sharing and competition. Agent decision rules themselves can evolve over time, as a result of such factors as learning and habit-formation.

While some adaptive agent approaches to consumer behavior assume rational or optimizing decision rules, the “consumat” approach developed by Jager reflects the realities of non-optimal behavior, as well as processes of social comparison and habit formation (Jager et al., 2002). This approach is based on a comprehensive meta-model of human behavior, which integrates explicit modeling of need satisfaction drivers and context-dependent methods of cognitive processing (see Figure 2).

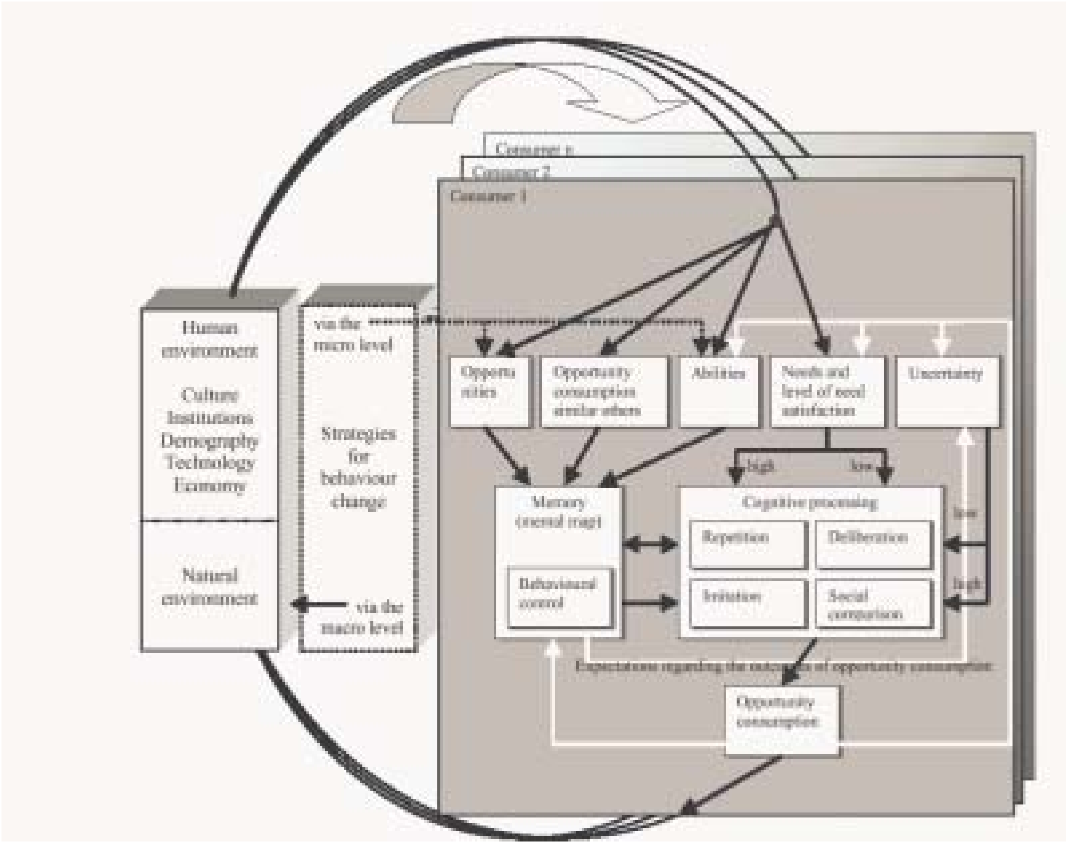



Figure 2: Conceptual meta-model of consumer behavior (from Jager 2000, p. 97)

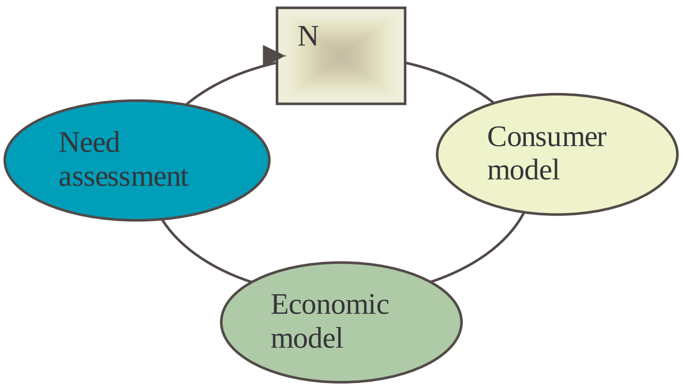
## Economic and life cycle consequence assessment

As illustrated in Figure 2, consumer behavior co-evolves with the rest of the socio-economic system. Impacts of consumption on the economic system are of importance for two important sets of reasons in life cycle-based sustainable consumption analysis. First, there is the standard need within life cycle assessment to estimate the consumption-driven perturbations of process output (and corresponding impacts on process emissions and resource consumption) within the supply chains of alternative product systems. Second, there is the need, not currently met within standard LCA frameworks, to address "rebound" consumption due to differences in disposable income wrought by product alternatives that differ in life cycle cost, and to estimate feedback effects of initial consumption changes upon second-round consumption, upon income and prices, upon levels of need satisfaction. Need satisfaction impacts depend in turn upon prices, levels and types of employment, distributional nature of economic impacts, etc.

Not only is consumption income-driven, but as mentioned earlier, the work of Segal has made clear the role of price evolution and market dynamics on the relationship between levels of consumption and need satisfaction. For example, in a residential housing market with a limited supply of safe houses, aggregate increases in income – even if universally achieved – will bid up the price of the safe housing rather than allowing higher levels of satisfaction of the need for safe housing.

We propose that a modeling framework for life cycle sustainable development would therefore include a dynamic input/output-based LCA model with an endogenous (and disaggregated) household sector, dynamic labor markets with migration, dynamic capital investment for both growth and replacement, and regional economic competition. For example, we propose to adopt for LCSD application the "Policy Insight" model developed by George Treyz and colleagues (Treyz 1995). We suggest that for "sustainable consumption" analysis, this new dynamic I/O life cycle framework would then be integrated with a bottom-up system of consumer behavior modeling such as the "consumat" approach of Jager, and with assessments of how core economic needs are being met. The integrated modeling approach is represented schematically in Figure 3.

Figure 3: Conceptual modeling framework for Life Cycle Development

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## Understanding consumption patterns - including time use, skills, and market failures

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### Abstract

In order to be able to realise the transition towards sustainable consumption it does not suffice to offer ever more sustainable products and services, households will have to make changes in their purchase decisions and in a broader sense also in their lifestyles. To incite the desired kind of changes in purchase decisions and lifestyles one needs to understand how households operate. In addition one needs to know how the relevant markets work with respect to enabling/facilitating the changes in purchases and lifestyles.

The research challenges following from the above sketched sustainable consumption problems amount to:

1. Describing and modelling consumption behaviour in a way that enables researchers and policy makers to identify principal driving forces of consumption trends in the medium to long term, as well as identify the interplay between the driving forces, whereas driving forces encompass economic, social, cultural, demographic and technical factors;

2. Identifying those factors that are suitable for policy intervention, as well as identifying the necessary conditions for such policy interventions to be feasible and effective, and last but not least to provide indications of the order of magnitude of doses-effect relationships between policy instruments and intended consumption changes.

For the kind of approaches aimed at in point 1 several concepts have been developed and tested[51]. Usually these methods focus on the use of resources due to household consumption, either directly expressed in physical terms, or initially in money terms. In those approaches the use of time is not or rudimentarily included, whereas skills are entirely left out. For the eventual consumption of products and services the input of time and skills has a large influence on the attainable quality level, on the ability to substitute between alternative ways of provision and consequently on the response to incentives for more sustainable consumption patterns. In addition, due the implied prices of substituting between time, money and a household's requirement level the shaping of the daily and weekly time budget of households has also a large overall influence on the propensity to swap strategies (e.g. do-it-yourself vs. mechanisation vs. outsourcing).

[51] . E.g. household metabolism concept, household cohort models, lifestyle enriched consumption and ownership models (see inter alia Vringer and Blok, 1995; Noorman and Schoot-Uyterkamp, 1998; Princen, 1999; Brown and Cameron, 2000; Weber and Perrels, 2000).

The paper will discuss the need for an integrated micro to macro approach in which the formation and use of the money budget, the time budget and the skills collection is modelled in an interconnected way, whereas the linkage to a description of the production system allows for translation into physical impacts (emissions, space claims, etc.). Apart from the challenges ahead regarding estimation of functions and data availability, this approach implies also that the concepts extends far beyond the core of consumption as such, and links closely with for example the labour market, the housing market and spatial planning, and with the institutional and cultural framing of time use (opening times, working times, etc.). Furthermore, the approach can be built up in two main layers, being the medium term perspective and the long term perspective. In the latter also life cycle considerations (career path, pension) need to get a place.

The modelling approach as described above renders indications on what factors policy interventions can be focused. Apart from insight in consumer behaviour in the widest sense this also requires understanding of the (dis)functioning of markets. For example, what is the range of choice actually offered to consumers, what can be improved in the process of product design (e.g. consumer involvement), etc.

From a policy feasibility point of view the sketched possible transition pathways are all subject to acceptability tests from policy makers and politicians and the public at large. For example, up to now wealthy countries are to some extent willing to consider measures that imply the redistribution of global growth in wealth. On the one hand this significantly narrows down the manoeuvring space in the transition pathways, on the other hand acceptability is not based on entirely fixed criteria and images. So, another relevant research questions is to what extent and how these images and criteria might change.

Apart from addressing the overall concept of the integrated micro to macro approach, the paper will highlight some aspects by means of examples, such as involving social-cultural trends in a socio-economic energy & environment model, and the aspect of quality differences within one consumption category in connection to expenditure models (related to a study on nitrate and phosphorus flows in Finland). Furthermore, some aspects of market failure will be touched upon. The overall concept intends to take account of connectivity with other (study) dimensions of sustainable consumption such as governance and environmental impacts.

## Understanding consumption patterns - including time use, skills, and market failures

### *Introduction*

In the late eighties and nineties a wave of studies emerged in which one way or the other natural resource use was linked to the consumer or to a consumption perspective. Especially in the fields of energy use and transport applications can be found (Schipper, 1989; Fujime, 1994; Vringer and Blok, 1995; Weber and Perrels, 2000). In recent years the sustainability discussions are dominated by climate policy related issues. In the social-economic realm that has translated itself in a focus on macro-economic studies dealing with emission trade, tax burden sharing, international competitiveness and trade and macro-economic effectiveness of policy instruments.

As the evaluations of early results of climate mitigation policies start to abound, the need for revision and more detailing of the macro-economic approaches becomes more evident (UNFCCC, 2001 and 2002). Furthermore, in transport and land use planning the ongoing failures to contain urban sprawl and congestion in many countries and the rising interest in road pricing has also rekindled interest in demand side studies (Himanen, Lee-Gosselin and Perrels, 2003). Similarly, the liberalisation in electricity markets has temporarily reduced the interest in demand side management. However, the over-capacity has diminished significantly in most liberalised markets, while gradually the concern about limited foresight capabilities with respect to medium term capacity adequacy is building up. As a consequence demand side management is expected to become soon a topical issue again in electricity policy studies (IEA, 2002). The different trends mentioned will probably contribute to a resurgence in consumer and consumption oriented socio-economic studies. It is however of great importance to ensure that next to studies that are immediately serving public or business policy interests, progress in methodology is achieved, especially with respect to the ability to make more comprehensive assessments of the sustainability impacts of consumption as well as the ability to integrate consumption oriented studies with general economic models as well as ecological or physical models. The present paper deals with some aspects of these methodological challenges.

In this paper the focus will be on the socio-economic analysis of the functioning of households, more in particular how households combine material resources (including money), time resources and skills to provide ready-to-consume products (or services if you like). First the concepts of the so-called lifestyle approach will be introduced. Subsequently, time use and consumer expenditure modelling will be discussed. The paper concludes with a list of needs for merging the approaches (in a lifestyle context) for integrating the approach with generic economic policy evaluation models. In due course it gives some hints on the plans in this area in VATT.

### *The need for a consumer perspective in socio-economic sustainability research*

In order to be able to realise the transition towards sustainable consumption it does not suffice to offer ever more sustainable products and services, households will have to make changes in their purchase decisions and in a broader sense also in their lifestyles. To incite the desired kind of changes in purchase decisions and lifestyles one needs to understand how households operate. In addition, one needs to know how the relevant markets work with respect to enabling/facilitating the changes in purchases and lifestyles. There is, however, still a sizeable methodological gap between what we can do today and what is needed. The discussion in this paper tries to spell out what is needed to bridge the gap.

The consumer focus is often underrated in socio-economic studies on environmental policies, not the least in the to date macro-economy dominated climate policy studies. There are three reasons to revise that image: firstly, private consumption is the largest demand category in most economies. In addition, large parts of export production (for most countries the category second in importance) are also meant for foreign consumption. Thus consumption of households is eventually the main driver for the volume and assortment of commodities produced. Secondly a detailed modelling of household consumption patterns offers increased possibilities to account for the effects of non-economic influences on direct and indirect energy use and related emissions of households. Finally at a conceptual level both economic mainstream and the self-understanding of modern democracies postulate the consumers/citizens to be the ultimate sovereign. Consequently a modelling approach placing the consumers in the focus of interest may contribute to give this perspective real standing in the political process. It may thus be a valuable tool for the necessary political discourse on future energy options, providing a common perspective for experts from various disciplines as well as decision makers and the wider public.

The research preferably extends its orientation to longer term structural changes in society, which have an impact on the volume and composition of consumption patterns. This could be termed the long-term lifestyle. Based on earlier work (Weber and Perrels 2000) the hypothesis is accepted that in the context of natural resource use lifestyle can be identified by means of expenditure patterns of time and money. In turn these patterns are on the one hand influenced by broad societal and technical changes and on the other hand the expenditure patterns predetermine to a significant extent the required type and amounts of energy.

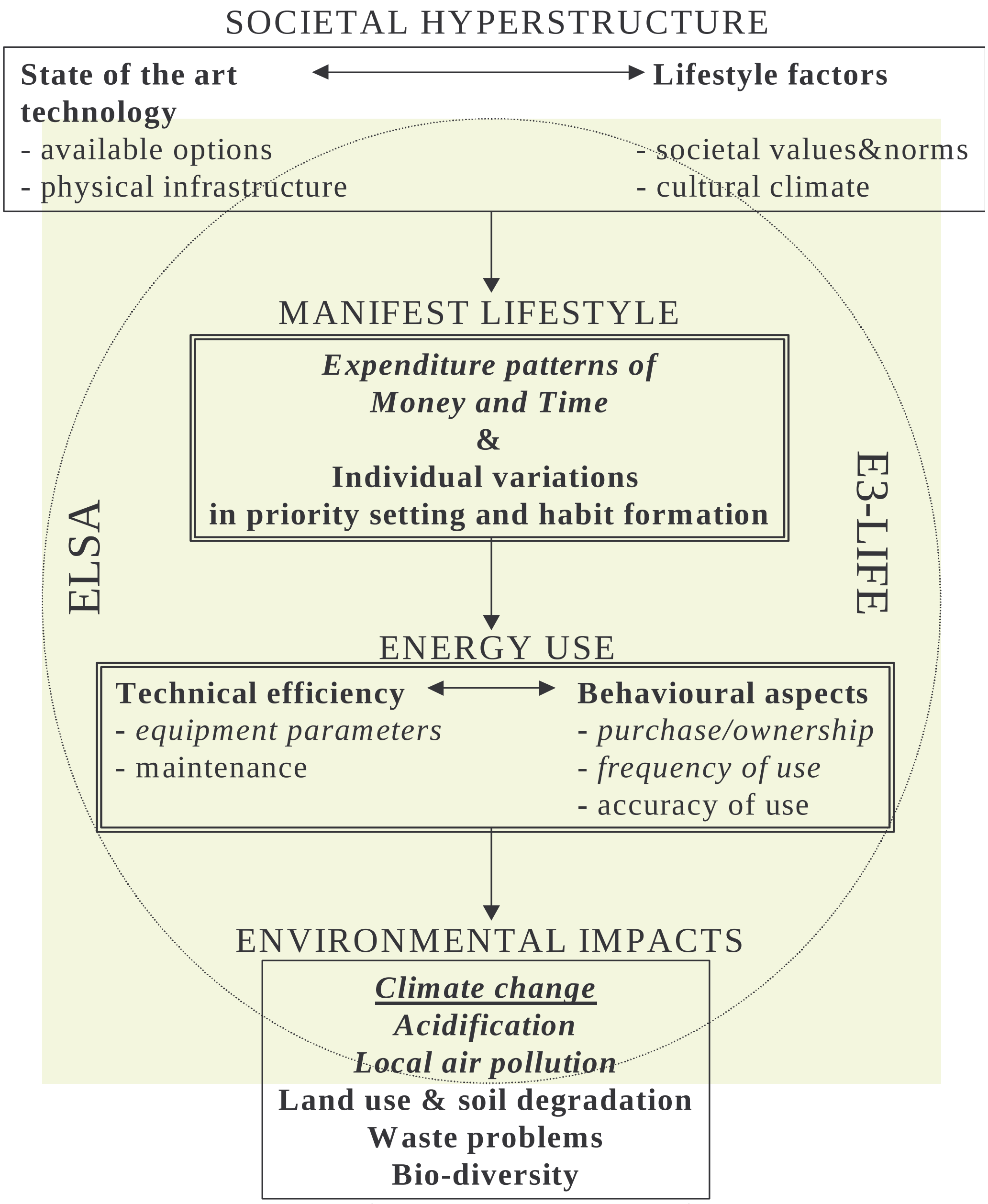


Figure 1: The embedded long term lifestyle approach and coverage of the models

The overall approach is summarised in Figure 1. As regards the operationalisation it means that lifestyles are understood as the patterns of equipment ownership, expenditures of time and money and energy use of households. Similar to most lifestyle concepts in sociological research, lifestyles expressed by just mentioned patterns are perceived as dependent variables, of which influencing factors are investigated. Contrary to approaches often found in marketing research, no lifestyle groups or types have been identified since earlier studies in this direction provided no satisfactory results. Rather, households have been differentiated by household types according to their position in the lifecycle (young singles, young couples, middle-aged families etc.) in order to account for the impact of the position in the lifecycle on household consumption. Additionally, the influence of social-economic household characteristics such as income, education level, type and number of employment, and size of municipality can be included. In summary as shown in figure 1, the core of the suggested models is in the middle segments, but both the broader societal context and the first line environmental implications with respect to resulting emissions are to be taken into account in the modelling approach.

## Linking home production to home consumption

### *The basics on combining time and money*

Households purchase goods on the market, dispose of durables (capital goods) that provide services over a range of years, and combine these consumables with durables' services and own labour input to obtain a product or service that is ready-to-consume (i.e. a warm meal). The volume and the quality of the consumables and the durables purchased depends on the (net disposable) income, the relative prices of the commodities, and the requirement level of the household. The requirement level is the apparent or specified level of quality and volume of the different ready-to-consume services needed. The requirement level, in turn, depends on household characteristics, such as household composition, household size, age of adults and children, education level of adults, type of environment (city, village), occupancy (employed, retired, …).

Becker (1965) introduced a first operationalised theory of integrated time and resource use in a household. This concept is also connectable to micro-economic (bottom-up) description of an economy, on the one hand via the links with the labour market and on the other hand via links with consumer expenditures (and hence aggregate private demand). DeDerpa (1971) added some interesting features to the basic approach. As this relates to time saving, mechanisation and resource use intensity, it is well worth to review his model.

A household produces a portfolio of ready-to-consume products Z. For each product $Z_i$ it needs a to combine a bundle of purchased consumables $X_i$[52] and household labour time $T_i$ . In formula:

$$Z_i = f_i(X_i, T_i) \text{ , with } i = 1, .., n \tag{1}$$

The household disposes of an income Y, stemming from current or past labour and/or capital services. For linking up with the labour market Y has to be decomposed in a part from current labour ($w.T_l$) and other income sources not depending on (current) time input. This is ignored for a moment.

What remains is a budget constraint, in which the expenditures in the considered period equal the income of that period.

$$\Sigma_i (p_i.X_i) = Y \tag{2}$$

[52] . In this case also the flow of services from one or more durables are counted under X.

This is ignoring saving and dissaving behaviour. A proper inclusion would require multi-period treatment which also would alter the treatment of durables. By classifying savings and loans as purchases of financial services one can still claim to have covered everything.

The difference with Becker is that in DeSerpa's model the production time and the material input are not linked up with a fixed relation. For example time input can be larger due to lack of skills to produce the ready-to-consume good in the minimum time. It may also be the other way around, for example excellent cooking skills enable to produce a better meal from the same material inputs, but require more time input. In both cases equation (3) would be an inequality. Furthermore, the substitution of part of the material inputs by up-to-date but equally expensive technology (e.g. more effective appliances) may reduce the minimal necessary time input. In that case equation (3) would be an equality, whereas the technology substitution causes $a_i$ to drop while $X_i$ remains constant.

$$T_i \geq a_i.X_i \tag{3}$$

The utility the household is supposed to maximise can be depicted as follows:

$$U = U(Z_1,\ldots,Z_n) = U(X_1,.., X_n; T_1,..,T_n) \tag{4}$$

Maximisation of utility under the specified constraints leads to the following Lagrangian.

$$L = U(X_1,.., X_n; T_1,..,T_n) + \lambda. (Y - \Sigma_i (p_i.X_i)) + \mu . (T - \Sigma_i T_i) + \Sigma_i \kappa_i. (T_i - a_i.X_i) \tag{5}$$

Where $\kappa_i \geq 0$ (for i=1,..,n), $\lambda > 0$ and $\mu > 0$. $\lambda$ and $\mu$ represent the marginal utility of the money budget and time budget respectively. $\kappa_i$ is a parameter that corrects the marginal utility of time in case a ready-to-consume product is produced at the minimum time bound.

The first derivatives with respect to material input, time input and input intensity are:

$$\delta U_i/\delta X_i = \lambda . p_i + \kappa_i . a_i \tag{6}$$

$$\delta U_i/\delta T_i = \mu - \kappa_i \tag{7}$$

$$\kappa_i. (T_i - a_i.X_i) = 0 \tag{8}$$

The marginal rate of substitution between time and purchasing power (budget use) is:

$$\frac{\delta U_i/\delta T_i}{\lambda} = \frac{\mu - \kappa_i}{\lambda} \qquad (9)$$

In case a reduction of the time spent on the production of $Z_i$ approaches the technical minimum, $\kappa_i$ starts to deviate from 0 and hence (net) utility change is smaller due to loss of production of $Z_i$.

Technical changes in household production often relate to maintaining (or even augmenting[53]) output levels while reducing time inputs. In ideal circumstances the last unit of utility gained from time released from a technologically updated activity i should equal the utility attributed to the expenses on the technological renewal.

$$\frac{\delta U_i/\delta T_i}{\delta U_i/\delta X_i} = \frac{\mu - \kappa_i}{\lambda \,.\, p_i + \kappa_i \,.\, a_i} = 1 \qquad (10)$$

In case of a very flexible labour market in which the employee has a choice in daily labour time duration, the shadow price of time $\mu$ could be replaced by the net wage rate[54]. However in practice the supply of jobs with different daily working times is rather limited and consequently the approach of DeSerpa does not infringe so much on realism in this respect.

### Elaboration and limitations of the basic model

Winston (1982) elaborated the above concepts further by introducing a continuous time use model, which enables the inclusion of scheduling and activity switching, as well as a generally more flexible treatment of input intensity. The scheduling aspects have been further elaborated in Perrels (1992) eventually resulting in a set of nested multi-nomial logit models for description of scheduling behaviour of electric appliance use on the basis of household characteristics. These notions have been taken over in a more or less rudimentary way in the lifestyle oriented energy and emission models E3-Life and ELSA (Weber and Perrels, 2000). Such scheduling models are also useful for demand

[53] . For example, the spreading of washing machines went hand in hand with more frequent washes of clothing, while more recently the introduction of tumble dryers seems to have had similar effects. This means that the requirement level is not independent from technology, thereby complicating the analysis.

[54] . An additional problem is a tax system in which marginal labour tax rates for working household members are affecting each other.

side management policy assessments, especially if time dependent price responsiveness is included as well.

One concept introduced by Winston, which deserves mentioning, is the distinction between *goal utility* and *process utility*. The production of various ready-to-consume products concludes with a positive goal utility, but may have a negative process utility. For example cleaning activities will often not be regarded as ‘fun to do’, but quite useful as regards their results. In those cases the drive for substitution of time use without compromising the output is very strong. On the other hand the production of quite some ready-to-consume products have a positive process utility (it’s fun to do), while the goal utility is of minor importance. In the model of DeSerpa this would require a distinction between activities with negative and positive process utilities. Release of time from an activity to accomplish something else is supposed to have a positive effect on overall utility in the standard model (eq. 9). In a model distinguishing between negative and positive process utility eq.9 would get a second correction factor, which might result in negative marginal substitution values. This links well to the claim of Winston (1982) that people do not want to save time what so ever (as DeSerpa’s model is implying), they want to save time on activities that have negative process utilities and add time to those with positive process utilities. However, thanks to the ability of foresight and due to social harmonisation this substitution process is limited. This discussion on the direction and driving force of time reallocation is very relevant for guidance in prospective studies, as it connects to the question whether western society is developing in the direction of a ‘harried leisure class’, ‘selective epicurism’ or ‘relaxed indulgence’.

The approaches of Becker, DeSerpa and Winston have proven to be powerful to explain several phenomena. They also enable various ways of operationalisation of modelling time use and resource use and/or labour time decisions together (Gronau, 1977; Lambriex and Siegers, 1993). However, this appears only possible at fairly aggregate levels, since of disaggregated levels it appears to be very hard to link time use categories with material purchase categories (consumer expenditures). Therefore time use equation estimates and expenditure equation estimates are still largely if not entirely carried out separately. This is one challenge ahead to be improved.

### The requirement level and skills

Another underrated element is the treatment of the requirement level. As done in this article, usually some unknown but apparently existing (notion of a) requirement level is assumed, where its level is argued to depend on household characteristics as explained above. However, the dynamics in these requirement levels, either due changes in the considered household characteristics or due to influences outside the household (such as advertisement and peer groups), are studied entirely separate from the abovediscussed modelling approaches. Usually these are sociological or anthropological studies, which are often hard to link to the modelling approaches (or even outright oppose that idea). This is another challenge that needs to be resolved. Most probably potential for connections can be found in longitudinal analysis, meaning that the requirement level of a similar household type (with similar income) can still change due to external factors (trend or fashion). A possible approach is two stage estimation of Engel curves using pooled cross-section data, whereas the second stage would entail the estimation of the trend component. This requires however a thorough neutralisation of price movements and other temporal external factors such as degree days in case of heating and electricity consumption. The nobelist Becker constitutes an exception with respect economic analysis of some aspects related to the requirement level, such as addiction phenomena and the influence of taste (Becker, 1998). However, such concepts are usually not applicable in more generalised models of consumption as intended in this paper due to lack of data (Pollak, 2002).

Probably the most difficult part of the triplet money-time-skills is the skills part. Systematic data on (household care related) skills are scarce and, if available, scattered and non standardised. Indirectly, the expenditure and time use data sets provide some information on probable directions in skill development.

In figure 2 is shown how very different mixes of skills, expenses and time input enable to achieve the minimum requirement level (for one day meals in this case). With limited skills and scarce time cost run high. With more time it is possible to attain the requirement level with less expensive inputs (e.g. no fetched meals, but ingredients). Similarly with enhanced skills it is possible to satisfy the minimum requirement level while using less expensive products. If skills go up more or both skills and time rise further it gets possible to surpass the minimum requirement level, although beyond some level of skills or time input that invites to raise the expenses as well. The straight overall increase at the right hand side of the graph represents the switch towards a restaurant dinner. With high skills and sufficient time one can also achieve that level at home. So, if cooking skills would be diminishing on average the propensity to go to a restaurant would increase. There are various claims around (TTS,…; LUW,…) that cooking skills are diminishing. This would mean that households run into higher cost, if they want to keep up their requirement level, either by outsourcing the cooking part or going to a restaurant. In all likelihood such a development would have environmental impacts. The alternative would be that households are reducing their requirement levels or use a mixed strategy, for example cooking habits on weekdays and weekends look already quite different in various countries (SCP, 2001).

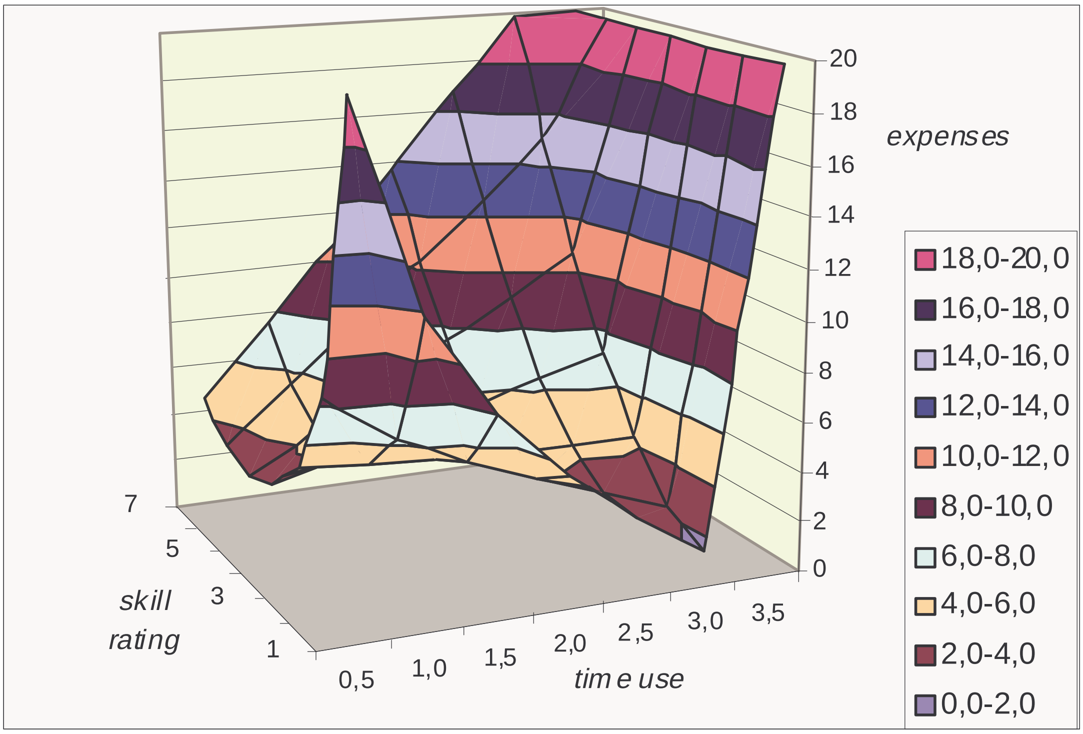


Figure 2: Hypothetical substitution plane between time use, skills, and expenses (offsetting variable) for producing meals for one day

## Consumption expenditure models

### *The basics*

In economics traditionally consumption studies were typically understood as analysis of purchasing behaviour and the derivation of demand equations. As a consequence this body of theory and methods is much more developed than the combined time and resource studies. The advantage of expenditure modelling is that it allows for easy linkage with macro-economic models. Since the early nineties numerous studies have been performed in which an expenditure system is linked to an input-output model with dual tables for natural resource use, emissions, etc. For an overview see Duchin and Steenge (1999). The earlier mentioned E3-Life and ELSA models also include such a consumption-I/O link, but they are altogether hybrid models due to the separate treatment of direct energy use (both at the demand and the supply side).

For a proper embedding of expenditure models, especially when used in generic economic modelling framework (e.g. for prospective studies), the assessment of the propensity to save has to precede the expenditure analysis. In as far as sustainable transformation policies are intent to affect investment decisions (and they are) the including of savings is even essential.

As regards purchase of durables it can be argued to separate them out from the other more or less ongoing expenditures. All in all this would lead to a three step procedure when constructing an expenditure system:

1. Split disposable income between savings and household budget

2. Split off expenditures on durables, model that part with a discrete choice model while including elements of stock-renewal models and the possibility to dissave or borrow
3. Estimate an expenditure system for the remainder of the budget

The allocation of the budget over consumption categories depends on income and prices, but also on changes in the requirement level and preferences at more detailed levels. The latter elements can be not represented directly, but some obvious influences e.g. related to differences in physical needs can be represented by proxies. Examples of these are amongst others household size, household phase, urban/non-urban environment and education level.

It is pretty standard to express the functions in terms of budget shares (S). In this case we assume there are m product categories to which the budget is spent and for each household type h a separate set is estimated. The equation below represents a so-called Almost Ideal Demand system approach (Deaton and Muelbauer, 1986).

$$S_{hm} = a_{hm} + \sum_j (b_{hmj} \cdot \log p_j) + d_{hm} \cdot B_h \qquad (11)$$

$p_j$ is the relative price of good j and $j \in \{1,..m\ldots,n\}$, while $B_h$ denotes the disposable real budget of household type $_h$.

Obviously it should hold that

$$\sum_m S_{hm} = 1 \qquad (12)$$

and

$$\sum_m d_{hm} = 1 \qquad (13)$$

as well as (14)

$$\sum_m \sum_j b_{hmj} = 0$$

Household preference proxy variables can be added to the basic form, but precautions have to be taken that the aggregation conditions (eq. 12-14) are fulfilled. For example it is possible to re-specify or correct the budget variable for household size. Also the constant $a_{hm}$ could be split up. Finally, truly new additional terms could be added, but that may require re-specification or extension of the aggregation restrictions. An additional problem is the often separate databases available for price and income on the one hand (time series) and household type specific preference proxies on the other hand (cross sections). The non-guaranteed solution to that is the use of more advanced estimation techniques. If it is only a matter of household size Engel-curves can be considered.

Also a multistage budget expenditure system can be applied, meaning that within all or some of the product categories, sub-categories are distinguished for which again allocation functions are estimated given the (estimated) budget share of the relevant main category. For example within the sector food sub-functions may be estimated for meat, vegetables and fruit, etc.

In actual application of the set of equations the results can be aggregated to national volumes by applying the appropriate demographic multiplicators. The results by expenditure category need to be transformed into a demand vector by producing sector. This requires a special transformation table and also a correction for value added taxes, and other indirect taxes and subsidies.

### Distinguishing volume and quality

For environmentally oriented analysis it would be attractive to analyse not only expenditures, but also volumes and qualities. The use of volumes would allow for better precision compared to the currently commonly used coefficients in the input-output tables. Furthermore, when the analysis can use expenditure observations *and* volume observations *and* prices simultaneously, it allows for a separation of quality and volume responses when prices, income or household circumstances change. In the Finnish AESOPUS study in which the influence of human intervention on nitrate and phosphorus flows are analysed, such a separation of quality and volume is carried out (Sullström and Perrels, 2002). Even the influence of trends can hopefully be separated out since the study can use pooled cross-section data spread out over a period of 13 years (85, 90, 95, 98).

The following summary gives an impression of the approach. More details can be found in Deaton (1988) and Brubakk (1997).

**Definitions**

| | |
|---|---|
| $p_i(T,M)$ | observed price per standard unit[55] of commodity i in year T and month M |
| $p_i(T,M)^*$ | derived price per standard unit of commodity i in year T and month M |
| $p_{hi}(T,M)^*$ | derived price per standard unit of commodity i as experienced by household type h in year T and month M |
| $X_{hi}(T,M)$ | observed – group average – expenditures by household type h on commodity i in year T and month M |
| $V_{hi}(T,M)$ | observed – group average – volumes purchased by household type h on commodity i in year T and month M |
| $V_{hi}(T,M)^*$ | derived – group average – volumes purchased by household type h on commodity i in year T and month M |

$ws_{hi}$ weighing factor of household type h in the unit price index according to share of the of total expenditures of household type h in the total expenditures on commodity i

[55] . Depending on the nature of the product, these are kilos or litres, or pieces (e.g. CD's, trousers).

Derived prices and volumes are obtained as follows:

$$p_{hi}(T,M)^* = X_{hi}(T,M) / V_{hi}(T,M) \quad (15)$$

$$p_i(T,M)^* = \Sigma_h\ p_{hi}(T,M)^* \,.\, ws_{hi} \quad (16)$$

$$ws_{hi} = X_{hi}(T,M) / \Sigma_h\ X_{hi}(T,M) \quad (17)$$

$$V_{hi}(T,M)^* = X_{hi}(T,M) / p_i(T,M) \quad (18)$$

The challenge is first to analyse the development of consumption patterns by means of using the total differential of the identity $X_{hi} = V_{hi} \,.\, p_{hi}^*$

$$d_m X_{hi} = p_{hi}^*.d_mV_{hi} + V_{hi} \,.\, d_mp_{hi}^* + d_mV_{hi} \,.\, d_mp_{hi}^* \quad (19a)$$

or

$$d_T X_{hi} = p_{hi}^*.d_TV_{hi} + V_{hi}.d_Tp_{hi}^* + d_TV_{hi} \,.\, d_Tp_{hi}^* \quad (19b)$$

The change in the observed (average) unit-prices $d_mp_{hi}^*$ and $d_Tp_{hi}^*$ can be decomposed into a genuine price change of the commodity(type) i and a quality change of the observed average of purchased commodities i (or commodity types i), as shown in eq.20:

$$\forall_h : d_m\, p_{hi}^* = d_mp_{hi} + d_mqc_{hi} \quad (20)$$

Even though the average quality of commodity i bought by different household types will differ between these groups, it is unlikely that the genuine average price change for commodities of type i differs significantly across the groups of household types. This means we assume that:

$$\forall_{h=1..n} : d_mp_{h_1i} = d_mp_{h_2i} = \ .. = d_mp_{h_ni} \quad (21a)$$

and equally

$$\forall_{h=1..n} : d_Tp_{h_1i} = d_Tp_{h_2i} = \ .. = d_Tp_{h_ni} \quad (21b)$$

In that case eq.20 can be also written as:

$$\forall_h : d_m p_{hi}^* = d_m p_i + d_m qc_{hi} \quad (22)$$

However $d_m p_i$ and certainly $d_T p_i$ can be obtained from official price statistics. Consequently, a value can be attributed to the quality changes by household $d_m qc_{hi}$ and $d_T qc_{hi}$ .

On the basis of this analysis a decomposition analysis of price and quality effects can be carried out for the entire pooled-cross section database and the results can be added as new variables. Subsequently a somewhat adapted value and volume version of eq. 11 i.e. including household characteristics can be estimated (see also Brubakk, 1997). A non-exhaustive overview of conclusions on response type is given in Table 1.

Table 1: Response combinations of households distinguished by quality and volume

| DX | dV | dp* | dp | dqc | Conclusions |
|---|---|---|---|---|---|
| **Large** | large | small | small | Small | The change in expenditures has other reasons, such as income change or changes in other products (prices) |
| Large | small | large | large | Large but opposite or small | Demand is inelastic and/or households compensate price changes by quality choice changes |
| Small | large | large | Large or small | Small or large | Typically penetration upswing of new technology, which is cheaper and/or much better |
| Small | small | small | small | small | Well settled and reasonably mature (and necessary/basic) commodity, income changes affect other commodities |

The pooled cross-section data-base also allows for regional or municipality type differentiation of expenditure patterns. Since elsewhere in the AESOPUS project the impact of nitrate and phosphorus flows will be regionalised as much as possible, possible regional/spatial differences (other than due to demographic structure differences) will be analysed.

## Some first results from the data analysis

As regards tendencies in food quality adaptations in relation to time or household compositions, a first scan has been carried out to check on influences on the tendency to buy fast food (fetched food, freezer-to-microwave meals) or otherwise slow food (as much as possible raw materials).

| | Model 3 sfast2b=C+a.kaytetmk+b.jasenia+c.pika+d.vkotu+f.psup+g.vamto+h.taajama | | | |
|---|---|---|---|---|
| | **1990** | **pR2** | **1998** | **pR2** |
| **C** | 0,42275 | - | 0,47075 | - |
| **a** | -2,0395E-07 | | -4,3692E-07 | |
| **b** | -0,04889 | | -0,03871 | |
| **c** | -0,00414 | | -0,00405 | |
| **d** | 0,01512 | | 0,01788 | |
| **f** | | | | |
| **g** | 0,06986 | | 0,05286 | |
| **h** | -0,02316 | | -0,02979 | |
| ***R2*** | | *0,273* | | *0,2827* |

Table 2: First correlation scanning results for fast food factors

**Legend:**

Sfast2b – share of fast food in total food&drinks budget

Kaytetmk – disposable income

Jasenia – no. of family members

Pika – age of respondent

Vkotu – education level of respondent

Psup – gender of respondent

Vamto – occupation of respondent

Taajama – degree of urbanisation

Results are shown for 1990 and 1998 surveys

Figure 3 below gives an impression of the volume changes within the group of grain based products. Like the volume the total expenditures on this item went down somewhat. Nevertheless the dynamics within the group is still large, with probably relevant changes from a environmental viewpoint.

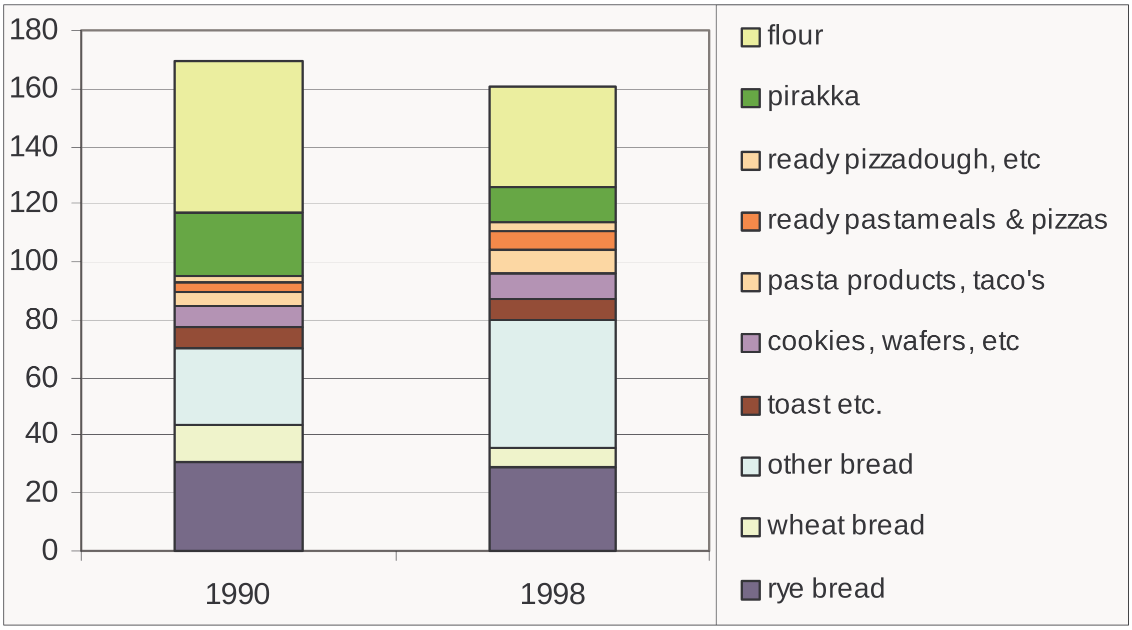

Figure 3: Changes in volume purchases of grain based products between 1990 and 1998 (kg)

**Towards comprehensive models – what is still lacking?**

As explained in the previous chapter separate household time use + resource use models exist as well as expenditure models. The first challenge is to closely interconnect these models. In countries in which both consumer expenditure survey data and time use survey data are available for various years such an interconnection can – in principle – be built. Practical obstacles should not be underestimated, however, when one intends to aim to good quality linkages.

Auxiliary information on skills, skill development and relation between skills and other household characteristics, as well as influences of trends are very welcome. Similarly, auxiliary information on purchase of durables and the influence of information on the selection of ecological favourable alternatives is needed.

Another aspect is the link up with the labour market and thereby enabling the connection to AGE models.

The above models were still focusing on the medium term. For the long term life-cycle income profiles need to be included, whereas technological development (of homes, appliances, vehicles) as well as social dynamics (household formation, size impacts etc.) need to be considered explicitly.

A separate area is spatial influence on household behaviour. This includes:

- choice of residence location and type of residence in relation to work location(s) and location of principal services;
- vehicle ownership and travel behaviour
- infrastructure and city planning (‘the supply side’)

There are several spatial trends that heavily influence the logistics of home production (mega-stores versus neighbourhood shops; tele-services and tele-working).

In the framework of its 2003-2005 strategy VATT is planning to conduct some basic research on sustainable consumption in the upcoming years, starting in 2003. Partly this will be a direct spin-off from AESOPUS, partly new basic efforts. In addition there is the aim to participate in the national cluster programme on eco-efficiency research (concerning sustainable consumption as well as waste). As regards the more certain parts of the efforts work will concentrate on:

- Completing the work on expenditure functions, including the separation of quality and volume aspects
- Linking the expenditure functions to an input-output model and to an AGE model
- Obtaining Finnish time use data and organising them in a data-system together with consumer expenditure data

As regards the testing of policy instruments one feature should be mentioned, being market failures[56]. Up to date instrumental impact assessment has often analyse instruments one by one or assumed no interaction effects (apart from those that happen to be already integrated in the model structure, such as for taxes). More integrated assessment is called for (Perrels, 2000). This links closely to the notion of market failures. The usual models are often:

- overlooking aspects that do matter (such as the skill factor in households);
- assuming well operating markets, whereas asymmetry and incomplete information is very common in consumer product markets;
- not ideally suited to take into account interaction effects of instruments, although this can partly be alleviated by preparatory studies.

The positioning of energy efficiency in policy packages is a good example of the above mentioned difficulties. The non-tangibility of the issue seems to give it a disadvantage right from the start. The same non-tangibility is one of the causes why markets for energy efficiency are hard to develop, not the least because of lack of information and asymmetry.

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## *APPENDIX A – Overview of the AESOPUS study – economic focus*

The contribution from VATT focuses on modelling the economic side of processes that affect the man made intervention in the N- and P- flows in Finland.

To modelling will focus on the following aspects:

- consumer behaviour, in particular through the estimation of a set of consumer expenditure functions, with extra detail for food expenditures; the set can function as a sub-model for simulating consumer response to price changes and to changes in demographic characteristics, and – to some extent – quality characteristics; (see e.g. Riihellä, 1997; Suoniemi and Sullström, 1995, Leppänen et al, 2001; Pellekaan and Perrels, 1995).

- a dual input-output matrix system, showing both value flows from sector to sector *and* physical flows, including the implied N- and P-content of these flows; to this end there will be extra detail for the agricultural sector, while also a system of regional satellite accounts will be available; the results of the consumption sub-model can be fed into the input-output system in order to simulate impacts throughout the economic system and the impacts on the resulting (man made changes in) N- and P-flows;

- impacts at the production side can be taken into account in various ways:

- by changing the technical coefficients in the input-output system; in order to preserve as much as possible overall economic consistency this is to be combined with adopting demand response and technical change information, from existing (focused) studies (e.g. Lehtonen, 2001; Aakkula, 1999);

- by running a VATT general equilibrium model – with possibilities to handle e.g. taxation of fertilizer input; this option better ensures overall economic consistency but has limitations regarding the levels of detail - both spatially and product wise – compared to the input-output system (see e.g. Lankowski and Ollikainen, 2001; )

- preparation of a baseline economic development based on a reference scenario, that includes up to date forecasts for economic growth, demographic developments, and already agreed but still to be implemented policies (e.g. climate policy, EU enlargement; Baltic Sea co-operation regarding the pollution control) with significant impacts on the man made intervention on N- and P-flows (also Vaittinen, 2000; Honkatukia and Ollikainen, 2001; Perrels, Kemppi and Lehtilä, 2001);

- assessing the impacts of selected policy packages targeted at the reduction of man made N- and P- flows.

A schematic overview of the economic working of the system is shown in figure 1.

Eventually the modelling system should enable us to answer questions regarding dosage – effect relations of various policy instruments, the possible occurrence of positive and negative side effects of measures (e.g. other environmentally benign effects of reducing N- and P- contents, social-economic redistribution effects).

The various model developments require preparations regarding data collection, modelling feasiblities, and scenario specification. The latter has started only very recently. This paper will briefly outline activities regarding data collection and modelling preparations.

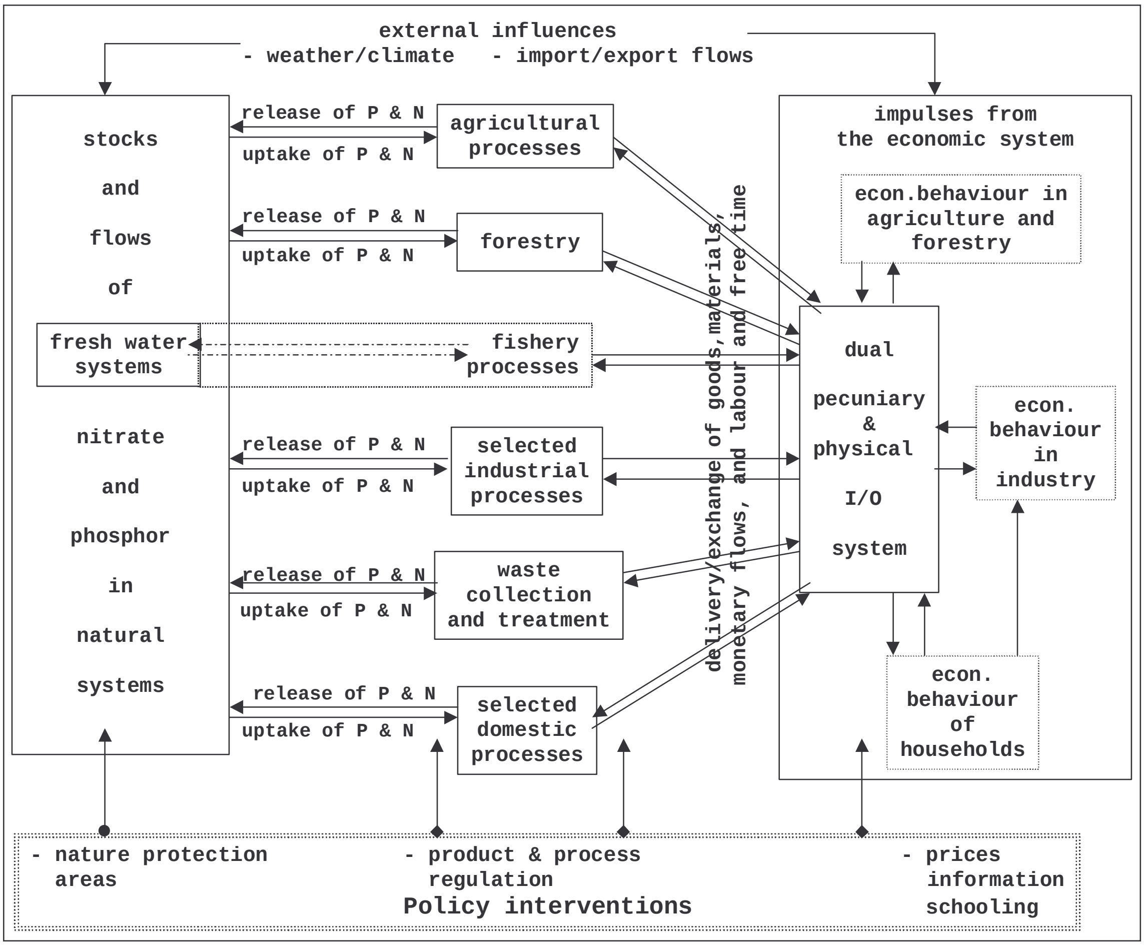


Figure A1: The system of production and consumption in relation to impacts on N- and P-flows from an economic viewpoint

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# An environmental space based approach to assessing the environmental impact of household consumption

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Relevant projects include Towards Sustainable Europe (1993-1996), Sustainable Consumption Indicators (1998-1999), Wealth and consumption: the EKC hypothesis(2000), Social sustainability indicators (2002), Sustainability Strategies (2002-2005).

## Abstract

Unsustainable consumption and production patterns are one of the key driving forces behind the unsustainable development of the World. The environmental impact of household consumption is a matter of regular reporting, either based on an economy-wide analysis with households as a sector of final demand, or on household economics using consumption statistics.

However, it can be shown that neither SNA based accounting nor household economics provide the proper instruments to assess the environmental impact of household decision making. An alternative way of assessing the contribution of households to the total environmental pressures is suggested.

For this behalf, an alternative life cycle wide environmental impact assessment scheme is suggested covering the major pressures on the environment caused by household decision, except for toxicity related effects. It is based on the environmental space concept, measuring energy consumption, material flows and land use. For the latter, a simple but sufficient ordinal classification scheme is presented.

Using the SNA approach, the main clusters of consumption can be identified, and when combined with the household focussed analysis their influence potentials can be assessed.

The methodology is described in some detail and used to analyse the environmental relevance of the main clusters of household consumption. Other applications of the methodology are briefly discussed.

## Introduction

Redirecting our societies and economies towards sustainability is a task that cannot be attributed to any subgroup of society - politicians, business leaders, NGOs,... - but one that needs to involve society at large if it is to be mastered effectively. Households through their demand side influence on the economy are potentially one of these major actors, but as long as they do not act in a coherent manner, they will remain a “sleeping giant“. This is why reliable and easily understandable information is of crucial importance if the already given environmental awareness of households is to become a relevant driving force in the market.

Any such change in consumption patterns needs to attribute an important role to consumer behaviour. Whereas economic incentives through green taxes are discussed as a means to modify consumption patterns based on the prevailing economic preferences by raising the price of environmentally suspicious products, new means of communication are sought for two reasons. On the one hand, they should enhance public support for the introduction of the economic incentives, and on the other hand they should stimulate the further evolution of household consumption patterns to give greater emphasis to the environmental impacts of the goods and services consumed. Whether the reference to an environmental cause is able to motivate ‘green purchasing’ depends on a number of factors, not least on the communication itself. In particular, the cause given “must strike a sensitive chord, (..) information must be disseminated in relation to this cause and (..) the cause must be related to some precise consumption elements” (Zaccai 2000).

The environmental impact of household consumption can be decomposed into three determinants (Röpke 2001):

- the level of consumption,
- the composition of consumption, and
- the environmental intensity of goods and services produced for consumption, including both direct and indirect effects.

According to this decomposition, any analysis should be based on the environmental intensity of products, and it should capture the level and composition of consumption. Consequently, the research results presented in this paper both refer to the identification of those areas of consumption, in which private households can make significant contributions to environmental sustainability (effects), and how to present these areas by means of a transparent and comprehensive set of indicators (reflecting composition and measuring levels).

Sustainability indicators have long been discussed as a means to bridge the gap between environmental causes and specific elements of consumption. In Agenda 21, chapter 40 calls for the development of indicators for sustainable development as concrete, issue-related guidance for taking and evaluating action. However, to be effective, these indicators have to be integrated into a broader communication strategy which emphasising the relation to the environmental causes and the environmental (and other, e.g. health) benefits resulting from making use of the orientation provided by the indicators. Such an indicator-based communication strategy can also serve to overcome the “three traps” preventing actors from transforming their awareness into everyday action in eco-social dilemma situations (causing “the tragedy of the commons”), i.e. in situations when those to invest efforts are separated from the beneficiaries by means of time, space or social grouping (Reisch, Scherhorn 1999).

The analysis of the environmental impacts of households is focused on consumption clusters that permit to depict different life spheres of the private household. Two criteria guided the investigation of the relevance of these clusters:

1. The significance of the consumption cluster: Does it justify high-priority action regarding environmental concerns?
2. The potential influence of households: Are households the key actor determining the environmental impacts originating from a consumption cluster?

Since most current sets of indicators for the environmental impacts of household consumption cover eclectically selected and widely differing aspects of the issue, first of all a conception sound basis had to be established (chapter 3). The proposal presented is based upon analysis of the linkage between resource consumption as a driving force and the state of current environmental problems. As a result, resource consumption is identified as a simplified, but reliable presentation of trends in environmental burden generation. In other words, growing resource consumption goes together with growing environmental pressures and vice versa, although not necessarily proportionally. The key resources and relevant consumption clusters identified are (Lorek et al 1999, Röpke 2001):

- energy and material consumption, as well as land use, are the basic resources, and
- construction and housing, food/nutrition and transport (in this order) are consumption clusters which call for high-priority action for reducing environmental use.

This conception base for indicator selection can be applied to all industrialised countries. It is possible, however, to adapt the system of indicators to the diversity of country size, infrastructure, climate, heating etc. by „tailor-made“ indicators. They could be developed along the same line of thought (consumption statistic derived prioritising) used in the study presented here. Some further modification of the selection criteria for consumption cluster indicators might be needed for (other, notably) developing countries due to global differences in wealth, preferences, consumption patterns, culture etc.

### Environmentally sustainable household consumption: The conceptual basis

In particular in the industrialised countries there has been an ongoing dispute about the importance and influence of private households with respect to environmental resource consumption (see e.g. VROM 1994; Miljöverndepartementet 1995) . However, although the *“the unsustainable pattern of consumption and production, particularly in industrialised countries“* had been identified to be a *“major cause of the continued degradation of the global environment“* (United Nations 1993), research on the areas in which households can make a significant contribution to sustainable consumption is still quite limited.

In order to identify these areas, first the most appropriate kind of accounting system for an actor-centred approach (“where can they really make a difference ?“) to household consumption has to be identified. Any assessment of the environmental impact of household consumption if intended to guide consumers must permit to compare the goods and services consumed regarding their respective environmental impact. Doing this on the basis of their contribution to the most debated environmental problems like climate change, eutrophication etc. necessitates the aggregation of environmental effects. This is a highly complex process (most advanced in EuroStat 1999), based on subjective assessments of relative relevance as much as on scientific measurements. For the average consumer, its components and in particular the weighing factors needed for the aggregation procedure are all but transparent. Consequently, the usefulness of any such methodology is limited as regards the everyday use in the shopping mall. Therefore a transparent and simple, but still directionally safe system of assessing the environmental impacts based on an evaluation of the current accounting methodologies has to be developed that can be used to identify the relevant aspects of consumer behaviour.

### Frames for accounting

Household consumption is usually defined either based on macro-level economics (households as final users), or on the micro level by domestic science analysis (counting the equipment of a household and accounting for the in-house consumption of energy and water). The first frame focuses on private consumption as represented in the system of national accounts SNA, the second deals with individual consumer behaviour within the household. Consequently, in the first frame all upstream environmental impacts are allocated to the consumer/household, whereas the second one includes hardly any upstream analysis.

The methodology of national economic accounting is based on the premise that goods and services are produced to meet demands of final users: production is no end in itself. Accordingly, all production efforts, upstream from the final consumption and including the resources consumed as well as the pollution released can be allocated to specific end-uses.

The end-use is categorised into private consumption, government consumption, fixed assets and exports. However, the government's demands for goods and services also serve the needs of the population, e.g. the demand for security or education. Consequently, since publicly produced services are consumed privately, government consumption could be considered an intermediate with private consumption the final end-use (services going to the business sector do serve private consumption indirectly). The case is similar for fixed assets: Since they are a necessary precondition for the production of consumer goods or intermediates, they as well could be attributed to the final purpose of private consumption. Only the exports cannot be ascribed to the inland population.

As a result, in any national economy 80% or more of the domestic environmental resource consumption can be allocated to private consumption and its actors, the households, and with a trade deficit the figure rises above 100%. This approach serves the purpose of monitoring the entire life-cycle of the consumption of goods and services from cradle to grave, but gives no hints as to which actors might be in a position to influence the environmentally relevant resource consumption. In this sense, private consumption as defined in the SNA and/or extended according to the argumentation above is a “sink category“, not an actors category and will allocate a much higher share of environmental impacts to the households than they will be able to actively influence in reality.

The situation is the opposite for the second frame, the domestic science approach. Since accounting for the goods consumed in the households, it is the standard basis for the educational and consultancy efforts of environment and consumer organisations. The main items accounted for include domestic electricity and water consumption, the frequency of electrical appliances ownership and purchases of products with environmental labels, however without being able to quantify the upstream environmental impacts. The information is used to develop green consumer guides, shopping lists and household consumption statistics (see e.g. UBA 1994), again without being able to base this advice on a life-cycle wide, full scale environmental assessment.

A further problem arises from the frequent mixture of these two approaches, without explicitly clarifying which one has been used to establish which aspect of the environmental relevance of household consumption. As a result, e.g. the average per capita energy consumption is reported alongside the households' equipment level with a microwave or other applications (OECD 1998). The environmental relevance of such reporting remains unclear or at best non-quantifiable.

While the macro reporting approach does not deliver advice to the consumer supporting her or his day-to-day decision making, the approach of accounting for the in-house consumption cannot bridge the gap between counter and kitchen on the one and the environment on the other hand. In reality however, households can do so, at least to a certain degree.

Obviously, the real influence of consumers is somewhere between what is covered by the two different measures described, making a new, actor-centred approach necessary. At first glance it seems plausible to define a third level in between the two established ones, reflecting the real influence of consumers. This however turns out to be unworkable, since demand side influence is a moving target. How much influence consumers have is dependent on a number of factors and differing not only between sectors and products/services (e.g. by closeness to the end-user or substitutability) and consumption clusters (e.g. through different elasticity's), but also between social groups according to their life styles, levels of commitment, information and purchasing power. Each of these factors (and many more) is influencing the day-to-day behaviour in private households.

As it is obviously not possible to define a general accounting framework, the assessment of consumer influence has to be differentiated according to different consumption clusters. For the purpose of developing generally applicable sets of indicators, however, sociological characteristics cannot be taken into account since they differ too much between regions and societies. Nonetheless on the national level they provide important *additional information*, which in particular could be used to derive group specific guidance to greening household consumption (see e.g. Scherhorn 1991, 1993; Schultz et al. 1999).

On the macro level, however, the task is to identify the most environmentally relevant consumption clusters and specify the environmental impact of household consumption accordingly. A precondition for this step, however, is to derive a simplified, but directionally safe measure of environmental disturbance.

## Environmental disturbance and resource consumption

"Based on the idea of a limited system, it makes sense to say that the human economy has a 'size' in relation to the natural system, of which it is a part." (Röpke 2001) Ultimately, most environmental problems are related to the growth of this 'size', and the following section of this paper is dedicated to demonstrate this fact.

### *The input based approach*

Usually environmental stresses are characterised by the symptoms they cause like climate change or acidification of freshwater, or by the pressures causing these symptoms like greenhouse gas emissions and cation immissions. However, since the list of pressing environmental problems is a long one, and since different substances can act in a synergistic way affecting several symptoms (like CFCs causing climate change as well as ozone depletion), simplification is needed and usually achieved by aggregation. This is a scientifically sound procedure as long as the aggregation is based on comparable physico-chemical effects of the respective substances, resulting in indexes based on a common unit of measurement like the Ozone Depletion Potential ODP or the Greenhouse Warming Potential GWP (on the methodology see Statistisches Bundesamt 1997). This level of aggregation, however, still leaves us with a high variety of indicators to be taken into account, and any further step of aggregation is based on subjective value judgements (Spangenberg, Bonniot 1998; EuroStat 1999), like e.g. the aggregation of ODP and GWP into a single measureless "atmospheric quality index". Obviously, in this case bottom-up aggregation has reached the limits of meaningful application and must be complemented, e.g. by a top-down analysis of disturbance factors as a suitable methodology to provide a simplified and more general view.

Furthermore, the end-of-the-pipe environmental protection of the 70's and 80's, putting the emphasis on measuring and regulating the intentional output (product quality) as well as the unintentional one (effluents) by command-and-control policies is reaching its economic and administrative limits. On the edge of the new millennium, new approaches are needed, from the level of instruments (contracts and voluntary agreements - agree-and-control - complementing legislation) to the basic approach to measurement and regulation itself. With increasing attention given not only to the quality of outputs, but to the absolute quantity of throughputs, the scale of the economy (Daly 1996) becomes an increasingly important topic, and accordingly more attention is paid to the input side (Schmidt-Bleek 1992).

Every human activity needs material as its physical basis, energy to go ahead and a realm where it takes place, i.e. area. Material flows, energy consumption and land use are thus the primary factors of environment use and thus disturbance potentials on the input side, whereas emissions, toxins and other effluents are the (traditionally more prominent) pressures on the output side of the industrial metabolism (Ayres, Simonis 1994). Consequently, Röpke (2001) states that "we can define the environmental impact of a specific consumption good as the appropriation of inputs necessary to provide a unit of that good.

As far as it is possible to characterise (not: measure) environmental stresses by input analysis (see chapter 3.2.3), this approach provides a much simpler means of environmental monitoring than output-focused analysis. Not only is the number of substances entering the anthroposphere significantly lower than the number leaving it (some 200 inorganic materials as compared to several 100,000's), also the entry gates are much fewer (in Germany about 20,000 as compared to several millions exits to the environment, without air, but including water, see (Spangenberg et al. 1999) Obviously a reduction of input would ceteris paribus reduce hazards and risks on the output side. If a reduction of input by e.g. a factor 10 is achieved, environmental pressures on the output side are bound to decrease as long as the total toxicity for humans and the environment per kg of substance does not increase tenfold over the same time. Given the current knowledge about the detrimental effects of substances, however, it seems quite plausible that such an increase in substance-specific risks can be avoided, although given the limited predictability of ecosystem sensitivities, on a case-by-case basis still a serious risk remains. The total, however, should rather decrease significantly than increase. Thus the working hypothesis is that resource flows although not suitable for *measuring* the environmental pressures are a feasible tool to *characterise* them and in particular their dynamic.

The trend of resource consumption increasingly becoming part of political and scientific discussions in evaluating and measuring environmental impacts is important for consumers as well. In shifting the focus of concern from the reduction of emissions to resource consumption, from industrial chimneys towards the sales point, this development is changing the role households from being a victim of environment hazards to being co-producer. The growing attribution of environmental responsibility to households calls for their empowerment as actors, partly by equipping them with reliable information about the resource intensity of the goods and services on supply.

### Measuring the resource inputs

Measuring energy consumption is a well established procedure, with annual energy consumption already an indicator in the CSD list (for the methodology sheets see UNDPCSD 1996, p. 166-167; UNDESA 1998). Measurement of material flows has been developed more recently; at the macro level it is measured as total material requirement TMR (Adriaanse et al. 1997; Schmidt-Bleek et al. 1998; Spangenberg et al. 1999). However, intensity of material use is already one of the consumption-pattern-indicators in the CSD system (UNDPCSD 1996, p. 176-178), and TMR has been included in the list of indicators for measuring changes in consumption and production patterns (UNDSD 1998, p. 19 - 22). As they are well established in the international literature, no detailed explanation of energy and material flow accounting is provided in this paper.

Land use is so far a case less standardised with no quantitative measure internationally accepted. (UNDSD 1998, p. 26-28) proposed this indicator hoping for international agreement on the methodology and data generation, which has not materialised yet. In the absence of suitable quantitative measures, here a semi-quantitative (ordinal) one has been applied, based on a qualitative hierarchy of use intensities. For this analysis it was sufficient to define the following four classes of land use, in decreasing environmental quality, which are related to a number of indicators for ecosystem health in the revised CSD list of indicators (UNDSD 1999b):

- man-made, i.e. built environment, characterised by soil sealed off by settlement, transport and production infrastructure,
- anthropogenically managed eco-systems with high input levels, like intensive agriculture, dependant on the hands-on steering of the system dynamics by humans,
- naturally managed eco-systems with low anthropogenic inputs, like sustainable forestry or fishing, with the management heavily dependent on exploiting the inherent regulation mechanisms and humans restricted to setting some framework conditions,
- unmanaged eco-systems, like nature reserves and other protected or unused areas, with limited human influence e.g. by forest dwellers or small scale hunters and gatherers.

Given the need to reduce the current level of resource use significantly (a factor ten, one order of magnitude has been proposed for industrialised countries, (Schmidt-Bleek

1994; United Nations General Assembly 1997), it is plausible that all major options to decrease resource consumption will have to be used. In other words: a basic assumption for the further conclusions is that resource use reductions are undertaken consequently across the board, thus affecting all sectors and all environmental problems. As soon as deliberately exemptions are introduced, the two-way correlation of resource flow reduction and environmental pressure relieve would be broken.

### *Resource use and environmental problems: Causes and symptoms*

Characterising environmental pressures and their trends by analysing the input side by its very character cannot not result a quantitative description of the various damages. However, it indicates which pressures have to be reduced and which corresponding changes in consumption clusters are needed in order to minimise (if not cure) the known environmental damages and as well minimise or prevent future ones (Hinterberger et al. 1996).

This kind of assessment is called *directionally secure* if with decreasing inputs the level of environmental damages will be decreasing with a high probability (Schmidt-Bleek, Friedrich 1994). The most serious of the current environmental problems can be addressed this way, except for those caused by relatively small flows of highly active substances like dioxins or pseudo-hormones (essentially an impact of the anthropogenically modified chemical environment on humans, not of humans on the environment). Politically speaking, such substances must be covered by health and safety regulations and banned from the sphere of the consumer, rendering the efforts to develop corresponding indicators superficial. This, however, is not intended to denote the need for proper information for the other actors like producers and public authorities (for more details of the reasoning behind the input-pressure link see Lorek, Spangenberg 2001, Spangenberg, Lorek 2002).

### Consumption clusters - where households can make a difference

In order to analyse the life-cycle-wide environmental impact of household consumption (not to be confused with the influence households have on environmental impacts), the national accounts based approach including public services consumption by households is the most appropriate one. As a next step, the total of household consumption can be disaggregated into the ten consumption clusters most frequently quoted in the literature. Applied to these clusters, the framework can serve to identify the most environmentally relevant ones by accounting for all resource uses activated by the consumption pattern, regardless of the relative influence of the actors involved. For the ten clusters chosen we find that together they represent more than 95% of private household resource consumption on the macro level (BUND/MISEREOR 1996). In alphabetical order they are:

- clothing
- education/training
- food
- health care
- housing (incl. construction)
- hygiene

- laundry and cleaning
- recreation
- social life
- transport

These clusters will be considered of prior environmental importance as fields of household decision making if they are both environmentally relevant and accessible to significant influences by consumers' choices. The latter is here assessed by means of plausible reasoning, without a detailed sociological or political science analysis.

Three sectors can be identified which primarily consist of state and institutional consumption (Reisch, Scherhorn 1999), in which households as customers have limited influence on the frequency of services consumption, and hardly any on the (environmental) quality of service provision:

- health care: hospitals, rehabilitation institutions,...
- education/training: kindergartens, schools and universities,...
- social life: including the police, the military and other public services

Since the resource consumption per unit of service in the sectors is beyond the reach of consumer influence, they will be omitted from the further analysis of priorities for consumer action, regardless of their undisputed environmental significance.

When analysing the seven remaining clusters regarding their share in key resource consumption, it turns out that the total requirement of

- construction and housing,
- food and
- transport

adds up to nearly 70 % of material extraction, energy consumption and land use. Each single cluster represents more than 15 % of energy and material consumption (in this calculation, leisure mobility is subsumed in the transport category; if not so, leisure would emerge as the fourth sector of particular environmental relevance: Reich, Scherhorn 2000). The remaining four clusters

- hygiene,
- clothing,
- cleaning and
- recreation (without transport)

that can be influenced by households actually consume - if at all measured in detail - less than 5 % of resource consumption each. Given the relatively small share in resource consumption, the limited although significant influence of households e.g. on the resource intensity of clothing or cleaning agent production, and assuming that a straightforward reduction of consumption is indeed possible, but again only to a limited degree, ten percent reduction of total resource consumption in these four sectors together seems to be a conservatively estimated maximum potential. Although this is not a quantity to be ignored, these sectors are considered as fields of environmentally secondary (maybe not so from a sociological point of view).

The following analysis and indicator development will therefore concentrate on the three environmentally dominant areas identified as *priority fields of action.*: construction and housing, food and nutrition, transport and mobility (see table 1).

Table 1: Where household can make a difference

| Consumption clusters | Influence of private Households | Environmentally relevance |
|---|---|---|
| Clothing | x | |
| Education/Training | | x |
| Food | x | x |
| Health care | | x |
| Construction/Housing | x | x |
| Hygiene | x | |
| Cleaning | x | |
| Recreation | x | |
| Social life | | x |
| Transport | x | x |

With this approach, hazardous impacts on humans' health *caused by the environment* will not be recorded. These include above all *chemicals with human-toxic effects*, i.e. cancerous, teratogenic, mutative, allergic and endocrine disruptor substances but also eco-toxically doubtful, hardly biodegradable or bio-accumulating substances, but as well wide-spread and health relevant disturbances such as noise[57].

Whereas the importance of a specific good and service for sustainability is, in general, only minor, numerous goods and services have a symbolic function besides and above their utility function. Some of them indicate the membership in a certain social or lifestyle group or serve as a symbol of status for the compensatory consumer (Scherhorn 1991). The importance for environmental sustainability and the perceived symbolic value of the products or services consumed need not be matching at all. This lack of congruence, however, does not reduce the validity and importance of the communicative function. On this basis, selected goods and services can be singled out that might serve as „icon indicators", which due to their communications and social distinguishing function play an important role in sociological and psychological consumption analysis, however less in the environmental one.

[57] As long as goods and services contain such substances, their avoidance is an essential aspect of health conscious consumer behaviour. The protection of humans against toxic substances is, however, rather the task of national legislation in order to legally prohibit harmful goods and substances, than one of individual consumer choices. Thus toxicity concerns are a subject of sustainable production patterns rather than one of sustainable household consumption.

### Sustainable household consumption: Indicators and actors. The transport case study

In order to develop conclusive and communicative indicators for household use, the three priority fields of action (construction and housing, food and nutrition, mobility and transport) have to be analysed to identify the dominant factors driving resource consumption.

Based on the existing (partly quite poor) data, for each priority field a few consumption issues have been identified offering the most significant potentials for reducing resource consumption. These can be characterised by indicator, and the relative extent of influence of different actors including private households in the field, estimated by common sense can be presented by a rough scheme with 0 = little influence, + = significant influence, and ++ = strong/dominating influence). As “sound institutional and social arrangements and eco-intelligent infrastructure can mould habits and steer behaviour without even touching the value question” (Reisch, Scherhorn 1999), providers of such infrastructure and social actors are relevant players to be taken into account in the influence schemes.

This application of the analytical framework introduced in this paper is presented by Sylvia Lorek in her paper on “Indicators for environmentally sound household consumption”. Further applications include for instance the analysis of the environmental impacts of consumption in different income strata, an evaluation of the Environmental Kuznets Hypothesis on the micro level.

### Discussion

Affluent consumer have a significant influence on the sustainability of consumption and production patterns, however a non-quantifiable one. The options they have and the behaviour they adopt is bound by the cultural, political and informational setting they are part of. It varies with the information they have, attitudes, fashion and social position.

Furthermore, there is hardly any consumption decision taken by households without influence of other social and economic actors: the spheres of influence are overlapping, and between social actors there is a "shared but differentiated responsibility" as much as between countries.

In order to empower consumers to contribute their part to the change of consumption patterns, unambiguous information about priority fields of actions of utmost importance – without, the plethora of unranked "to do's" will cause frustration rather than motivation and will lead to ignorance and inertia rather than to change.

Sustainable consumption indicators identifying most effective options to reduce the total resource throughput of our societies can be a tool to motivate consumers and help them monitor the effectiveness of their action. It helps focusing on the most promising options and helps avoiding fruitless debates on issues of minor environmental relevance like fashion, hygiene and cosmetics.

Integrating these indicators with an actor analysis helps structuring the respective policy fields in a way which makes the role of the actors as obvious as the need for multi-level policy integration. Once indicators for other actors were available, the mutual monitoring could develop into a kind of social control, a traditional mechanism of social cohesion currently undermined by the increasing influence of anonymous institutional actors. For establishing sustainable consumption and production patterns, higher levels of transparency and accountability, making all institutions involved behave as good citizens, would be a significant step forward.

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# A Framework for a Community-based Comparison of Consumption Patterns

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## Abstract

It is widely acknowledged that reversing the trend of ever increasing environmental pressure requires changes in consumption patterns to go hand in hand with technological improvements and population policy. With this study we aim to go beyond the usual instruments of better information and market price correction, as they have not proved sufficiently effective. Instead we develop a framework for a community-based process of understanding problems with existing consumption patterns, developing alternative scenarios and measures for changing over to paths towards the preferred scenario. For the analysis and group facilitation a triangulation of methods (scenario building, life-cycle assessment, multicriteria evaluation and participatory decision processes) is used. Case studies are planned for several UK regions.

## Introduction

Duchin and Lange (1994) showed that even with the adoption of clean and efficient modern technologies throughout the world, emission targets established at the 1992 Rio de Janeiro UN Conference on Environment and Development (UNCED) will not be met. In order to meet these targets, changes to lifestyles with less environmental effects are necessary, yet the barriers for questioning our consumption patterns are substantial.

The aim of this paper is to develop a conceptual framework of a life-cycle based analysis of existing consumption patterns of households, the development of alternative consumption patterns and the design of community-based discussions of these alternatives.

## Theoretical framework

The analysis of this study builds on two main elements, namely that household consumption is socially shaped and that consumption patterns can be changed.

### *The social shaping of household consumption*

Sociologists (e.g. Granovetter 1985) and institutional economists (Hodgson 1988) have argued for a long time that the neo-classical representation of economic behaviour is a misrepresentation insofar as it underestimates the role of the formal and informal institutions surrounding consumers. Instead consumers are conceptualised as follows: (a) they are embedded in institutions, which constrain, but also enable their behaviour (Giddens 1984; Hodgson 1988); (b) they are part of social groups from which they learn through interaction; and (c) routines and conventions are explicitly accounted for (Hodgson 1988; Thevenot 1994).

These claim were recently supported by laboratory experiments. For example, experiments about the production of public goods have shown that people's readiness to contribute increases if the participants have a possibility to punish and if there is face-to-face interaction with other participants (Bowles and Gintis 1998; Fehr and Gächter 2000; Ledyard 1995). These experiments have shown that people's behaviours are dependent on the institutions within which they operate and on other people's behaviours. These results are relevant in our context, as consumers adopt more environmentally sound consumption patterns they are contributing to the production of a public good. Therefore, we suggest a framework aiming at groups of consumers rather than individuals.

Also people, who are, as citizens, motivated by their concern for the environment, want to contribute to a larger goal. This cannot meaningfully be reduced to something - which serves their individual interests. In the "visioning" (vision creation) phase alternative scenarios and actions necessary for realization are developed. What starts as a loosely defined common interest in minimising household waste and resource use, can evolve into a norm, as citizens meet, exchange information and discuss their experiences and possible solutions. Through these discussions (and following actions) the citizens develop shared definitions of what is environmentally sustainable behaviour, shared meanings of what is the 'right' thing to do, and shared conceptions of their critics (Georg 1999).

Hence, a community-based approach (a) enables actions, which need a collective consent (i.e. widening possibilities for action), and (b) the community functions as reinforcer (all contributing to a larger goal and through continued practice, routines can be changed).

### *Consumer preferences and democracy*

Consumer sovereignty as it is usually assumed in neoclassical economics says that preferences are not only given, but also do not change (Stigler and Becker 1977). Preferences can only change in response to non-rational factors such as advertising or other forms of 'propaganda' (Norton et al. 1998). With this strong assumption, every (rational) change in behaviour must be initiated within the economic system. According to Stigler and Becker (1977), "the great advantage ... of relying only on changes in the arguments entering household production functions is that all changes in behaviour are explained by changes in prices and incomes, precisely the variables that organize and give power to economic analysis" (quoted in Norton et al. 1998). The implicit assumption of this route is, however, that there cannot be alternative ways to rationally understand or evaluate processes of preference change (Norton et al. 1998).

A consequence of this approach is that valuation is purely subjective. "There is no disputing tastes since they are unique to each individual, and to judge such subjective feelings is to impose those of the judge upon those being judged. ... Applied to consumption this is merely a specific application of a more general position in which it is contended that it is impossible to assess the outcome of the valuation process – values. Judgements of value are unique to the beholder" (Hamilton 1987:1545n).

Over recent decades many objections to the neoclassical representation of consumer behaviour have been raised. Most commonly accepted is that sometimes people want to fulfil needs that they would be better off not to have (e.g., persons addicted to drugs or alcohol) (Scitovsky 1976; Stigler and Becker 1977; Elster 1979). Individual desires, thus, may not be consistent with individual self-interest, particularly not if a longer time frame is taken into consideration. There are also limits to people's knowledge and information that may make individuals not always judge their wants correctly (Simon 1961). If there are structural limits to practical rationality concerning future events and consequences of action on remote places, this is crucial when discussing sustainability. The incompleteness of knowledge does not only stem from ignorance (lack of information), but also from inherent indeterminacies in social-ecological processes.

The critique concerning addiction and bounded rationality has been incorporated into theory at least in part, for other concerns this have proven more difficult. "The preferences of a person are the product not only of biological needs but also of a socialization process. Therefore, they are determined by, and tend to reflect and reinforce, existing social relations. This means that a theory which requires the maximum satisfaction of the preferences chosen in a given social context contribute to reinforce that social context, and is therefore a theory strongly distorted in a 'conservative' sense" (Screpanti and Zamagni 1993). This is a severe charge, particularly for questions related to sustainability. Besides acknowledging the social context (last section) we need to search for possible paths for change.

Instead of assuming individual consumers with given and/or fixed preferences, we start from the assumption that consumers are to some degree shaped by their social and environmental context and that their preferences may change over time (O'Hara and Stagl forthcoming; Stagl and O'Hara 2001). Norton et al. (1998) point to the tension between individual and social interests in posing the challenging question: Is it not the assumption of consumer sovereignty that is undemocratic instead of influencing preferences as a society? They argue that how much influence the individual has and how much influence is allowed to the public is rather a matter of degree than an absolute category. The difference in the result between a command-and-control sustainability approach and one where preferences are influenced is that in the former people are feeling deprived whereas in the latter they may feel better off and proud to contribute to sustainability.

## Case study: Household consumption in UK regions

In the UK governmental regulation and information campaigns were not used as much as in other countries (e.g. The Netherlands, Germany) to encourage households to adopt more sustainable consumption patterns. To come in line with other European countries recently the UK government has set itself ambitious goals with regards to the reduction of household waste and (to a lesser extent) energy consumption. To reach these goals households will not only need information about the consequences of their behaviours, but additional encouragement to change their behaviours. Therefore we plan to assess the impact of current consumption patterns, develop scenarios with community representatives in three UK regions (Wales, England and Scotland), calculate the change in the impacts for these alternative consumption patterns and facilitate workshops for communities to decides about actions.

## Data and methods

### *Building of consumption pattern scenarios*

Scenarios are developed in creativity workshops and with stakeholders. Participants are asked to explore technological as well as social innovations leading to more sustainable consumption patterns. The workshops are intended to generate a vision of consumption patterns that are radically different from the present. An approach which was applied successfully in a similar context is back-casting, where workshop participants are asked to focus on a year in the future (usually several decades ahead) to envision futures that constitute shifts to different (more sustainable) development paths (Green and Vergragt 2002).

The scenarios contain general and localised elements. The former draw on ideas from previous projects (e.g. SusHouse) and they pool ideas from the regional workshops. The localised elements allow for different ways to implement the envisaged solutions.

### *Comparison of impacts of existing consumption patterns with different scenarios*

To compare different development paths or scenarios of consumption patterns based on life-cycle data, we use structural economics, which describes production and consumption activities inseparable from their social and biophysical context.

The core of structural economics is the input-output model. The fundamental purpose of the input-output model is to analyse the interdependence of economic sectors and therefore it takes the whole life-cycle of a product into account. The extensions of input-output models include social institutions (Social Accounting Matrices) and the environment (environmental accounts).

We use this analytical framework for analysing scenarios about alternative consumption patterns based on different social and technological assumptions. Structural economics provides us therefore with information about the effects of different consumption patterns on the economy, society and the environment.

In the UK input-output tables are available at a regional level (e.g. Wales). We will extend these tables with reference to resource accounts (emissions, resource use) and calculate the changes in impacts corresponding to the respective consumption scenarios.

To compare a discrete number of scenarios and their impacts in a structured way a multicriteria evaluation tool (e.g. Promethee) is applied[58]. While multicriteria evaluation is an optimisation method, which provides a ranking of a given number of alternatives, it has also been applied as part of a process of deliberation and social learning (e.g. De Marchi, et al. 2000). For this study the entries for the impact matrix are derived from the structural economic model and the weights are elicited in deliberative workshops.

### *Deliberation about consumption patterns*

The next and final steps are deliberative workshops with consumers. These workshops serve two purposes, namely (a) to inform households about consequences of their consumption choices, to suggest alternatives and to identify areas where individual

[58] For a comparison between different multicriteria methods see De Montis et al, forthcoming.

action and collective action on the community level are possible, and (b) we hope to find out about the attractiveness and acceptability of the alternatives developed.

## Next steps

After a series of workshops in different regions of the UK we aim to provide a toolkit for groups in other regions to start their own deliberative workshops. The database and manuals will be provided on the Internet.

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# Advantages and limitations of eco labels as consumer and environmental political instruments. Report from the European DEEP project.

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## 1. Introduction: Eco-labels in Europe

The objective of this paper is to discuss the advantages and limitations of different kinds of eco labels in Europe within the framework of *ecological modernisation*.

Within an integrated product policy (IPP) environmental product information is one important tool (Rubik & Scholl 2002). In the business to consumer dialogue, eco-labels are a central part of "transmitting environmental information" (E&Y et al 1998). Other consumer oriented information channels are test reports and test notes from consumer organisations and test institutions, quantitative product informations from producers on the package or information through internet, personal sales talks and advertising.

Eco-labels include various symbols, schemes, and institutional and legal arrangements. We can distinguish between mandatory and voluntary labels in the following way (Rubik & Scholl 2002):

- Mandatory labels like the EU energy label, relevant for household appliances and mandatory labels for chemical products
- ISO-type I eco labels, classical third-party labels like the EU-flower, the German Blue Angel and the Nordic White Swan.
- ISO-type II eco labels, self-classification by industry or retailers
- ISO-type III eco labels, quantitative environmental product declarations (EPD)
- Other relevant labels, including social labels and organic labels
- Other not relevant labels, including recycling symbols like the green dot

The mandatory labels are based upon EU-directives and are valid for chemical substances and household appliances in Europe**.**

The Blue Angel in Germany was the first voluntary ISO-type I label in the world, established in 1978. During the 90ties similar eco-labels were established in nearly all EU and EFTA countries (Rubik and Sheer 2002). Most of the labels are nationally based and are run by national eco labelling bodies, with the exception of the White Swan established by the Nordic Council of Ministers and valid for all the Nordic countries (Stø in Rubik & Scholl 2002). The labels cover both consumables, durables and services, and the main focus is the *environmental* impact of the product, in a life cycle perspective. In most cases the classical eco-labels do not include foodstuffs. There are usually developed separate national labels for organic food. The criteria are developed in a multi-stakeholder perspective and the actual label is a positive, well-known symbol.

The EU-flower covers goods and services within the European Economical Area and was established by EU directive in 1992. The EU-flower has so far not managed to function as an effective environmental product information scheme in Europe.

A large number of ISO-type II labels are found in the European market established and run by the industry or retailers. These self-classifications are often one-dimensional, covering only certain aspects of the product, like *recycled* paper products, *phosphate free* detergents. ISO-type III labels – Environmental Product Declaration (EPD) - are under development in Europe. Such quantitative data will, however, be more relevant in a business-to-business communication.

This paper is based upon results from the EU-project DEEP: **Developing Effective and Efficient Product Information Schemes** - Assessing and expanding product information schemes between voluntary and mandatory approaches. The project is developed within the fifth framework work programme Energy, Environment and Sustainable development. The coordinators of the project are IÖW from Heidelberg, Germany, and the partners are ITACA, University of Rome, Italy; Randa Group, Barcelona, Spain and SIFO, Norway. (http://w3.uniroma1.it/deep)

The main objective of the DEEP project is to analyse the conditions under which environmental product information schemes (EPIS) are efficient and effective tools:

- to achieve sustainable development;
- to assess previous experience with eco labels in different European countries and
- the relationship of these schemes with business strategies, Integrated Product Policy (IPP) and market conditions;
- to define strategies aimed at linking EPIS with other IPP measures;
- to explore how eco labels can be used for realising sustainable consumption patterns, creating green markets, fostering innovation and development of green product and services,
- implementing multi-stakeholder initiatives.

The *research process* is divided into two major steps: First, past experience with EPIS in Europe - with a special focus on Germany, Norway, Italy, and Spain - are analysed by reviewing the state-of-the art in the four countries and performing a number of case-studies in each country for selected market sectors, including a four country consumer survey (Stø, Strandbakken & Strand 2002). Second, operative and strategic proposals with respect to possible links of EPIS with other IPP tools will be elaborated mainly based on insights gained at workshops with relevant stakeholders.

This paper will focus on three aspects of eco-labels in the European consumer market. First, we will address the importance of consumer knowledge and trust in the labelling schemes. This will be done before we turn to the main question: the *advantages and limitations of eco labels as consumer and environmental political instruments.* We will discuss these advantages and limitations along two dimensions:

1. We will compare consumables, durables and services, and asking if various kinds of labels are more suitable for some products than for others
2. We will discuss the relation between mandatory and voluntary labels, where we specially will focus on various kinds of voluntary labels:

- ISO-type I labels, the "classical" eco labels like the Blue Angel, the White Swan and the EU flower
- ISO-Type II labels, self classifications
- ISO-type III labels, numerical EPD (environmental product declarations)

## 2. Ecological modernisation, eco labels and consumers

Ecological modernisation is a modern social science catchword; much used in environmental sociology and in the ecological discourse. It has been regarded as the *real* perspective guiding the World Commission for Environment and Development, as environmental sociology's break with small low-tech rural utopias, as a (political) right turn for the environmental movement as well as a left turn for industry. It is a new name for the current environmental politics in the European Union. At the same time it is the theory behind that change, simultaneously.

We will treat ecological modernisation as a two dimensional phenomenon: First as a mainly historical-sociological description of pragmatic changes in environmental policy in some European countries; secondly as a more pure theoretical approach in environmental sociology, conceptualising sustainability for industrialised and rich societies.

The "modernity" aspect of the concept mainly refers to what Anthony Giddens usually calls "simple modernity":

> *'Modernity' can be understood as roughly equivalent to 'the industrialised world', so long as it be recognised that industrialism is not its only institutional dimension (Giddens 1991, p. 15).*

This kind of modernity is correlated with a belief in rationality, in science and more generally in (quite) rational actors and planning. In this context it then presupposes quite rational consumers. In the ecological modernisation of consumption we expect consumers to have confidence in experts and in macro actors, having general trust in systems they often are not able to understand (like airlines, hospitals and eco-labelling bodies.

### *2.1 New politics*

The Word Commission's report from 1987 introduced, or at least popularised, the concept of sustainable development. This concept actually entails the idea of an *eco-friendly economic growth*; in idea that would have been plainly absurd to environmentalists in the seventies, and to environmentalists still operating in a seventies paradigm. The environmental movement might have believed that it would maintain its position and even regain momentum by focusing on the definition of sustainability, but in hindsight this was less about definitions than about a changed practice. As the environmental issue was about to move from the periphery and into the centre, the initiative went from social movements and over to social elites in business, administration and politics.

While sustainable development might be regarded as a "UN"-perspective, with its concern over third world poverty, fair trade, social rights and bio-diversity, ecological modernisation should be seen as an "OECD"-perspective, focusing on industrial processes and pollution prevention (Strandbakken 1999, p. 4). The new politics, and the debate about it, seems to have started around 1980, and it got its definite breakthrough as a policy approach in the aftermath of the Brundtland report. What, then, are the main elements of this approach?

- Most important is the idea that environmental measures might be profitable, and not necessarily a financial burden for industry. “Pollution Prevention Pays” (PPP) and “creating win-win-situations” are modern slogans expressing this view (Spaargaren 1997, p. 12, Weale 1992, p. 31).
- Prior to that, the environmental problems have to seen as solvable; elites had to believe that challenges could be effectively met by the present economical-political system. The seventies idea of “revolution or doom” is too inflexible to encourage pragmatic environmental measures.
- Ecological modernisation sort of redefines the relationship between the state, its citizens and business; environmental authorities seek cooperation with (selected) social movements and the more enlightened actors in industry. Participation in legislation and regulation encourage environmentalists and business to seek consensus and step-by-step approaches.
- A more active use of technology, and positive view of its role.
- A gradual recognition of the fact that some of the most important environmental problems go beyond the limits of the nation state, encouraging international agreements and control regimes

This “new politics of pollution”, as Albert Weale (1992) called it, has been quite successful in Western Europe. Industry has introduced clean technology, often with state subsidies, and emissions to water and air has been greatly reduced. Some examples of successful change are unleaded gasoline (Russel & Millstone 1995, Throne-Holst 2000), phosphate free detergents (Nork-Staehle 1995, Throne-Holst 1999), the ban on CFCs (Conrad 1995), and - more generally - municipal waste, municipal sewage and energy efficiency on a broad scale (in appliances, in industry, domestic). In these (and similar) fields the new politics of pollution that we call ecological modernisation has been very successful.

The limitations of this approach can be summarised as follows:

- There is a difference between reducing poisonous emissions and reducing emissions of greenhouse gases, because they are more a function of the overall economic activity. So far the policy approaches from ecological modernity has failed to address the greenhouse questions effectively.
- This weakness might be generalised. Modern societies do things more effectively, but they do more and more things.
- The general focus on the problems of rich and developed countries removes attention from the third world, world economic systems, distribution, fair trade etc.
- Ecological modernity has so far mainly been an approach to changing the production side of the economy. The consumption side has not received the same amount of attention.

We will elaborate further on the last point; ecological modernisation and consumption, a bit further down.

### *2.2 New theory*

Theoretically, "ecological modernisation" stays close to political and economic reality. It is mainly describing the broad changes in policy and in mentalities and trying to account for the reasons behind these changes. Ecological modernisation theory is by and large not very abstract and conceptual.

The theoretical foundations were laid in Germany in the eighties, where Martin Jänicke and Joseph Huber started to renew the thinking about society and the environment after observing the development of the German environmental policy. In his early works, Jänicke strongly advocated state supported ecological modernisation processes, and therefore also an enlarging of the state's steering capacity. His view on agency has been summarised in this way:

> *Although ecological modernisation is targeted primarily at market actors and the industrial sector, its main bearer should still be the state (Spaargaren 1997, p. 14).*

In his later writings he has more emphasised the new relationships between civil society and the state that has come about, partly as a result of environmental problem solving.

Joseph Huber also discusses the role of the state in promoting environmental change, taking a less optimistic view of state interventions than Jänicke. He fears that state interventions might frustrate the innovation process. His main theoretical contribution, however, is his break with the "counter-productivity" or "de-modernisation" theories of Gorz, Commoner, Schuhmacher, Illich and others that dominated the environmental discourse from the early seventies. The background perspective of these thinkers is the Malthus-inspired "limits to growth" perspective of the Club of Rome, and their solution or response usually advocated zero growth, small-scale rural utopias and simpler, more "humane" technology. Spaargaren points to this aspect of Huber's work:

> *Notice the fact that Huber's theory implies a radical break with the demodernization ideology in the sense that he calls for a further modernization of the existing institutions of industrial society (Spaargaren 1997, p. 15).*

This might seem quite obvious today, but it was a very brave move in the early eighties. Another aspect of Huber's writings that has remained relevant is his formulation of the "two processes" of ecological modernisation; the "ecologizing of the economy" and the parallel "economizing of the ecology".

It seems as if Jänicke's and Huber's work in the early and middle eighties was not translated into English, so their contributions had little impact outside the German speaking world. To a large extent it was Maarten Hajer and Albert Weale who introduced the new concepts to the world beyond Germany, Austria and Switzerland.

Albert Weale's *The new politics of pollution* from 1992 compares the reaction to acid rain in Britain and Germany in the 1980s. In Germany, this challenge led to a kind of policy renewal and new patters of cooperation between actors, while in Britain there was a lack of policy momentum.

## 2.3 Ecological modernisation of consumption

As indicated, most literature on ecological modernisation so far has focussed on the production side of the economy. The perspective is, however, just as relevant for consumption. We might even say that most of the environmental initiatives directed at consumption in the last 10-15 years in the rich countries actually presupposes a "modern" view of the environmental issues. In the first step, an analysis of consumption practises under the heading of ecological modernisation will probably mainly be concerned with more objective and technical aspects of environmental aspects of consumption and products.

At the most general level, an environmental concern with consumption suggests a pragmatic and anti-apocalyptical view of the environmental issues. To advocate incrementalism and small changes in a positive direction for a large number of persons indicate that one believes that it is possible to respond to the challenge even under present economic-political conditions, and it also indicates a view of environmental problems as a result of a great number of small and individually insignificant acts. This is a break with some of the more radical environmentalism from the seventies.

Environmental Product Information Schemes, like eco labels, often are developed in a multi-stakeholder logic; interest groups' initiatives, state support, business cooperation etc. Without the aforementioned *redefined relationship* between the state, its citizens and business, ecolabelling would not come about in its present form. Mandatory energy labelling and successful type I labels do not seem very likely under a political climate like that of the seventies.

The same should probably be said about collecting and handling of consumer waste. Some sort of state or municipal overall responsibility is common, but cooperation from households and often also from business is necessary.

Further, a degree of green public procurement often seem to be necessary for giving ecolabelled and organic products enough volume to survive in the market, again emphasising new relationships between actors.

A corporativistic approach to legislation and control in the field of environmental consumption brings interest groups together in ad hoc committees and it encourages compromise. This probably gives "enlightened" business and "modernised" environmentalists a market advantage (even if this strategy may backfire for environmental organisations accused of corruptibility and sell-out).

As a kind of "modernism", ecological modernisation of consumption will carry a positive view of technology, taking science and product development into the service of the environment.

In order to develop a successful ecological modernisation of lifestyles and consumption practises in the rich parts of the world, parallel to the changes achieved in large parts of the production sphere, we have to communicate with citizens as customers and as domestic managers. This means that in the sphere of ecologically modernised consumption we have to presuppose at least a "rather rational" actor, able to seek and process information, and willing to act on it. Without such an image of the consumer, eco-labels are meaningless. Producers and retailers communicate with consumers via labels administered by third party bodies; that is the logic behind both mandatory and voluntary ISO Type I labels, and in such a logic we take for granted that labelled products are environmentally better than unlabelled, that consumers are concerned with the environment in general and that they are interested in expressing this concern through their buying behaviour. This rationally is, however, limited to simple symbols.

This again means that for an ecologically modernised consumption, questions of consumer knowledge of eco-labels and of consumers' perception of the meaning of eco-labels are important. So are questions of what kinds of information they demand for durables, consumables and services, and – more general – what information sources they tend to trust in environmental matters. These are important questions for an assessment of the ecological modernisation of high-consuming, affluent lifestyles. The consumer trust is important because ordinary consumers are not able to verify the scientific data from the production process of consumer goods. One of the aims of this paper is to address the crucial question how eco labels should be institutionalised to create consumer trust. Who do consumers trust, EU-commission, national governments, businesses, scientific community or environmental and consumer NGOs?

### *2.4 Some limitations of ecologically modernised consumption*

We regard these attempts at developing ecologically modernised lifestyles as positive, and as an interesting perspective for the study of eco-labels. There are, however, still some limitations and problems with this approach:

- The pragmatic way solves some kinds of problems better than others. It generally deals more successfully with matters of consumption patterns than with consumption levels. This dilemma is also present in the race between efficiency and economic growth; we get more fuel-efficient cars, but there are more cars and each car drives more kilometres.
- The "new responsibility" of environmental organisations might steal integrity and independence, and at a later date it might jeopardise their popular support.
- It is probably *not true* that pollution prevention always pays, and expectations that they will might create an image of painless sustainability. We might still have to deal with changes that demand effort, perhaps even sacrifice.
- Related to the previous point: Ecological modernism as a movement has so far – for production as well as for consumption – probably gone for the low hanging fruits In the future we might confront other kinds of fruit.
- The demand for more environmentally friendly consumer products might work as a trade barrier for the developing countries, hindering market access and therefore be an obstacle to sustainable development outside the OECD countries.
- The modernist approach (Giddens' "simple modernity") has a blind spot for things that go beyond use value and exchange value (price) in consumption.

## 3. Data and methods

This paper, and the project on which it is based, utilises both secondary and primary data. In the discussion of the environmental impact of consumption we have used life cycle analysis as a platform and background for the project. Our primary data are a combination of quantitative and qualitative material. We have carried out a quantitative consumer survey in Germany, Italy, Norway and Spain. In addition, the project is built up around three case studies; *tissue paper* representing consumables, *washing machines* representing durables and *tourist accommodation* as an example of services. In these case studies, we carried out qualitative interviews with relevant stakeholders in the four countries. The stakeholders were representing producers, distributors, consumer and environmental NGOs, governments and eco labelling bodies. Most of the interviews were personal interviews, but to some degree we use the telephone.

The quantitative consumer survey was carried out by telephone from early to late summer 2001 in Germany, Norway, Italy and Spain. Each interview lasted approximately 20 minutes, and 1000 respondents were interviewed in each country. A common questionnaire in English was translated into the national languages. The questionnaire consisted of 21 main questions and some background variables.

The survey focused upon search activity for tissue paper in the past, the next purchase of a washing machine, and previous and future purchases of holiday accommodation. The questions also covered a wide variety of questions about trust in information from, and eco-labels backed by, different agencies. There is also a section that includes questions about national and European eco-labels.

Cross-country studies always have their own challenges. Everyday life varies considerably between the countries. How the market-place functions and what kinds of environmental information are available in the different countries also varies considerably. In the search for common issues and common concepts, the more complicated and precise issues must be left behind. We have therefore also included several questions concerning attitudes to explore assumed differences between the countries. In addition there are the linguistic challenges in composing identical surveys in four languages.

All in all the survey results were satisfactory. The questionnaire seems to have functioned reasonably well in all four countries. The German survey results have the fewest missing, and few respondents used the *do not know* option in the questions. The Norwegian results were a little less impressive than the German ones, but still quite good. One exception was the holiday accommodation question that did not function well for Norway, mostly due to the fact that Norwegian holiday habits are very different from the other countries. The Italian results had more missing than the first two, but the results were still satisfactory. There were some more problems with the Spanish results. There was substantially more missing than for the other countries, reducing the representativity of the results.

## 4. General aspects: knowledge and trust in eco-labels

The DEEP project is carried out in four different European countries with a wide variation in experiences with eco labels. This gives us an opportunity to study the importance of consumer knowledge about and trust in the labelling schemes. Both consumer knowledge and trust among consumers are important factors in the ecological modernisation. We all know that the rational economic man is a fiction. However, the model presupposes some rationality among ordinary consumers, otherwise the eco labelling schemes are only a shot in the dark.

### *4.1 Consumer knowledge*

The respondents were asked to name any environmental labels they could spontaneously think of. Each country reported answers for a common group of labels, and then also in addition various national and regional symbols. We have included the recycling symbols in this overview, event though is it not an eco-labels .As we can see, there are significant differences among the four countries (table 1 and 2).

Table 1: Three most spontaneously mentioned environmentally related labels including social labels by country in absolute numbers

| | Germany (1021) | | Norway (1000) | | Italy (1000) | | Spain (1004) | |
|---|---|---|---|---|---|---|---|---|
| **Most mentioned** | Blue Angel | 578 | The Nordic Swan | 700 | Recycling Triangle<br>Panda WWW<br>Albero | 14<br>13<br>9 | Green Dot | 194 |
| **Second most mentioned** | Green Dot (Grüner Punkt) | 553 | Recycling symbol | 199 | Energy label | 6 | Blue Flag | 39 |
| **Third most mentioned** | Recycling symbol | 70 | Green Dot<br>WWW Panda<br>Debio Ø | 50<br>48<br>47 | | | AENOR<br>DGQA | 27<br>22 |

Table 2: Number of eco-labels that respondents spontaneously mention

| | Germany | Norway | Italy | Spain |
|---|---|---|---|---|
| **1 label** | 48,5 % | 56,1 % | 3,5 % | 18,1 % |
| **2 labels** | 29,4 % | 16,8 % | 0,1 % | 4,0 % |
| **3 labels** | 5,4 % | 3,0 % | 0,0 % | 1,3 % |
| **4 labels** | 0,4 % | 0,7 % | 0,0 % | 0,2 % |
| **5 labels** | 0,2 % | 0,0 % | 0,0 % | 0,1 % |
| **Mentioned no labels** | 16,2 % | 23,4 % | 96,4 % | 76,3 % |

- The Blue Angel and The White Swan is well know among respectively German and Norwegian consumers
- The recycling symbols are recognised by consumers in Germany, Norway, Spain and to some degree Italy
- European consumers do not know the EU-flower, only 1% mention the flower.
- German and Norwegian consumers mention a large number of eco labels or similar environmental symbols, while the situation in Spain and Italy is quite different where more than ¾ did not mention any labels at all.

## 4.2 Who do consumer trust as sources for environmental information?

We followed up on this ranking by asking *who* the respondents trust as a source of information concerning environmental issues, on a scale from 1 Trust a great deal to 5 Do not trust at all. We found that environmental organisations and scientists consistently score the highest, while business and industry score the lowest in all four countries.

Table 3: Trust in environmental information from different sources ranked by the sum of the two strongest degrees of trust on the scale from 1 (Trust a great deal) and 5 (Do not trust at all). In percent of those who answered

| | Germany | | Norway | | Italy | | Spain | |
|---|---|---|---|---|---|---|---|---|
| 1st | Environmental organisations | 74 % | Scientists<br>Environmental organisations | 66 %<br>62 % | Scientists | 61 % | Environmental organisations | 53 % |
| 2nd | Scientists | 65 % | | | Environmental organisations | 53 % | Scientists | 48 % |
| 3rd | European Commission<br>Media | 26 %<br>23 % | Government | 36 % | European Commission | 37 % | Media | 34 % |
| 4th | | | Media | 26 % | Government<br>Media | 21 %<br>21% | European Commission | 25 % |
| 5th | Government | 19 % | European Commission | 21 % | | | Government | 13 % |
| 6th | Business and industry | 14 % | Business and industry | 17 % | Business and industry | 16 % | Business and industry | 9% |

Non-significant differences at 5% are ranked together. Other differences are mostly significant at 1% or more.

As expected, Government received a higher rate of trust in Norway than in the other countries, as this is a very common result from cross-country studies. As a non-EU member it is also not surprising that the European Commission has it's lowest ranking in Norway.

Spain had a very large number of missing, so the Spanish results are only representative for the half of the respondents that answered the question. Given that, we immediately notice that Consumer and Environmental organisations are ranked first and retailers are ranked last in all four countries. The results for Germany and Norway show a larger spread in the percentages than for Italy and Spain in the extremes, though the German results do not differentiate between the European Commission, National government and producers. Independent body including several stakeholders holds a second ranking in Germany, Norway and Spain, and third in Italy. Government has a relatively high ranking in Norway again with a relatively high percentage; in the other countries Government has a percentage in the twenties and a lower ranking. Notice again the high ranking for the European Commission in Italy. Producers have a second-to-last ranking in all the countries with percentages in the twenties, a steady and relatively poor result.

We then turned to the more concrete question about trust in eco labels administrated by various institutional arrangements; including European Union, Governments, NGOs, retailers, producers and independent bodies (table 4).

Table 4: Trust in an eco-label administered and guaranteed from these institutions ranked by the sum of the two strongest degrees of trust on a scale from 1(Trust a great deal) to 5(Do not trust at all)? In percent of those who answered

| | **Germany (1021)** | | **Norway (1000)** | | **Italy (1000)** | | **Spain (556-605)** | |
|---|---|---|---|---|---|---|---|---|
| **1st** | Consumer and Environmental organisations | 78 % | Consumer and Environmental organisations | 73 % | Consumer and Environmental organisations | 53 % | Consumer and Environmental organisations | 67 % |
| **2nd** | Independent body | 55 % | Independent body | 63 % | European Commission | 44 % | Independent body | 52 % |
| **3rd** | European Commission<br>Government<br>Producers | 28 %<br>25 %<br>25 % | Government | 53 % | Independent body | 36 % | European Commission | 41 % |
| **4th** | | | European Commission<br>Producers | 27 %<br>24 % | Government<br>Producers | 28 %<br>28 % | Producers<br>Government | 33 %<br>29 % |
| **5th** | | | | | | | | |
| **6th** | Retailers | 12 % | Retailers | 18 % | Retailers | 21 % | Retailers | 21 % |

Consumers in all four countries prefer eco labels administered by consumer or environmental organisations. Independent bodies have also strong support in Germany, Norway and Spain. The government have again a mush stronger position in Norway than in the other countries, and the European Commission has the strongest backing in Italy.

The consistent poorer results for retail than for producers, with lowest ranking for retailers and quite low percentages, is interesting. Could lack of familiarity with eco-labels backed by retailers explain part of these results?

Comparing the results for the two trust questions is not strictly possible, since different institutions and organisations are used. We still point out, with due caution, that environmental organisations (together with consumer organisations in the second question) do very well in both questions, and that respondents in all four countries seem to agree upon the relatively low percentages and low ranking for producers and retailers (or business and industry in the first question). For the European Commission and National government the results are less clear with the exception of the high ranking and percentage for national government in Norway and the same for the European Commission in Italy.

Consumers in Europe prefer that eco labelling schemes are scientifically based and are administrated by environmental and consumer organisation or by independent bodies. The independence of producers' and retailers' interests seems most important, but the independence of governments and European Commission is also a part of the picture in most countries.

## 5. Eco-labels more relevant for some product and product groups than for others?

Eco labels are a consumer information tool, and information is only one among several environmental policy instruments. Two other main instruments are legislation and regulation on the one hand, taxation and other economic instruments on the other. In the political climate in Europe, both legislation and taxation are problematic instruments among governments and business stakeholders. It is therefore easy to turn to information tools, and various forms of labels are introduced in the consumer market.

But environmental information will certainly be more relevant and effective for some environmental problems than for others. The large polluting problems in Europe, related to both water and air, have been addressed mainly by technology innovations, political regulation and economic instruments. Still, environmental information to consumers is important because a sustainable environmental development is dependent upon the behaviour of a large number of ordinary consumers.

As mentioned, we carried out case studies within three product categories: tissue paper (consumables), washing machines (durables), and tourist accommodations (services). Are eco-labels more relevant and effective for some products categories than for others?

This question can be addressed in two different ways. We can relate the question to the environmental impact of the products in a life cycle perspective, and we can look at the consumer attitudes and behaviour related to the product categories.

### *5.1 Tissue paper*

For tissue paper, like many other consumables, the main environmental impact is related to the production phase. The production of paper is substantially more important the use phase. This means that the crucial consumer decisions are taken in the shops, at the point of sale. Eco labels – and other environmental product information schemes – can be important instruments, and help consumers in their routinised decision process. For consumables, simple symbols are crucial. In the everyday shopping behaviour consumers ordinary don't use much time and resources to select one product instead of another. This is an argument in favour of classical eco labels.

But how do consumers themselves look at this question? Do they really search for environmental information when they buy tissue paper, and what kind of information do they prefer, table 5 and figure 1.?

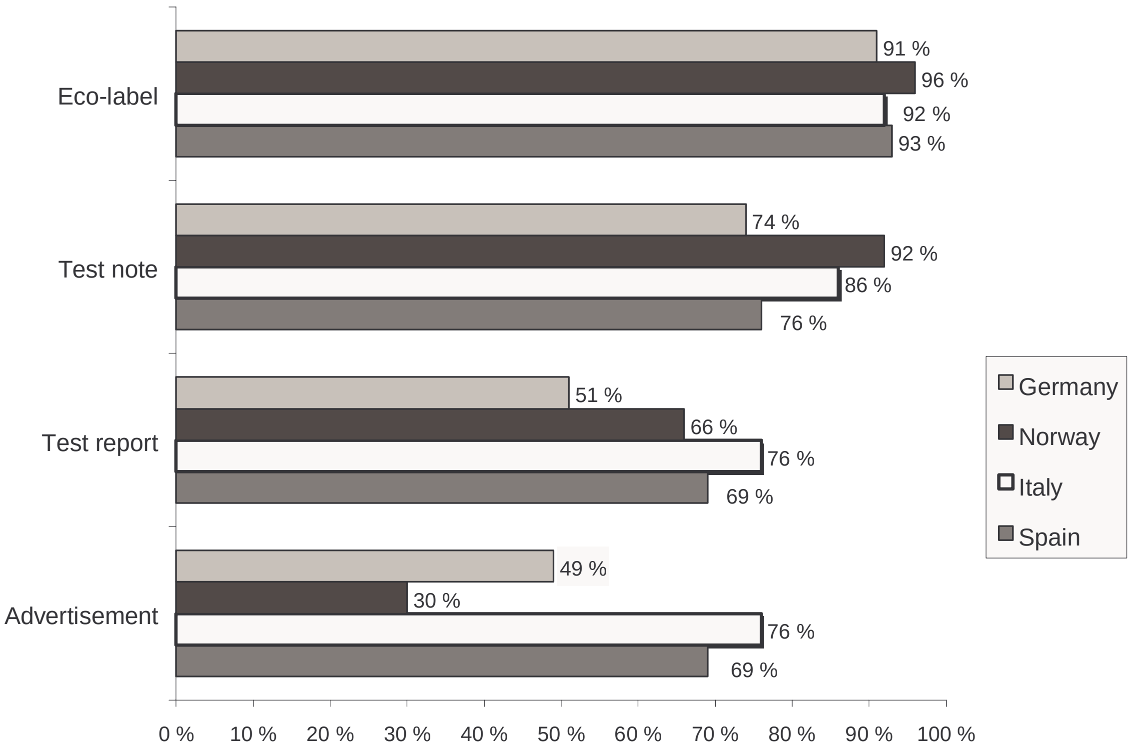
Table 5: How often do you look for environmental information when you buy tissue paper?

(Always, frequently and sometimes are shown. Only respondents who answered the question are included):

| | Germany | Norway | Italy | Spain |
|---|---|---|---|---|
| **Tissue paper** | 70% (N =993) | 72% (N=980) | 43% (N=932) | 37% (N=866) |

N denotes the number of respondents that the percentages are in relation to.

Figure 1: What forms of information concerning the environmental aspects of tissue paper would you like? In percent of those who searched.




Consumers in our four countries to a large degree search for environmental information when they buy tissue paper. This is specially the case in Germany and Norway. We also see that eco-labels are the preferred environmental information tool in all countries, but also test notes are a popular instruments. Consumers in Norway and Germany mostly do not look at advertising as an interesting environmental information channel.

This means that eco-labels have a strong potential to function as a successful instrument for consumables in our four countries. It is an easy decision to take for consumers, the products are found in most shops and the symbols are understandable and trusted among ordinary people. This potential has been realised in Norway and Germany, and also some positive tendencies are found in Italy. The market shares for eco-labels in Norway and Germany are relatively high, and the reason for this is also found is positive attitudes among the industry and retailers.

### Washing machines

Washing machines, like most durables, are more problematic than consumables because the main environmental impact is found in the use phase. The use phase, the washing process, is probably far more important than the production phase for washing machines, as far as energy is concerned. This means that the simple symbols, either in form of classical eco labels or in the form of the mandatory EU energy label have a limited effect on the environmental impact of the product. The labels might inform consumers about the environmental impact of the production phase, but the focus is on the use of energy and water and the washing effect of the machine. They do not, however, advise consumers on how to reduce the general environmental impact of the washing process.

To what degree do consumers search for environmental information when they buy washing machines, and what kind of information do they prefer, table 6 and figure 2?

Table 6: How often do you look for environmental information when you buy washing machines? (Always, frequently and sometimes are shown. Only respondents who answered the question are included)

| | **Germany** | **Norway** | **Italy** | **Spain** |
|---|---|---|---|---|
| **Washing machines** | 93% (N=1012) | 73% (N=928) | 75% (N=980) | 56% (N=933) |

N denotes the number of respondents that the percentages are in relation to.

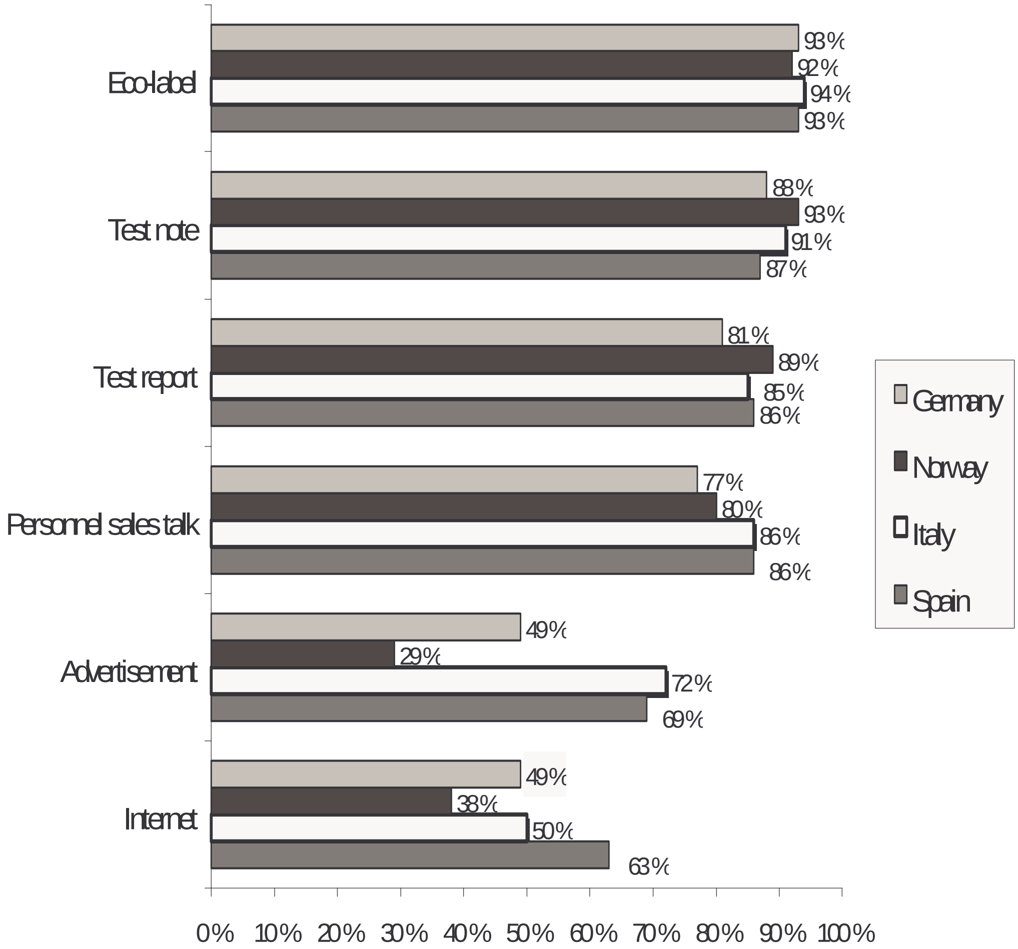



Figure 2

Consumers search for environmental information when they buy washing machines, but they spontaneously do not mention the mandatory energy labels when they were asked an open question about eco labels. Eco labels and test notes are the preferred environmental information tools, and consumers in Norway and Germany have negative attitudes towards advertising as far as environmental information are concerned. It is also worth noting that the internet – so far – is not recognised as an environmental information tool.

The mandatory energy label function as an environmental information tool at the point of sale, even though consumers don't mention it as an environmental label. In the selection phase, the choice of products is important. The main environmental impact is, however, linked to the use phase of the washing machine. If we want to reduce the environmental information of the washing process, we have to combine eco and energy labels with other environmental instruments.

## Tourist accommodation

The environmental aspects linked to tourist accommodation are multi-dimensional. Some of them are mainly related to the production phase, such as supply of organic food and eco-labelling products. Others are more related to the use phase, such as use of energy and water and linkages to public transport systems. The responsibility is also shared between the owner of the hotels and the user of the accommodation. For consumers the choice of accommodation is important and you can choose between labelled hotels and ordinary hotel accommodation. In the next phase the use of the accommodation is crucial. As we see it, tourist accommodation has more in common on with washing machines than tissue paper.

It this dualism reflected in consumer search for environmental information when they plan their holiday accommodation, and what kind of information do they prefer, table 7 and figure 3?

Table 7: How often do you look for environmental information when you buy holiday accommodation? (Always, frequently and sometimes are shown (Only respondents who answered the question are included)

| | **Germany** | **Norway** | **Italy** | **Spain** |
|---|---|---|---|---|
| **Holiday** Accommodation | 25% (N=852) | 14% (N=451) | 30% (N=552) | 42% (N=556) |

N denotes the number of respondents that the percentages are in relation to.

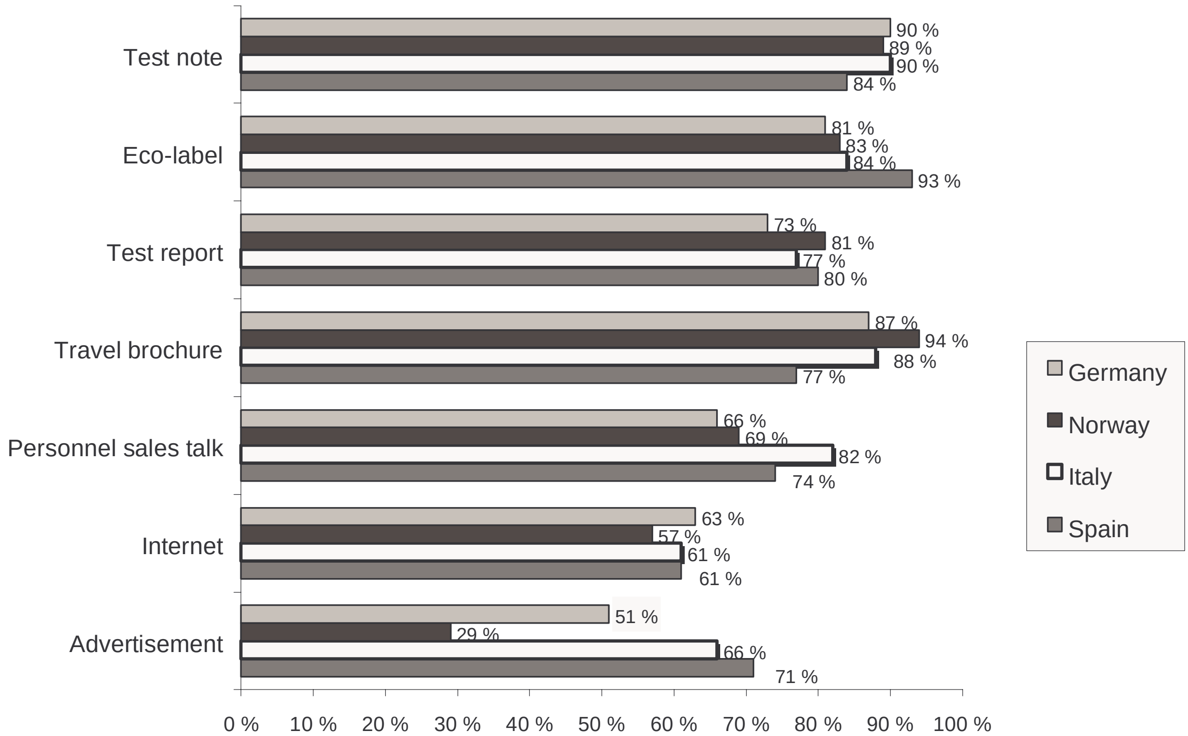



Figure 3

When consumers plan their holiday accommodation, environmental aspects play only a minor part in the planning process. This is specially the case in Norway where only 14% look for environmental information when they buy holiday accommodations. But also in the three other countries are the environmental searchers significantly fewer than for washing machines and tissue paper.

The reasons for these differences can be found along two dimensions. First of all holiday accommodation is multi-dimensional as far as environmental impact is concerned. The choice of tissue paper is a simple one; holidays and accommodation are more complicated. Secondly, washing machines and tissue paper belong to the ordinary routinised consumption while holidays is something spectacular for most people. There are other rules and goals in the everyday life than for holidays, in this is also the case for environmental questions? We probably do not want to emphasise the environmental problems of holidays.

Among consumers who look for environmental information related to holiday accommodation, the preferred information tools are the same as for washing machines and tissue paper. Eco labels and test notes are on top of the list in all four countries. However, they have strong competition from travel brochures. The reason for this is the fact that consumers are very much concerned about the adaption to a landscape; this is regarded as the primary environmental aspect of tourist accommodation among consumers in our four countries, - especially in Spain and Italy.

## 6. Advantages and limitation of various kinds of eco labels

As we have seen eco-labels are only one environmental instrument, better designed for consumables than for durables and services. But there are various kinds of eco labels, and the choice between different choices of schemes is also crucial. As described above we distinguish between:

Mandatory labels like the EU energy label (household appliances) and labels for chemical products on the one hand, and voluntary labels on the other. Among the jungle of voluntary labels we also distinguish between:

- ISO-type I eco labels, classical second- party labels like the EU-flower, the German Blue Angel and the Nordic White Swan.
- ISO-type II eco labels, self-classification by industry or retailers
- ISO-type III eco labels, quantitative environmental product declarations (EPD)
- Other relevant labels, including social labels and organic labels
- Other not relevant labels, including recycling symbols like the green dot

We will first discuss the relation between mandatory and voluntary labels, and continue with the relation between the voluntary types. At last we will briefly comment "other labels".

### *6.1 Mandatory labels*

Are there reasons to believe that mandatory labels are more suitable for some products or product groups than for others? The strengths of mandatory labels are obvious. Similar rules are applied within the large regions where the scheme is recognised, no discrimination and no technical barrier is allowed within the region. Mandatory labels seem to be very effective to deal with one factor (poison, biohazard, danger) or with one dimension (like energy). Within the European Union we have witnessed the success of the energy label on electrical household appliances and danger labels on chemical products

On the other hand, an international regime has to be established that defines standards that might not suit all member countries, due to different national cultures. Mandatory labels will have to insist on minimum standards, rather than best available technology. They will probably not stimulate innovation. Further, labels might function as a trade barrier to third party countries, and mandatory labels need some political legitimacy among government and businesses.

As we see it, mandatory labels should primarily be developed within sectors of high priority (like the danger warning), for “black products” that we would not like to label “eco-friendly” and for sectors where it is difficult to reach to any kind of voluntary agreements.

Generally, there are problems concerning the control regime of the energy label in Europe, where producers’ and retailers’ self-classification so far has been systematically biased.

The present political climate in Europe clearly gives preference to voluntary agreements

### 6.2 ISO-type I labels

The main advantage of ISO-type I labels probably is that they use simple symbols; it is easy to communicate the message to the consumers. In addition, they gain credence by being scientifically based and organised through a third party control regime. Type I-labels seem to work very well for consumables, providing information at the point of sales. Such labels will typically contain summed up information, where expert panels estimate the relative importance of various impacts (pollution, energy etc.), presenting the consumer with the result of a process, but with free public access to criteria. The average consumer just has to relate to the symbol. This simple presentation of rather complicated matters seem to have a potential for being met by high levels of trust from consumers.

Type-I-labels’ main shortcoming might be that they are national or regional, so far not a success on a European level. Further, they obviously work better for some types of products than for others, even with a number of national differences.

### 6.3 ISO-type II labels

ISO-type II labels really are a type of advertising. Main problems concerning such labels are that the message is often unclear, labels often one deal with just dimension (no chlorine...), they are at best semi-scientifically based, and they rely on self-classification. In the Nordic countries they tend to conflict with the Marketing Control Acts, prohibiting the use of phrases like “eco friendly” etc. Type II labels will generally have a problematic relation to questions of trust, and - related to that – to generally non-existent control regimes.

Potential environmental advantages of Type II-labels are first, that for the *least sophisticated* producers or retailers, a Type II-label might be a starting point for a positive change process, concentrating on doing at least something. This might for instance be very relevant for tourist accommodations in the Mediterranean. Second, for leading *environmental innovators*, such labels might highlight their best products, employing technology that is ahead of competitors and beyond the labelling bodies.

### *6.4 ISO-type III labels*

So-called ISO-type III labels provide numerical information, beyond the symbols. They are also known as Environmental Product Declarations (EPD). So far, they do not seem very relevant for consumers, who would be hard put to make sense of such quantitative data (how many tons of CO2 is it reasonable to emit during the production of a hundred tonnes of cement?). It has been described as an instrument mainly for business-to-business communication, but for small and medium enterprises the correct interpretation of the numerical sheets will probably be almost as difficult as for ordinary consumers.

Development of Type III labels is a promising step for business, but for consumers, as well as for small retailers and producers, the information will have to be translated. For Type I-labelling of bigger and more complex entities (like hotels, airlines and so on), EPDs will probably be perfect tools.

### *6.5 Other labels, some comments*

There is a jungle of labels out there: There are a large number of recycling labels, often without any developed organisation to handle the waste. There are organic food labels, social and ethical labels, all with some environmental interest. In addition, we meet country of origin labels, and locally based labels.

In this context they are probably most interesting as examples of the kind of "do-good-overload" that modern consumers have to deal with. Most stakeholders call for a simpler system, with a limited number of labels for consumers to relate to.

## 7. Concluding remarks and discussions

The German and Norwegian example shows that there is a huge potential for ISO-type I labelled consumables in Europe, given that the labelling bodies are able to build consumer knowledge and trust, and given that they establish some sort of cooperation with producers and retailers. Early in the project, we noticed that paint was a huge success in Germany, much in the same way as eco-labelled detergents were successful in Norway, while eco-labelled paint was no success at all in Norway (Rubik & Scholl ed., 2002). We believe that this is mainly explained by industry's different attitudes in the two cases.

For durables, like the washing machine, it seems as if the mandatory energy label has greatly reduced the relevance of traditional type I-labels, because energy use and water use cover most of the environmental impacts already. The labelling bodies could obviously distribute eco-labels (swans, angels or flowers) to the most energy efficient products (the double A's), but we have to presuppose that the consumer is able to read as much himself.

The lack of consumer interest in the environmental aspects of tourist accommodations among Norwegian consumers also shows a kind of limitation for labels: There has be some sort of consumer interest or general focus on the issue. The labels have to seen as dealing with matters that are important.

Which roles do consumers and consumption play on the ecological modernisation of Western societies? There are many answers to this question. The technological "optimists" will reduce the important of individual decisions because technological improvements and innovations are the main answer to the sustainable challenges, not individual behaviour. However, in the race between production and consumption, we can observe that the technological improvements in the productions phase are counteracted by an increased consumption. In spite of technical improvements within important sectors such as cars, household appliances, textiles and households chemicals, environmental impact of consumption in our societies keeps increasing.

The reason for this is the increasing importance of the use-phase of products. For most durables (like washing machines), the main environmental impact is linked to the energy consumption in the use phase of the products. Even for consumables the use phase is relevant for many products, because of the importance of the recycling phase (like copy and printing paper). Therefore consumers have a crucial strategic role to play in ecological modernisation. On the other hand, the responsibility for sustainable development cannot be placed on the consumers alone. This responsibility must be shared with all relevant stakeholders such as industry, retailers, governments and NGOs.

Individual choices matters. The goals for environmental and consumer policy can only be reached by well-informed consumers, and we have in this paper shown that eco-labels can be important tools in the business-to-consumer dialogue:

- In countries with long experiences with eco-labels, these labels are well known and trusted among consumers
- Even among consumers in countries with newly developed eco-labels the trust in these labels is reasonable high.
- Consumers in Europe will prefer eco-labelling schemes organised by independent bodies and consumer- or environmental organisations, and not schemes developed by retailers and industries. The confidence in national governments and the European Union is higher than the businesses, but significant lover than NGOs and independent bodies.
- Consumer prefer a wide range of information tools, including test reports and test notes, but eco-labels are regarded as an important tool for consumables, durables and services
- The eco-labelling criteria must be scientifically based. The trust in science is very high. On the other side the trust in advertisement is low, and this is especially the case for Norway compared with Germany, Italy and Spain

Our study has shown that eco-labels have been a substantial success in some countries, for some product groups. The challenges for the future are to expand these experiences: 1) from the successful product groups to other important groups, 2) from successful countries to other countries, and from the national to the European and global level. This can only be possible if we increase our understanding of the mechanisms behind the success stories and the failures in the European eco labelling process the last twenty years.

## *Appendix A: Spontaneous mention of eco-labels*

| | Germany | | Norway | | Italy | | Spain | |
|---|---|---|---|---|---|---|---|---|
| **Eco-labels** | No. | % | No. | % | No. | % | No. | % |
| EU Flower | 10 | 1 | 17 | 1,7 | 4 | 0,4 | 12 | 1,2 |
| Blue Angel | 578 | 56,6 | 2 | 0,2 | 2 | 0,2 | 4 | 0,4 |
| White Swan | 3 | 0,3 | 700 | 70 | 7 | 0,7 | 8 | 0,8 |
| AENOR | | | | | | | 27 | 2,7 |
| DGQC | | | | | | | 22 | 2,2 |
| Blue Flag | 7 | 0,7 | | | 2 | 0,2 | 39 | 3,9 |
| EU Energy Label | 19 | 1,9 | | | 6 | 0,6 | 8 | 0,8 |
| FSC – Forest Stewardship Council | 15 | 1,5 | | | 2 | 0,2 | | |
| Öko-Prüfzeichen | 31 | 3 | | | | | | |
| Debio Demeter | | | 47 | 4,7 | | | | |
| Legambiente | | | | | 5 | 0,5 | | |
| Grüner Punkt | 553 | 54,2 | 50 | 5 | | | 194 | 19,3 |
| Recycling Symbol | 70 | 6,9 | 199 | 19,9 | 14 | 1,4 | | |
| **Other environmental labels** | | | | | | | | |
| Öko Tex Standard 100 | 8 | 0,8 | | | | | | |
| TÜV Umweltsiegel | 22 | 2,2 | | | | | | |
| Naturtextil | 1 | 0,1 | | | | | | |
| Öko-test | 25 | 2,4 | | | | | | |
| **Other social labels** | | | | | | | | |
| Fair Trade Max Havelar | 4 | 0,4 | 6 | 0,6 | | | | |
| WWF – Panda | 15 | 1,5 | 48 | 4,8 | 13 | 1,3 | | |
| **No answers** | 151 | 14,8 | 212 | 21,2 | 892 | 89,2 | 719 | 71,6 |
| **Non-eco labels** | | | | | | | | |
| CE | 26 | 2,6 | | | 8 | 0,8 | | |
| Stiftung Warenstest | 47 | 4,6 | | | | | | |
| Godt Norsk | | | 35 | 3,5 | | | | |
| Gartner | | | 19 | 1,9 | | | | |

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# The interaction between environmental norms and behaviour: a panel study of organic food consumption

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## Abstract

This paper is based on the conviction that one can get a deeper understanding of the attitude-norm-behaviour relationship in the environmental field by analysing the dynamic interaction over time between relevant attitudinal variables and specific behaviours of interest. In this paper we present the results of such an analysis, based on a panel survey with a random sample of about 2400 Danes interviewed up to three times in the period 1998 to 2000, and focusing on buying organic food products.

## Summary and conclusions

It is an old discussion within social psychology whether attitudinal variables guide or, rather, result from behaviour. This study shows that there is truth in both claims and that one can get a deeper understanding of the attitude-behaviour relationship in the environmental field by analysing the dynamic interaction over time between relevant attitudinal variables (beliefs and norms in this case) and specific behaviours of interest. Here we have presented the results of such an analysis, based on a panel survey with a large random sample of Danish consumers interviewed up to three times in the period 1998 to 2000, and focusing on buying organic food products.

Confirmatory factor analysis reveals strong correlations between the general attitude, subjective (social) norms, and personal norms towards buying organic food. Of the three, the personal norm is the strongest predictor of behaviour. From this evidence it is inferred that the overall attitude is dominated by moral normative considerations, at least as far as its relationship with behaviour goes, and that the influence of the subjective (social) norm on behaviour is mediated through the personal norm (as suggested by Schwartz, 1977). Structural equation modelling of the cross-sectional relationship between attitudinal variables and behaviour shows that the former account for 80% of the variation in the latter and that approximately 90% of this effect is accounted for by the personal norm. The perceived costs (expensiveness) of organic foods have an additional effect in the expected direction. The influence of these determinants is greatly attenuated in a longitudinal analysis, when past behaviour is included in the analysis, and explained variance increases about 10%.

The attenuation of other parameter values shows that the stability in attitudinal variables to a substantial degree accounts for the behavioural stability, reflected by the parameter for past behaviour, as suggested by Ajzen (2002). However, the increase in explained variance indicates that other variables that account for stability in behaviour are missing from the analysis. Since the study focuses on everyday products that are typically purchased frequently and in stable surroundings, habit is an obvious candidate.

Based on research on how old habits can be broken and new habits form in the environmental field, it is suggested that breaking old habits depends on internalised self-transcendent values being activated and transformed into a specific personal norm for acting in a pro-social way in the situation and forming a new one on whether expected and experienced consequences of performing the behaviour are rewarding or punishing. Confirming these hypotheses, the panel analysis reveals that consumers' change their purchase pattern more towards organic food products the stronger personal norms they hold for buying organic and the less they perceive organic products as expensive. The panel analysis also finds significant cross-lagged paths from past behaviour to the belief and norm variables. Performing an environmentally friendly behaviour, such as buying organic food products, seems to reinforce personal norms about such behaviour. In addition, it seems to lead to favourable changes in beliefs about the costs of performing such behaviour. The latter means that the consumer's ambivalence about buying organic products is reduced by experience. Hence, it seems that environmentally responsible behaviour and supporting norms and beliefs interact dynamically in a way that – once set in motion – can result in a virtuous circle.

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The full paper is available from the authors.

## How to Link the Use of Consumer-Products and the Consumer-Exposure to Chemicals?

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### Abstract

Chemicals are ubiquitous in our life as they are the ingredients of most products we daily use. Therefore, consumers are constantly exposed to a broad spectrum of chemicals. Some of these chemicals might be irritants or might have other harmful effects to the human health which are in most cases dose-dependent.

Consumers are not necessarily aware of the presence of chemicals in consumer products. Therefore, the impact of different use patterns on their exposure to various chemicals might not be evident to them.

Few scientific studies have addressed this problem and exposure data are scarce. The authors therefore simulate on the basis of "*SceBRA*", a scenario-based risk assessment approach, various use patterns to calculate for a wide product spectrum the resulting exposure to synthetic fragrance substances. The product spectrum was selected from various personal care and cosmetic products as well as from cleaning agents and detergents.

The results of first calculations on the basis of *OECD*-equations clearly demonstrate the strong correlations between use behaviour and exposure. Therefore, establishing such exposure calculations might influence positively the consumers' use of products and contribute in this way to a more sustainable selection and application of personal care and cleansing products.

## Introduction

During the last decades thousands of chemicals have been used to improve the characteristics and efficiencies of manifold consumer products. Today, approximately 100'000 different chemicals are known to be in use in *OECD* countries, e.g. (Geiss et al., 1992). Although these chemicals have been constantly released (and are still being released) to the environment, little is known about most of their possible effects.

Instruments that are used to test the impacts of chemicals do not only have to rely on sufficient data bases on the chemicals themselves (physicochemical properties *etc*.), see *e.g*. (Ford et al., 2000), but also on data on the actual use amounts of the chemicals and the consumers' use of products which contain such chemicals. While the physicochemical properties are available for an increasing number of chemicals, only little is known about the consumer behaviour (Van Veen et al., 2001). These knowledge gaps might be explainable: studies investigating consumers and their behaviour are time-consuming and expensive; the consumers' behaviour is highly variable; reliable consumer statements are not easily attained; the consumers' privacy is another factor that hinders access to consumption data. Only in recent years attempts have been made to improve the unsatisfying knowledge situation, e.g. (Ford et al., 1999, Weegels, 1997, Weegels and Van Veen, 2001). Nevertheless, large knowledge gaps remain and improvement potential still is high.

In this study the polycyclic musk fragrances *AHTN* and *HHCB* are investigated and the consumer exposure to these substances is calculated. *AHTN* and *HHCB* are important ingredients in many consumer products like soaps, shampoos, perfumes and laundry detergents (Ford, 1998) and are released into the aquatic environment via the sewage after the use of such products. The two investigated synthetic musk fragrances are persistent and lipophilic (e.g. Rimkus, 1999) and therefore accumulate in sediments, sewage-sludge and in aquatic fauna (e.g. Eschke et al., 1994). In recent years they have been also found in human adipose tissue and in mothers' milk (e.g. Rimkus and Wolf, 1996). Some hints for liver tumor initializing effects exist from studies with rats (e.g. Steinberg et al., 1999). These findings caused a controversial discussion on the use of the polycyclic musks although no significant effects on the human health have been recognized so far (e.g. Ford, 1998).

The first goal of this study is to gather reliable information on the use of personal care and cleansing products (e.g. use frequencies, use amounts, use times) and on the products themselves (e.g. fraction of investigated materials in products, number of products containing these materials, properties of products). These data can be used to enhance and improve existing models for calculating the consumer exposure to *AHTN* and *HHCB*. The data have to be presented in a transparent and comprehensive way. Another goal is the development of a software tool that helps to estimate the consumer exposure to chemicals contained in personal care and cleansing products. Only a restricted set of data should be necessary to provide the input data required by the model (the used product spectrum, the fraction of the investigated substances in each product, use frequencies, use amounts, duration of use, consumer-related information).

## Consumer behaviour

While individuals use products in roughly the same way at different times, inter-individual changes in the product use are stronger (Weegels, 1997). On the basis of their former research, Weegels and Van Veen (2001) have demonstrated this high variability in inter-individual product application by investigating the use of dish-washing liquids, all purpose and toilet cleaning agents, and hair spray in households in the Netherlands. Other detailed data on the variability of the consumers' behaviour are scarce.

It is not easy to obtain reliable information on the use of single products. Often use amounts per capita are derived from data on the total consumption or even production amounts of product groups by dividing these amounts by the total population, see e.g. (Van de Plassche and Balk, 1997). Sometimes, even production amounts of products are not available – even not for the manufacturer associations (personal communication from B. Huber, IKW, 2002) – and assumptions have to be made by using annual sales figures for single products (Van de Plassche and Balk, 1997). The available data on the use of personal care or cleansing products is often presented as average use amounts, times, frequencies, and is often based on the information provided by manufacturers' associations, e.g. the American Cosmetic, Toiletry, and Fragrance Association (USEPA, 1997), or the International Association for Soaps, Detergents and Maintenance Products (Van de Plassche and Balk, 1997). Other data are only best estimates because scientific studies are missing that could provide useful information (USEPA, 1997) (EU, 1996). Many data sources come from the United States and therefore are not easily transferable to European countries (Ford, 1998). Nevertheless, European authorities use quite similar data in their risk assessments (EU, 1996).

In this study, an additional source is used to obtain data on the consumer behaviour in Europe. The "Typologie der Wünsche Intermedia" (*TdWI*), a market survey agency of the German Burda-Verlag, Offenburg, performs regular consumer surveys of the German market for personal care products. Approximately 20'000 German-speaking consumers are visited each year. These consumers are asked to describe their product use (*esp*. the use frequencies). To identify special products they may use photos that are shown to them. Consumers are also invited to fill in prepared use diaries to document their use behaviour in detail. The results of this study are available and can be analyzed "online" (TdWI, 2002). These data give a reliable impression of use frequencies for numerous personal care products which are investigated in this study. Additionally, the *TdWI* data contain the number of affected consumers for different age groups which might be very important to discriminate between age-related use patterns. In addition to the *TdWI* data, we also refer to a recent diploma thesis especially focusing on the consumer behaviour during the use of personal care and cleansing products in Switzerland (Gaukler, 2002).

## Calculations with SceBRA

A few exposure models exist that can be used to estimate the consumer exposure. Some models, e.g. *CONSEXPO* (Van Veen, 1996), are quite sophisticated. Nevertheless, these models often use standard values to simulate the consumer behaviour and therefore are not able to illustrate the highly variable behaviour of consumers. It is also important to state that the models do not predict how many consumers use products in a certain way (Van Veen, 2001).

Therefore, we have chosen to simulate the user behaviour using a scenario-based risk assessment approach (*SceBRA*) that was introduced to investigate the exposure during solvent application in Switzerland (Scheringer et al., 2001). This approach makes it possible to illustrate manifold use patterns that might be typical of individual consumers. It is possible to represent a broad spectrum of different behaviours and product compositions. Different consumer groups can be easily introduced by inserting e.g. new figures for body proportions or typical use frequencies related to certain age groups.

Daily exposure estimates (*Equations* 1a, b; Table 1) are calculated for a first case study of synthetic fragrance substances (the polycyclic musk fragrances *AHTN* and *HHCB*). We use an equation that was proposed by the *OECD* to calculate the annual dermal consumer exposure to chemicals in viscous or liquid products (OECD, 1993):

*Equation* 1a: $M_d=w_f*F*A_{skin}*D_{prod}*F_{prod}*a_{dil}$,

*Equation* 1b: $M_d=w_f*F*M_{prod}*a_{dil}$, where

$M_d$= the potential dermal exposure per day (mg/day); $w_f$= the weight fraction of the fragrance in a product (%); F= the use frequency per day ($day^{-1}$); $A_{skin}$= the area of affected skin ($cm^2$); $D_{prod}$= the density of the product ($mg/cm^3$); $F_{prod}$= the thickness of product film on the skin (cm); $a_{dil}$= the dilution factor of the used product ($g_{Prod}/g_{Water}$); $M_{prod}$=the average product amount per application (mg/application).

Different forms of *Equation* 1a can be used to validate the outcomes of the preliminary calculations: instead of product film, density and affected skin area we have used the actual use amounts of products to obtain comparable exposure data (1b). The results are also presented in Table 1 (in italics).

Total daily amounts that potentially could be in contact with the consumers' skin during the use of products are presented for the fragrance materials *AHTN* and *HHCB*. Some of the investigated products are used undiluted, but others are used in aquatic dilution under normal use conditions. In these cases, dilution factors were assumed, i.e. the product amount was compared to the used water amount. Those values were taken from literature sources (USEPA, 1997), (Ford, 1998), and are presented in Table 2 among other parameters appearing in the equations. Three types of products with different fragrance contents were assumed and classified as low, medium and high fragranced products. This differentiation was chosen because of the relatively variable contents found in literature and provided by industry.

Preliminary calculations with the *SceBRA* approach using average (and/or age-dependent) data sets for use frequencies, product amounts, product compositions, *etc*. clearly demonstrate the variability in the consumer exposure to *AHTN* and *HHCB* contained in personal care and cleansing products. The exposure depends on consumers' ages and sexes. Female consumers experience clearly higher exposures than comparable male consumers (with the exception of infantile consumers) (Table 1).

The parameters listed in Table 2 and other parameters used for the calculations are taken from various sources. Some should be named here: 1) for product composition (COLIPA, 2000), (Boeck, 2002), (Ford, 1998), (BACIS, 2001), (personal communication from Wella Switzerland, 2002); 2) for applied amounts (USEPA, 1997), (Ford, 1998), (Grieshammer et al., 1997), (Weegels and Van Veen, 2001); 3) for water amounts (USEPA, 1997); 4) for consumer related parameters (USEPA, 1997), Swiss

Statistical Authority; 5) for data on consumer behaviour (TdWI, 2002), (Gaukler, 2002), (Ford, 1998).

Table 1: Calculated dermal exposure (mg/day) per person to the polycyclic musk fragrances *AHTN* and *HHCB* for products with low, medium and high fragrance content. Ten consumer groups and a product spectrum of 21 personal care and cleansing products are assumed (regular font: (1a); italic font (1b)).

| **Consumer group** | **Md low** | | **Md medium** | | **Md high** | |
|---|---|---|---|---|---|---|
| **Infantile f** | 6.2 | 0.5 | 15.9 | 1.3 | 35.1 | 2.8 |
| **Infantile m** | 6.3 | 0.5 | 16.1 | 1.3 | 35.6 | 2.8 |
| **Juvenile f** | 27.5 | 3.0 | 77.7 | 7.5 | 162.9 | 14.0 |
| **Juvenile m** | 19.6 | 2.1 | 53.1 | 5.3 | 103.5 | 9.2 |
| **Twen f** | 29.0 | 2.7 | 83.5 | 6.8 | 171.4 | 12.5 |
| **Twen m** | 25.8 | 2.0 | 70.8 | 5.1 | 135.8 | 8.8 |
| **Adult f** | 29.4 | 3.1 | 84.5 | 7.7 | 175.0 | 14.3 |
| **Adult m** | 23.2 | 2.0 | 65.9 | 5.1 | 127.9 | 8.8 |
| **Aged f** | 27.5 | 2.6 | 80.5 | 6.6 | 168.4 | 12.3 |
| **Aged m** | 14.9 | 1.4 | 39.6 | 3.3 | 75.4 | 5.3 |
| **Average*:** | **24.6** | **2.3** | **69.5** | **5.9** | **140.1** | **10.6** |

*** Averages without Infantile consumers**

Female consumers experience maximum daily exposures to fragrance materials around 170mg beginning with juvenile age. The daily exposures for comparable male consumers are lower and more heterogeneous (between 75mg and 135mg).

If the average per capita exposures are extrapolated to the total population of the European Union (380 million, Table 3), the total annual use amount of the investigated fragrance materials is 3’412t for low and 9’635t for medium exposure. The current calculations slightly overestimate actual use amounts that have been estimated to be approximately 2’100t in 1995 (Van de Plassche and Balk, 1997) and seem to stabilize at this value (Brändli, 2002).

Table 2: Specifications on parameters used for preliminary calculations.

| | Fragrance Fraction [%] | Musk fraction [%] | Density [mg/cm3] | Dilution [gProd/gWater] | Applied Amount [g] |
|---|---|---|---|---|---|
| Hand soap 1 | 1 | 0.05 | 1020 | 0.002 | 1 |
| Hand soap 2 | 2 | 0.1 | 1020 | 0.002 | 1 |
| Hand soap 3 | 5 | 0.25 | 1020 | 0.002 | 1 |
| Liquid soap 1 | 1 | 0.05 | 1020 | 0.002 | 1 |
| Liquid soap 2 | 2 | 0.1 | 1020 | 0.002 | 1 |
| Shower gel 1 | 5 | 0.25 | 1020 | 0.00033 | 10 |
| Shower gel 2 | 6 | 0.3 | 1020 | 0.00033 | 10 |
| Shampoo 1 | 0.2 | 0.01 | 1100 | 0.01 | 10 |
| Shampoo 2 | 0.5 | 0.025 | 1100 | 0.01 | 10 |
| Shampoo 3 | 1 | 0.05 | 1100 | 0.01 | 10 |
| Conditioner 1 | 0.2 | 0.01 | 1000 | 0.01 | 14 |
| Conditioner 2 | 0.5 | 0.025 | 1000 | 0.01 | 14 |
| Conditioner 3 | 1 | 0.05 | 1000 | 0.01 | 14 |
| Hair gel 1 | 0.2 | 0.01 | 1100 | 1 | 3 |
| Hair gel 2 | 0.5 | 0.025 | 1100 | 1 | 3 |
| Hair gel 3 | 1 | 0.05 | 1100 | 1 | 3 |
| Hair foam 1 | 0.5 | 0.025 | 960 | 1 | 2 |
| Hair foam 2 | 1 | 0.05 | 960 | 1 | 2 |
| Hair spray 1 | 0.5 | 0.025 | 800 | 1 | 5 |
| Hair spray 2 | 1 | 0.05 | 800 | 1 | 5 |
| Hair spray 3 | 2 | 0.1 | 800 | 1 | 5 |
| Day creme 1 | 0.5 | 0.025 | 980 | 1 | 1 |
| Day creme 2 | 1 | 0.05 | 980 | 1 | 1 |
| Day creme 3 | 2 | 0.1 | 980 | 1 | 1 |
| Night creme 1 | 0.5 | 0.025 | 980 | 1 | 1 |
| Night creme 2 | 1 | 0.05 | 980 | 1 | 1 |
| Night creme 3 | 2 | 0.1 | 980 | 1 | 1 |
| Cleansing lotion 1 | 0.5 | 0.025 | 1400 | 1 | 3 |
| Cleansing lotion 2 | 1 | 0.05 | 1400 | 1 | 3 |
| Body lotion 1 | 0.5 | 0.025 | 1400 | 1 | 10 |
| Body lotion 2 | 2 | 0.1 | 1400 | 1 | 10 |
| Body lotion 3 | 5 | 0.25 | 1400 | 1 | 10 |
| Hand lotion 1 | 0.5 | 0.025 | 1400 | 1 | 0.5 |
| Hand lotion 2 | 2 | 0.1 | 1400 | 1 | 0.5 |
| Hand lotion 3 | 5 | 0.25 | 1400 | 1 | 0.5 |
| Antiperspirant 1 | 0.5 | 0.075 | 1400 | 1 | 3 |
| Antiperspirant 2 | 1 | 0.15 | 1400 | 1 | 3 |
| Perfume 1 | 5 | 0.75 | 1400 | 1 | 0.5 |
| Perfume 2 | 15 | 2.25 | 1400 | 1 | 0.5 |
| Perfume 3 | 30 | 4.5 | 1400 | 1 | 0.5 |
| Bathing oil 1 | 10 | 0.5 | 1400 | 0.01 | 18 |
| Detergent 1 | 0.1 | 0.005 | 1065 | 0.008 | 80 |
| Detergent 2 | 0.2 | 0.01 | 1065 | 0.008 | 80 |
| Detergent 3 | 0.3 | 0.015 | 1065 | 0.008 | 80 |
| Detergent 4 | 0.5 | 0.025 | 1065 | 0.008 | 80 |
| Detergent 5 | 1 | 0.05 | 1065 | 0.008 | 80 |
| Dishwasher 1 | 0.1 | 0.005 | 1300 | 0.001 | 5 |
| Dishwasher 2 | 0.2 | 0.01 | 1300 | 0.001 | 5 |
| Dishwasher 3 | 0.3 | 0.015 | 1300 | 0.001 | 5 |
| Dishwasher 4 | 0.5 | 0.025 | 1300 | 0.001 | 5 |
| Dishwasher 5 | 1 | 0.05 | 1300 | 0.001 | 5 |
| All purpose | 0.2 | 0.01 | 1040 | 0.003 | 30 |
| All purpose | 0.5 | 0.025 | 1040 | 0.003 | 30 |
| All purpose | 1.5 | 0.075 | 1040 | 0.003 | 30 |
| Toilet cleaner 1 | 0.2 | 0.01 | 1020 | 0.01 | 100 |
| Toilet cleaner 2 | 0.5 | 0.025 | 1020 | 0.01 | 100 |
| Floor cleaner 1 | 0.2 | 0.01 | 1020 | 0.01 | 100 |
| Floor cleaner 2 | 0.5 | 0.025 | 1020 | 0.01 | 100 |

Exposure calculated with the equation 1b is significantly lower than the preliminary results: a ten- to twelve-fold decrease of the exposure is observed. These significant differences may have several origins. The *OECD* approach can be seen as a worst-case scenario which estimates the product amount on the basis of three parameters: the product density, the product film and the affected skin area that is in contact to a product. Overestimations may take place if 1) the product density is incorrectly estimated (in this study some product densities are estimated which are probably too high), 2) the product film on the skin is too thick (the film in this study is assumed to be 0.1mm, probably this assumption is not valid for the whole affected skin), 3) the affected skin area is overestimated (in this study average skin area values are assumed and exact assumptions on total affected skin areas remain difficult). All these uncertain variables seem to demonstrate that the use of the applied product amount might deliver more stable and reliable data on the exposure. Calculated per capita exposures (1b) are extrapolated to the total population of the European Union and result in total use amounts of 324t for low, 823t for medium and 1'475t for high exposures (Table 3). These figures are clearly below reported total amounts of *AHTN* and *HHCB* annually used as fragrances in personal care and cleansing products in Europe.

Table 3: Average dermal exposure (mg/day) per person calculated for products with low, medium and high fragrance content using *Equations* 1a and 1b. Total annual amounts (t/y) are obtained by extrapolating to a total European population of 380 million.

| | **Md low** | **Md medium** | **Md high** |
|---|---|---|---|
| **Average Exposure in mg/day** | 24.6 | 69.5 | 140.1 |
| **Total Amount in t/y (density, film)** | 3412 | 9635 | 19426 |
| **Average Exposure in mg/day** | 2.3 | 5.9 | 10.6 |
| **Total Amount in t/y (product amount)** | 324 | 823 | 1475 |

## Conclusions and Outlook

The *SceBRA* approach is useful to illustrate the use of a broad spectrum of personal care and cleansing products and to calculate the resulting consumer exposure to fragrance materials that are used in these products. The results of first exposure calculations using a product spectrum of 21 personal care and cleansing products show that the resulting exposure is age- and sex-dependent and that female consumers experience higher daily dermal doses than comparable male consumers. This difference is even more evident if exposures are normalized to the body weights.

Therefore, the *SceBRA* approach seems to be appropriate to estimate the consumer exposure to chemicals used in products. Nevertheless, a lot of work has to be done before a useful tool can be presented that is applicable in the risk assessment of chemicals:

- The data used in the preliminary calculations have to be evaluated and confirmed;

- Reliable data bases have to be established for each parameter;

- Additional products have to be introduced (*e.g.* shaving products);

- Important approaches exist that can be used to estimate the consumer exposure to chemicals, which have not been investigated yet. The underlying equations have to be tested and results should be compared to *SceBRA* approach calculations;

- The variability of consumer behaviour has to be illustrated with higher resolution by applying the data sets provided by the *TdWI* study and similar data sources;

- The number of affected consumers has to be completely integrated into the calculations; it has to be combined with the number of simulated use scenarios;

- The time-dimension should be introduced and the use time as well as the retention of products on the skin should be used in the exposure calculations to reflect the actual exposure time;

- The uncertainty and parameter sensitivity of exposure calculations has to be determined.

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