

**Proceedings : Papers presented as Posters**

## **Sustainable Consumption and Production: Opportunities and Challenges**

### **Launch Conference of the Sustainable Consumption Research Exchange (SCORE!) Network**

Thursday 23 November to Saturday 25 November 2006

Wuppertal, Germany

Edited by: Martin Charter (The Centre for Sustainable Design) and  
Arnold Tukker (TNO)

[www.score-network.org](http://www.score-network.org)

Organised by The Centre for Sustainable Design, Farnham, UK, and  
TNO, Delft, Netherlands, with support of the UNEP-Wuppertal Institute  
Collaborative Centre on Sustainable Consumption and Production  
(CSCP) and endorsed by IHDP-IT

The conference is organized in support of the UN's Ten Year  
Framework of Programs on Sustainable Consumption and Production,  
back to back with an invite-only policy meeting on SCP organized by  
UNEP and the CSCP.



This file is prepared for double-sided printing.

Authors were provided a format and clear instructions for lay-out. Most authors followed these instructions very good, leading to a consistent presentation of most of the individual papers. Due to the large number of papers, the editors were unable to embark on the time consuming process of adjusting any lay-out errors in papers submitted. Papers had to be reproduced here in the lay-out in which they were submitted, and where authors did - or could - not follow our instructions this may have lead to slight inconsistencies in presentation.

Not all presentations made at the Conference are available as papers.

These proceedings are available via the website of the SCORE! Project:  
[www.score-network.org](http://www.score-network.org)

They can also be received (free of charge in electronic form) from:

Arnold Tukker (Arnold.Tukker@tno.nl)  
TNO Built Environment and Geosciences  
Delft, The Netherlands

December 2006

## Contents: Posters

Sustainable tourist consumption : A theoretical discussion on opportunities for change	Budeanu	5
Strategy and actions to actualize sustainable mobility projects in urban contexts : MULO system - Solar and human power for urban work vehicles	Ceschin	21
An international multi-lateral didactic activity for the development of furniture systems	Chaves	35
Socio-economic drivers of (non-) sustainable food consumption : An Analysis for Austria	Friedl, Omann & Pack	45
Prioritizing sustainable consumption patterns : Key decisions, key actors and potential improvements of the environmental balance	Kaenzig & Jolliet	65
Organizational and institutional innovation in companies for resource productivity	Kristof, Türk, Walliczek & Welfens	77
How to investigate and how to reduce the natural resource consumption caused by private households?	Lähteenoja, Lettenmeier & Moisio	83
How to Achieve Factor X Improvements in Transport? - Lessons learned from the FIN-MIPS Transport project	Lettenmeier, Lahteenoja & Saari	99
Teaching and Implementation Models for Sustainable PSS Development : Motivations, Activities and Experiences	McAloone	125
Environmental Impacts and Household Characteristics : An Econometric Analysis of Norway 1999-2001	Peters, Aasness, Holck-Steen & Hertwich	137

Analysis of Models for Solutions in Service/Product Engineering	Sakao, Maussang, Brissaud & Zwolinski	151
Credible sustainability reports : An empirical investigation on the interaction between sender and communication style: the case study of tegut	Stockebrand & Spiller	169
Coffee Provider System : Development and analysis of a product service system	Tanure, Bosse & dos Santos	179
Are sustainable electricity production and use possible? The Hungarian case	Vadovics & Kiss	189

# POSTER Sustainable tourist consumption

*A theoretical discussion on opportunities for change*

Adriana Budeanu<sup>a</sup>

<sup>a</sup>*IIIEE, Lund University, Sweden, adriana.budeanu@iiiee.lu.se*

## **1 Introduction**

Tourism is the largest migration in the history of humankind, performed yearly by almost 8% of world's population. Desired worldwide for its potential to generate income and economic growth, tourism is expanding fast and predicted to double in the next 15 years. (WTO, 2003) Vast and complex consequences of this large movement of people brought the necessity for adopting sustainability principles in all tourism developments and endeavors, in an integrated manner that will secure the long-term existence of tourism as an industry. The responsibility for preventing and reducing the negative impacts falls primarily into the hands of destinations and industry providers. Although a direct responsibility for reducing negative impacts falls on destination authorities or industry (Forsyth, 1996) one important source of impacts– the tourist – is hardly mentioned.

In pursuit of sustainability goals, governmental policies and business strategies are currently refined to include a sustainable focus by mitigating negative effects while keeping or enhancing tourism benefits. Integrated solutions are sought that stimulate tourism as part of regional development, investigating innovative opportunities with synergetic socio-economic benefits for tourists and hosting communities. Also tourist provision has greatly improved in terms of resource consumption and waste management of facilities (e.g. eco-efficient accommodations) and optimized transportation (e.g. tourism mobility networks). These initiatives however, are focused very much on the supply side of tourism, while in the demand side concerns for sustainability are rather low and superfluous. Despite time and financial investments, the results in actual reduction of negative impacts are still slow and disappointing. Tourist demand and its quality, an aspect somewhat overlooked by sustainable tourism research, might hold explanations to this situation.

Compared to corporate and governmental efforts, tourists are much less interested to adopt sustainable lifestyles or support responsible tourism products. Tools and strategies are designed to steer tourists' behaviour towards responsible tourism, such as awards, eco-labels and certification schemes, communication and awareness campaigns, educational programs. However, tourist response is still very low and fails to fulfil industry

sustainability goals and expectations. Despite their declared positive attitudes towards sustainable tourism, only 1 in 20 tourists act upon them and buy responsible tourism packages, choose environmentally friendly transportation or buy local produce. In order to be successful in reducing negative impacts and get a good return on their environmental and social investments, industry and destinations need a better match of their efforts with tourist decision-making and environmental mind setting. Seeing the gap between efforts to engage tourists and their low response as a result of incomplete understanding of tourist environmental behaviour, its intrinsic and dynamic determinants, this paper aims to identify missing aspects from current research and pinpoint to possible gaps in policy and research.

## 2 Tourism impacts and the relevance of consumers

Tourists' actions and behaviour are a major source of negative impacts. Their demand for leisure determines the pressure and speed of "consuming" destinations. (Urry, 1990) Their behaviour towards local culture, traditions and social organizations can lead to irritation and antagonism of host community. (Holloway, 1998) Tourist consumption resources and services can easily offset efficiency improvements (the rebound effect). In hotels for example, installing water efficient equipment (e.g. showers, toilets) can in fact result in an increase of water consumption, if unaware tourists increase the showing time. Tourist expenditure is important for generating local income; however if products purchased are luxurious imported items, the much-desired income leaks out to other regions or even countries. (Butler, 1998) Industry efforts and investments need tourists to 'vote with their wallets' for these initiatives, else the costs of environmental improvements become unbearable. Overall, tourist actions have an important role in tourism impacts positive and negative, which is yet not clear.

Convincing tourists to participate in reducing negative impacts of tourism, it is necessary to have a better understanding of how impacts occur and how can individuals make a difference by behaving responsibly. (Jones, Walker, & Bedford, 2004) While many assessments evaluate the negative impacts of specific activities e.g. transportation or in particular settings e.g. hotel and provision efficiency options, little is done to evaluate it in relation to how the tourists contribute to it or how it can this be corrected.

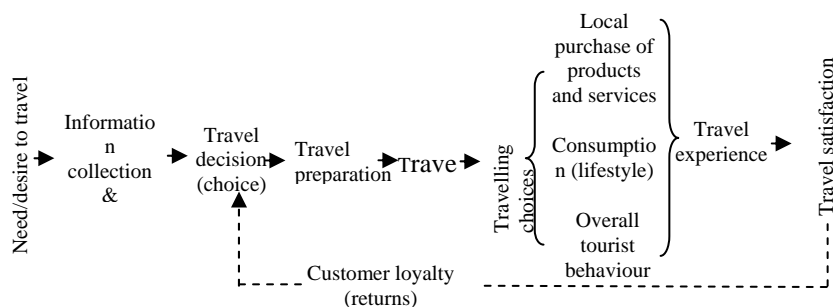


Figure 1: The holidaying process illustrating main tourist choices

Taking a life-cycle perspective on holiday processes this paper discusses different types of tourism impacts – as described by secondary sources – as a background for examining opportunities to induce sustainable tourist actions.

## 2.1 Selecting basic elements of a holiday package

Selecting a holiday package implies almost simultaneous choices of its basic elements: location (destination), transport and accommodation.

**Destinations** are chosen in accordance to people's motivations to travel, for their *climate and landscape*. The main movement of tourists is from the North to South, from cold to warm climate, with high concentrations of tourist in southern countries like Spain, France, Greece. Together with the country, specific preferences for *leisure opportunities* (culture, nature, history, adventure, etc) refine the main choice to a particular location. Though desired for the potential economic benefits, popular tourist destinations are easily in danger of becoming crowded and suffer from congestion, aesthetic pollution and litter, shortage of resources and waste overcapacity, low quality of water and air. Overcrowded destinations quickly lose their appeal as tourist attractions, and if corrective measures are not taken, they slowly decay.

One way of avoiding damaging destinations is by re-distributing tourist flows according to the carrying capacity of destinations. In order to do so, customers need to find available and affordable holidays that offer the same quality for money, but with lower environmental and social cost for destinations. The few existent alternatives (e.g. eco-tourism destinations) target a specific demand (and motivation to travel), and are no substitutes for the large flows of mass tourists. For example, Nordic tourists are known to have a heavy preference for Southern destinations that involves flying. Alternatives that generate less environmental impact are those close to home; however they would have to be extremely appealing to tourists in order to compensate for the sunny weather and warm climate (the main reason for them to travel). In order to offer such alternatives industry must re-invent the concept of holidays with sustainable tourism as a core design parameter, secure customer satisfaction and cost/value ratio, and match people motivation to travel, else have a good chance of being disregarded.

**Transport to and from destinations** is a consequence of choosing the holiday location. European tourism is predominantly domestic (62%) within EU15 borders, with a clear flow from North to South, and about 15% of total tourism is intercontinental. Most tourist transportation in the EU-plus<sup>1</sup> area is done by car (68%) and only about 39% is done by air with rail, coach or ferry holding a much lower share. (European Commission, 2004) however, air transport is the highest of all sources of climate change pollutants (CO<sub>2</sub>-equivalents) being responsible for 72% of total tourism emissions in the EU-plus. Predicted shifts of households' tourism patterns from one long holiday a year, to 4-5 shorter and multiple breaks, indicate that while overnight stays might have a steady increase, tourist travel (now accounting for 17% of each transportation mode: land, air, water) is likely to grow exponentially. In order to reduce impacts, modal shifts of air and car transportation to rail and public infrastructure are much needed. Despite their somewhat better

<sup>1</sup> EU-plus countries include all EU member states (post May 2004) plus Norway, Switzerland, Bulgaria and Romania.

environmental performance, coaches are not preferable alternatives due to their social and economic impacts. (European Commission, 2004)

*Air transport* to and from the destination, through its contribution to the global warming effect, is the most significant environmental impact of tourism today. However, it is also one of the unavoidable impacts sometimes, in the case of *long-haul destinations*, when due to time limitations specific landscape (in intercontinental travels) there is no acceptable alternative to flying. When it is not possible to replace flying with another transport mode, offsetting mechanisms can be used to compensate for the environmental impact created. For *short-haul destinations* tourists can find alternative to air or car transportation, by boat, train or coach. However, these alternatives are time consuming and people might not be happy to sacrifice 1-3 days of their 7 days holiday only for travelling. Unless serious compensations are available, a shift from quick flying to a time-consuming transportation is unlikely to happen.

Carbon offsetting mechanisms:  
<http://www.carbonneutral.com/>  
<https://www.cooldriving.nl/index.php>  
<https://www.coolflying.nl/index.php>

*Car transport* is probably most convenient mode for tourism allowing independent travelling and the comfort of bringing along personal items that enhance holiday satisfaction e.g. own camping equipment, baby carriage or children's preferred toys. Despite their environmental benefits, other transport modes have their advantages and disadvantages, and sometimes priorities of convenience and environmental performance are divergent and conflicting. (European Commission, 2004) In order to be successfully adopted by tourists, alternatives to private transportation have to offer similar flexibility (in terms of routes, volume of luggage) and eventual compensation for the lost comfort.

The use of *accommodation* services is a source of negative impacts through resource consumption (water, energy) and waste generation (waste water and solid waste). Occupancy rates in European countries indicate that many popular tourist areas are already or close to being overcrowded (Schmidt, 2002) and present environmental risks, for humans and nature. This calls for actions in both sides, to improve the performance of tourism facilities and to enhance customer's responsibility in consuming energy, water or generate waste.

Due to industry awareness and responsibility, there are already alternative accommodations with high environmental performance, using eco-efficient equipments for saving water and energy, recycling water or heating agents, automatic devices controlling air-conditioning and heating, etc. Their performance is signalled to customers through eco-labels, environmental or social awards, etc. However, due to the large numbers of eco-labels in Europe (over 70 eco-labels only in tourism in 2002) customer reaction to eco-labeled products has gone down in the past years. (Leire et al., 2004) Similar to transport, accommodation represents over 30% of the holiday budget (Budeanu, 2004) and its choice is done with careful and rational



evaluation of the value obtained for money. While financial resources are limiting the variety of choices, the final decision is made based on quality.

## 2.2 Individual tourist consumption (lifestyle)

Closely related to the quality and efficiency of tourist supply, individual consumption (e.g. food, water, energy, etc) is important with respect to the possibility of creating rebound effects.

### 2.2.1 Water consumption

Average water consumption per tourist per day vary from 240 liters / tourist / night to 440 liters / tourist / night, up to 800 liters / night in the case of luxury tourists (including water needed for watering gardens, swimming pool, sauna, golf court, etc). Depending on the location and type of accommodation, water consumption per tourist/night varies significantly.

Table 1: Water consumption per tourist / night (CREM, 2000, p. 36)

Accommodation	Denmark	The Netherlands	Finland	UK
Hotel/boarding house	400-500	260	200-300	n.a.
Holiday center/holiday homes	100-200	168	n.a.	n.a.
Camping and caravanning sites	60-80	200	n.a.	n.a.
Youth hostels (groups)	n.a.	200	n.a.	93

### 2.2.2 Energy consumption

Energy for heating, ventilation and air conditioning accounts for almost 50% of all energy consumption in hotels. Catering accounts for 25% and sanitary hot water for 13%, lighting for 7% and other sources (sauna, swimming pool, cooking and refrigeration, fuel for vehicles) for another 7%. (CREM, 2000, p. 38) The average consumption of energy varies with the season and the more sophisticated the tourist facility is the more energy consumes, as shown in the Dutch case. (CREM, 2000, p. 39)

### 2.2.3 Waste generation

Solid waste sourced by tourist establishments is a major problem in the Mediterranean region, amounting to almost 3 millions tones per year and expected to increase up to 12 million tones by 2025. (Stanners, 1995) Certainly such problem cannot be solved by tourists alone, but they certainly have an important role to play. According to Dutch research, the waste generated by tourist does not differ much between different types of accommodations, being 1.2 kilo/person/overnight in hotel, boarding house, holiday dwellings, and tourist campsites. (CREM, 2000, p. 41) In Denmark, tourist waste is on average 2-2.5 kilos/overnight stay, in Finland, the average is 0.5-1.0 kilos/overnight and in Austria is 1 kilo.

Individual consumption during holiday time replicates to a large extent the daily *consumption lifestyle* at home. Certainly allowing for a more indulgent attitude, holidays perpetuate people's habits in terms of their basic needs of showering, eating, lighting, heating/cooling, etc. Being easy for individuals to perform, *habits and routines* are hard to break and require strong motivation, conveniences and eventual compensation. Suggestions to limit individual consumption for the sake of environmental protection can be easily misunderstood by people as a reduction of comfort for which

they pay. However, if clear and straight explanations are provided, about why and what individuals can do to reduce negative impacts of their consumption, tourists can be persuaded. A good example is the “save water by reusing towels” message often found in hotels nowadays. Proved to be quite successful in attracting tourist attention to environmental matters, this example also illustrates that altering tourist habits require often repetition and explanation.

## 2.3 Purchases of tourism products and services at the destination

In addition to basic products bought as a package at the beginning of the trip, tourists make additional purchases of transportation, entertainment and goods in the destination. Their choice of products and services is optional and extremely various.

### 2.3.1 *Local choice of transport*

Two types of transportation are mostly used by tourists in destinations: the rental car or public transport. The previous section discussed briefly the impacts of car transportation as air pollution, congestion, noise, etc. Two types of alternative transport is currently offered to tourists in destinations: substitutes to private car use e.g. public transport, green alternatives, bicycling, etc., and integrated options where transport and entertainment are packaged and offered together. Australian examples show a great potential for reducing impacts by encouraging alternative transport, showing that such initiatives can yield as much as 7% reduction in car use, with a resulting increase of 11% in walking, 13% in public transport and 67% in bicycling. (Socialdata Australia, 2003) Similar entrepreneurial initiatives are found in Europe, as car-free destinations (Switzerland), new mobility systems (Austria), rail packages (Germany) or integrated coach alternatives (by Eurolines). However these are only small-scale initiatives that have yet to reach the mass market.

Such initiatives are still rare and heavily dependant on the availability of infrastructures and entrepreneurial capacity of tourism businesses. In order for tourists to choose alternative transportations (e.g. bikes, public transport) it must be convenient and made available. Habitual use of personal cars at home, for convenience (large family), comfort or status-statement, continue during holidays when tourists rent individual cars to perpetuate these routines or make status statements. Those used with public transport – such as average income or retired customers – are inclined to follow that habit during holidays too. Tourist choice of local transport in destinations is very much a matter of lifestyles and convenience.

### 2.3.2 *Choice of entertainment*

Activities that tourists take to enjoy their holidays are also relevant from an environmental perspective. Watching biodiversity may create severe disturbances for their behaviour, such as the case of the Loggerhead turtle that has lost breeding and nesting territory due to tourist disturbances in Zakynthos Island, Greece. (Poland, 2000) Similarly, overcrowding spaces with high sensitivity lead s to loss of fauna and flora that is sometimes

irreversible. The high degradation of Alpine ecosystems due to intense skiing activities is such an example, with voiced concerns about its possibility to recover. Even dispersed entertainment activities are significant with respect to their energy use. (Becken, 2001) Significantly enough, the exotic and more exciting activities are the most energy intensive.

Activity type (excluding transport)	Energy use MJ / tourist
Heli-skiing	1300
Diving	800
Scenic flights	340
Boat cruises	165
Sailing (motor)	140
Guided walks	110
Adventure activities	57
Rafting	36
Experience centers	29
Zoos	16
Museums	10
Visitor centers	7

Table 2: Energy consumption of leisure activities (Becken, 2001)

From a sustainable tourism perspective, entertainment activities with the lowest energy consumption are desirable e.g. visiting museums, zoos or experience centers. However, tourists are more attracted by the less environmentally friendly ones, due to

their popularity and exotism e.g. scenic flights, sailing (motor) diving. (Becken, 2001) For tourists to choose entertainment which is environmentally and socially friendly, it must match their motivation (e.g. excitement, sense of adventure, etc) else it is likely to be disregarded. Although the location of such attractions might not always be the best or with less comfort, tourists may be attracted by the authenticity and novelty of such entertainment activities. Examples of such activities are the “make it yourself” tours organized in the Greek islands for tourists that get to know the local culinary customs, traditional way of preparing foods e.g. olives, home-made jams, cheese and liquor, supporting local economies while enhancing tourist experience.

### 2.3.3 *Shopping*

Tourist expenditure has an important contribution to local economy of destinations. Not only products e.g. food, souvenirs, fashion products, but also services account for tourist expenditure e.g. hairdressers, medical services, etc. Despite the wishful thinking, the income generated often leaks out from the region due to imports (e.g. luxurious products such as Kodak, film, Pepsi, cosmetics, must be brought from outside the region) or due to foreign ownership of providing businesses. In destination Phuket (Thailand) around 90% of the diving companies are foreign. (Budeanu, 2004) Accounts of leakages can go up to 70 % of tourism revenues in Thailand, 80% in the Caribbean and 40% in India. (UNEP, 2001) The average import related leakage is estimated at 40-50% for small economies and 10-20% for advanced economies like Sweden. Another important impact of tourist purchase is its subject, which can involve endangered biodiversity species, or offensive services (e.g. prostitution). Open prohibition of such practices in many destinations have a strong rival in the human desire for uniqueness, a hidden enemy difficult to combat.

Tourist purchases are very hard to monitor and change because they are individual acts happening in random settings. The only way for tourists to choose to buy local products, and eventually from Fair Trade sources, is by

their own decision to do so. However, the influence of human habits is again prevailing. Due to the routinised decision making process behind it, habits simplify it, making daily life easier and quicker for people. Illustrative is the fact that the time taken by customers to analyse an eco-labeled products in the supermarket, is equivalent to the actual purchase of about 8 to 10 usual habitual products. Under stress and time limitation, habits can be a real barrier for changing to more sustainable behaviour. By contrast with habits, preferences are more flexible, being under easy influence of external factors such as advertising, fashion, status statements, etc. Previous experiences and personal encounters of family and friends are strong determinants for these choices, as well as personal moral values which can be stimulated to steer shoppers away from illegal or immoral products or services.

## 2.4 Overall tourist behavior

Behaviors that tourists display during their holidays have important consequences on the well-being of the local community. Differences in culture, status, economy, religions between guests and hosts can cause clashes and tensions, ending with social disruptions in local community and antagonizing atmosphere towards tourism. Disregards for local social and religious values sometimes lead to violent encounters and an increase in tourist crime.

Although not excusable, the careless attitude of tourists towards local's social priorities, accounts mostly for their ignorance of cultural differences, rather than on their conscious malevolence, and can be improved by awareness creation. Proper information can – without being patronizing – explain what and why differences are important to respect, correcting the belief that during holidays tourists can behave inappropriately, consume excessively resources and be disrespectful to the destination and its inhabitants. Successful campaigns organized by UNESCO, UNICEF and UNEP showed that having tourists understand their role and position as guests in another country, region or homeland is very important. Probably the most successful social campaign in tourism is ECPAT<sup>2</sup>, aimed to reduce commercial child abuse, which is supported by a large number of destinations, hotel chains and tour operators. Their successes demonstrate that tourist behaviour can be changed by appealing to moral values, either as individuals or as a community (through group pressure).

## 3 Intervention points for reducing tourist impacts

Two important points can be concluded from the previous discussion of impacts from tourist consumption. First, is the fact that the multitude of choices made by tourists during their holidays fall into four categories, each determined by different personal reasons. Attempts to replace them with more responsible acts would have to apply similar reasons in order to work else they are likely to fail. At the moment, arguments proposing alternative

<sup>2</sup> The ECPAT acronym stands for ' End Child Prostitution, Child Pornography and Trafficking of Children for Sexual Purposes' <http://www.ecpat.net/eng/index.asp>

choices to tourists reside only in the realm of environmentally and socially responsible attitudes, leaving out significant tourist arguments.

Table 3: Determinants of tourism consumption and alternatives

<b>Tourist decisions</b>	<b>Tourist consumption acts</b>	<b>Determinants of tourist acts</b>	<b>Sustainable alternatives</b>	<b>Arguments for sustainable acts</b>
Choice of package basic elements	Holiday location	Motivation to travel, local attractions	Destinations closer to home, able to handle tourist numbers, eco-tourism destinations	Low environmental and social impacts, close to nature
	Transportation to and from destination	Time available, comfort	Rail or public transportation	Low environmental impacts
	Accommodation	Service quality, financial resources	Eco-labeled accommodations	Low environmental impacts
Individual tourist consumption	Showering, indoor climate	Daily routine activities and lifestyle	Perform daily routines with care for the excess;	Low environmental impacts
Purchases of tourism products & services at the destination	Transportation	Convenience, status statement	Use local transport, car pooling, biking	Low environmental impacts
	Entertainment	Desire for entertainment, temptation of the exotic	Making local traditions into new tourism products, Virtual replacements of damaging activities	Knowing local culture, support for local economy, low environmental impact
	Purchasing	Basic needs (food), luxury needs, temptation of the exotic	Buy local products and services, buy Fair Trade products, avoid products of endangered species	Support for local economy, low environmental impact
Overall tourist behaviour	Attitudes in interaction with locals	Cultural differences, ignorance	Respectful attitudes	Moral values

The fact that arguments proposing sustainable alternatives do not “speak the same language” as tourists understand is a great barrier for such options being accepted or adopted. In propositions of sustainable alternatives of tourism products and services, environmental and tourist arguments must match to make sustainable tourist consumption possible.

Recreation behaviour results from evaluating which activities are most likely to produce the combination or balance of satisfactions that individuals seek at different stages in life. (Murphy, Niepoth, Jamieson, & Williams, 1991, p. 207) The motivation to travel is the most important determinant for choosing holidays (Lohmann, 2004; Middleton & Hawkins, 2002, p. 55) and has to fulfill peoples’ needs for relaxation, a break from work or pleasure. Similarly important is the ability to travel, determined by available resources that can be employed to satisfy the need to travel. After evaluating these two, a positive decision to travel is followed by a second round of specific decisions of destination, location, traveling options. Smaller decisions are made mostly based on individual personal preferences and perceptions of how the needs will be satisfied by the product availability and quality (evaluated as value for money). Once at the destination quick decisions are made constantly on how to spend the holiday time depending on tourist’s lifestyles and preferences. A factor that retrospectively influences tourist

decisions, are previous experiences, which constantly reshape personal preferences. (European Commission, 2004, p.91)

Overall, external factors influence tourist demand, being related to macro scale developments of economy (e.g. employment, exchange rates), politics (EU enlargement, taxation, environment), threats (terrorism, epidemics), demographic changes (ageing population, migration, education levels), technology (transport, communication, information), travel stimuli (advertising, traveling literature, etc), availability of offers (attractions, costs/value). Other external influences are changes in individual attitudes and ideologies, industry changes (influencing standardization of products, etc), rapidly changing preferences, quality expectations, booking behavior, etc. (Lohmann, 2004)

There is still a great deal of confusion with respect to what makes tourists change their minds. Tourism literature shows that environmental behaviour is multi-factor dependant on attitudes, preferences, motivations, background, experiences, information, etc. Furthermore, there is a distinction between determinants of tourist acts and those influencing environmental acts. Often used synonymous, there are indications that they are not equivalent. As sustainable consumption research indicate, habits, institutional contexts and convenience also determine customer acts (Mont, 2004; Shove & Warde, 2002) and have hindering potential for environmental behaviour.

Tourist environmental acts are the result of a complex combination of factors, grouped roughly in three categories: individual environmental beliefs and values, traveling patterns (habits) or preferences and their capacity to access different options offered by the market (available resources). When environmental attitudes are predominant, tourists show higher willingness to listen and accept suggestions that help them reduce negative impacts during their holiday. When tourist preferences prevail, tourists are likely to disregard information and suggestions for actions that interfere with their demands for comfort, relaxation, entertainment, etc. Demands for reduction of resource consumption (water, energy) or avoiding activities with high entertainment value because of negative impacts are mostly to be ignored in the latter case.

Individual's decisions to perform an act with positive environmental effects, is more influenced by internal barriers if it regards a short-term action, while long-term improvements are much more under the influence of external conditions. Frequently, environmentally friendly alternative tourist services, incur higher costs for the tourist in financial terms, in loss of comfort or convenience and in time. For example replacing flying with land transport clearly requires longer time spent on the road, associated discomfort and possible inconveniences in terms of accessibility to the service or additional logistics. In order to choose such alternatives, tourists must have sufficient motivation from personal values or externally stimulated motivations through financial or moral compensation (being convinced that they "do the right thing for a greater good"). Research on Swiss food purchasing behaviors reveals that contextual aspects of availability and convenience are much stronger than internal knowledge and

motivations, in preventing people from buying environmentally friendly food. (Tanner, Kaiser, & Wölfling Kast, 2004) Emphasizing social norms that support such choices (public opinions and campaigns, peer's valuation of responsible choices, etc) can activate individual beliefs and attitudes and determine responsible choices.

However such alternatives will only be considered when tourists have available resources to allocate. For a sustainable development, tourism needs a broad middle class of tourists, with time and money to travel. (Lohmann, 2004) While attitudes as values can shift tourist choices to responsible alternative holiday products, the resources are limiting factors unless properly compensated for. Furthermore, in order to be chosen, responsible holiday services must deliver good quality and the same entertainment as conventional holidays.

A good understanding of all three characteristic parameters is necessary for building successful propositions of sustainable tourism products that match tourists' willingness to listen and act in an environmentally responsible way. The low level of active support from tourists to sustainable tourism indicates that a good understanding of barriers that prevent tourists from behaving responsibly is still missing.

Another important point to make is the fact that arguments proposing sustainable tourism must be of the same nature with tourist arguments for making choices. Basic holiday elements are chosen after rational systematic evaluations of price, service quality, time, etc. These are hard to counter with arguments pleading for care, better attitudes and considerations toward locals and nature in general. Similarly, lifestyles and behaviours have their roots in personal preferences, mostly of hedonic nature, and they are hardly countered by environmental arguments. Even rational counter-arguments (e.g. financial compensation) are sometime ignored when hedonic satisfaction is at stake. Therefore it is suggested that promotions of sustainable tourism alternatives are made using similar arguments: rational arguments for alternative to choices, hedonic and attitudinal arguments for alternative behaviours and lifestyles.

#### **4 Tourist behaviour**

Research shows that generally tourists are very keen in supporting environmental and social performances of tourism industry. Over 40% of German tourists consider important to find environmentally friendly accommodation, and over 65% enjoy clean beaches and bathing water. (CREM, 2000; Ecotrans/FUR, 2002) Almost 85% of Dutch tourists are in favour of receiving sustainability-related information (CREM, 2000) and grading hotels according to their environmental performances. (Chafe, 2005) Similarly, 35% of British tourists show they would pay more for environmentally friendly holidays, while 30% would pay more knowing that their money would guarantee higher wages and working conditions for locals in destinations. Known worldwide for their positive attitudes and high environmental awareness, Nordic tourists are also supportive of eco-labeled hotels (Jensen, Birch, & Fredriksen, 2004) environmentally friendly travel

(Johansson, 2000) and clean nature. (Ankre, 2005; Zilinger, 2005) Overall, it can be said confidently that tourists are favourable towards tourism being provided in a more sustainable way.

Despite optimistic views generated by studies of tourist preferences, research looking into what tourists do (actively) to support these positive beliefs and attitudes, indicates that a large majority are still reluctant to change their own behaviour in order to support sustainable tourism products and services. (CREM, 2000; Grankvist, 2002) Almost 70-80% of tourists state their high concerns for eco-social components of holidays, but only about 10% convert this concern to action when they purchase (Chafe, 2005) in support of sustainability goals. Such a big difference indicates that attitudes and preferences towards sustainable tourism must be studied in relation to reasons hindering tourist environmental behaviour.

A less visible challenge is the quality of information about tourist behaviour. Most knowledge about tourist environmental values today is collected through opinion surveys, where tourists are asked about their actual tourist preferences (proven and tried in the past) and hypothetical environmental actions, which does not reflect their upcoming real behaviour. This gap is illustrated by the large difference between surveys results and reality.

## **5 Implications for policy and research**

The overview of impacts generated by tourist consumption showed four groups of decisional acts with negative potential. Actions to steer tourist choices – from a sustainability perspective – should capture the moments when these choices are made. Propositions of more responsible alternatives need to use a language employing similar arguments like tourist offers, and avoid clashing with these. With environmental values still having lower priority for most people, tourist arguments would prevail in a conflict situation.

Asked to behave responsibly, individuals find themselves often in social traps, caused by the conflict between their short-term personal gains with the long-term societal needs, such as concerns for sustainable development. Although considered the most difficult ones to break, such societal traps must be broken in order to achieve a sustainable future for all. (Bell, Greene, Fisher, & Baum, 1996, p. 521) Some tools for breaking such social traps and leaning the balance in favor of environmentally responsible behavior are:

- increasing the costs of environmentally destructive behavior (fines, fees)
- decrease the costs of environmentally proactive actions
- education to make people aware and also show how can they contribute,
- give feedback to people about the consequences of their behavior,
- rationalizing available resources for a better distribution, etc



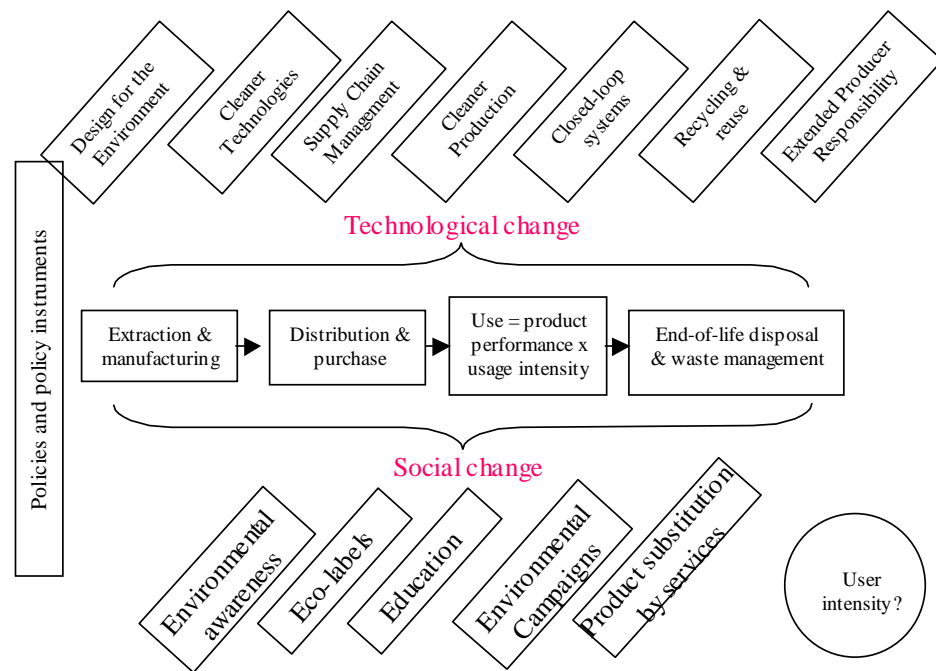


Figure 2: : Strategies for sustainable production and consumption (Mont, Dalhamar, 2004)

Capturing consumer attention and support for sustainable development strategies is probably the most difficult task of all. With infrastructures and policies designed for efficient resource use and waste management, with corporate strategies shifting from production-oriented to product-focused and from working alone to cooperating with suppliers and stakeholders, a change in consumer behaviour is still to come. Influencing people relies on understanding people's motivations and behavior. Therefore policies and tools aimed at steering individual behaviors depend heavily on the ability to understand motivations and decisions of individuals, in order to find the right incentive for change of large numbers of heterogeneous people.

Most tools and strategies targeting the societal change needed for sustainable consumption belong to awareness raising category. As the present paper discussed, people have other reasons for not behaving in a responsible manner, related to habits, convenience, personal preferences. As research shows the effectiveness of measures to change tourist behavior depends directly on individual's reason for acting wrongfully. (Roggenbuck, 1992) While informative tools are indispensable for creating a shift to sustainable tourist consumption, they have to be completed with strategies addressing hindrance factors too.

Research providing input to policy makers needs to broaden its spectrum in order to provide effective recommendations. At the moment, incomplete information about tourist hypothetical preferences proves to be ineffective showing very low results. Tools and strategies designed based on this

information (e.g. eco-labels, informational campaigns) come with no guarantees with regards to their effectiveness, leading industry and governments to believe that sustainable tourist consumption is close to impossible. Although current research focusing on identifying sustainable preferences has opened the way, by predicting possible tourist acts, a serious look backwards at the quality of information about tourist environmental behaviour seems appropriate. Further studies, need to develop such knowledge and complement it with the study of the dynamics between tourist and environmental values. Finding the balance between the two sets of motivations (tourism-related and sustainability-oriented) will lead to a sustainable tourism behaviour and consumption.

## References

- Ankre, R. (2005). *Visitor Activities and Attitudes in Coastal Areas* (No. 2005:1): European Tourism Research Institute (ETOUR).
- Becken, S. (2001). *Energy consumption of tourist attractions and activities in New Zealand* (Summary report of a project undertaken by Landcare Research and Tourism Research and Education Centre (TREC), Lincoln University.).
- Bell, P. A., Greene, T. C., Fisher, J. D., & Baum, A. (1996). *Environmental Psychology* (4th ed. ed.). Orlando: Holt, Rinehart, and Winston, Inc.
- Budeanu, A. (2004). *Integrating Sustainability in the Product Development of Tour Operators* (research report - summary). Lund: IIIIEE.
- Butler, R. (1998). Sustainable Tourism - looking backwards in order to progress? In M. C. Hall & A. Lew (Eds.), *Sustainable Tourism: A geographical perspective* (1 ed., pp. 236). Harlow, Essex, UK: Addison Wesley Longman Ltd.
- Chafe, Z. (2005). *Consumer Demand and Operator Support for Socially and Environmentally Responsible Tourism* (CESD/TIES Working Paper No. 104, Edited by Martha Honey): Center on Ecotourism and Sustainable Development (CESD); The International Ecotourism Society (TIES).
- CREM. (2000). *Feasibility and market study for a European Eco-label for Tourist attractions (FEMATOUR)* (research report commissioned by the European Commission, DG ENV No. CREM project no. 00.402). Amsterdam: Consultancy and REsearch for Environmental Management (CREM).
- Ecotrans/FUR. (2002). *Reiseanalyse 2002*. Retrieved november 2005, 2005, from [www.yourvisit.info](http://www.yourvisit.info)
- European Commission. (2004). *Feasibility and preparatory study regarding multi-stakeholder European targeted action Sustainable Tourism & Transport*. The Hague: European Commission, DG Enterprise.
- Forsyth, T. (1996). *Sustainable Tourism: Moving from theory to practice* (report): Tourism Concern & WWF-UK.
- Grankvist, G. (2002). *Determinants of choice of Eco-Labeled Products*. Unpublished doctoral dissertation, Göteborg University, Göteborg.
- Holloway, J. C. (1998). *The Business of Tourism* (5th ed. ed.). New York: Addison Wesley Longman Limited.
- Jensen, S., Birch, M., & Fredriksen, M. (2004, 9 December 2004). *Are tourists aware of tourism ecolabels? Results from a study in the County of Storström in Denmark*. Paper presented at the The 13th Nordic Symposium in Tourism and Hospitality Research, Aalborg, Denmark.
- Johansson, M. (2000). *Identification and promotion of attitudes related to pro-environmental travel behaviour*. Unpublished doctoral, Lund University, Lund.
- Jones, P., Walker, H., & Bedford, T. (2004). "Every little bit helps..." *Overcoming the challenges to researching, promoting and implementing sustainable lifestyles* (The research project was funded through a New Horizons Research Programme contract from the Department for Transport (DfT). The): Centre for Sustainable Development, University of Westminster.
- Leire, C., Thidell, Å., Helgadottir, B., Gisslasson, S., Pylvänäinen, E., & Niva, M. (2004). *Consumer perceptions, understanding and use of product related environmental information - A literature review of*

- the Nordic knowledge base* (research report). Copenhagen: Nordic Council of Ministers.
- Lohmann, M. (2004, 15 October, 2004). *New demand factors in tourism*. Paper presented at the European Tourism Forum, Budapest.
- Middleton, V. T. C., & Hawkins, R. (2002). *Sustainable Tourism: A Marketing Perspective* (1st ed. ed.). Oxford: Butterworth-Heinemann.
- Mont, O. (2004). Institutionalisation of sustainable consumption patterns based on shared use. *Ecological Economics*, 50(1-2), 135-153.
- Murphy, J. F., Niepoth, E. W., Jamieson, L. M., & Williams, J. G. (1991). *Leisure systems: Critical Concepts and Applications*. Champaign, IL, USA: Sagamore Publishing Co. Inc.
- Roggenbuck, J. W. (1992). Use of persuasion to reduce resource impacts and visitor conflicts. In M. J. Manfredi (Ed.), *Influencing human behavior - Theory and applications in recreation, tourism and natural resources management* (pp. 149-208). Champaign, Illinois: Sagamore Publishing Inc.
- Schmidt, H.-W. (2002). *Tourism and the environment* (statistics in focus No. 40/2002): Eurostat.
- Shove, E., & Warde, A. (2002). Inconspicuous Consumption: The Sociology of Consumption, Lifestyles, and the Environment. In A. Gijswijt (Ed.), *Sociological Theory and The Environment*: Rowman and Littlefield.
- Socialdata Australia. (2003). *Travel Behaviour Change Program: final report* (Travel Behaviour Change Program for parts of the Perth Metropolitan Area under the TravelSmart Program 2001 to 2005 No. Department for Planning and Infrastructure Tender Number 219/01). Fremantle: Socialdata Australia Pty Ltd.
- Tanner, C., Kaiser, F. G., & Wölfling Kast, S. (2004). Contextual conditions of ecological consumerism. *Environment & Behavior*, 36(1), 94-111.
- UNEP. (2001, October 9, 2001). *Impacts of tourism*. Retrieved 13 May 2003, 2003, from [www.unep.fr](http://www.unep.fr)
- Urry, J. (1990). The "Consumption" of Tourism. *Sociology*, 24(1), 23-35.
- WTO. (2003, June 2003). *CE/70/2/Doc. S. Report of the Secretary general - Meeting document*. Retrieved June 14, 2003, 2003, from [http://www.world-tourism.org/newsroom/Speeches/2003/ce702\\_doc\\_seance\\_A.pdf](http://www.world-tourism.org/newsroom/Speeches/2003/ce702_doc_seance_A.pdf)
- C:\Documents and Settings\AdrianaB\My Documents\My Documents\Library\EN-1\WTO-May 2003.pdf
- Zilinger, M. (2005). *A spatial approach on tourists' travel routes in Sweden* (No. 2005:3): European Tourism Research Institute (ETOUR).

# POSTER Strategy and actions to actualize sustainable mobility projects in urban contexts

*MULO system<sup>1</sup> - Solar and human power for urban work vehicles*

Fabrizio Ceschin

*DIS, Design and Innovation for Sustainability*

*INDACO-Politecnico di Milano*

## 1 Introduction

The Italian cities' expansion, from the 50' to forward, was marked by a rapid economic development and by a strong growth of the housing concentration in urban areas. That brought to an extraordinary increase of the mobility's demand, and therefore to an enormous traffic car growth, determining an increasing urban traffic jam. The consequence of that is a problematic air and noise pollution situation (with effects in the human health and in the environment), that bring to a quality of life deterioration in the urban contexts.

Inside this framework, urban light transport determines an important amount of consumptions and pollution: in fact more of the 10% of the energetic consumptions in transport activities is concerned with it, and even more elevate is the incidence in terms of atmospheric emissions.

That is briefly the intervention context of MULO research project. In fact MULO is a product service system (PSS) which is focused on the light transport work vehicles access, within the urban context. It reconsiders light transports on a sustainable point of view, basing on the use of clean energy like the solar and the human ones. In substance, it is a hybrid four-wheeled vehicles family, powered by solar and muscular energy. It consists of four versions: goods' delivery, people's transport, green areas maintenance, and peddling.

The PSS solution was born from a degree thesis developed in the **Design and Innovation for Sustainability** research unit (INDACO- Politecnico di Milano). The thesis generated a promising eco-efficient solution and now the research unit's new goal is to actualize some concrete applications of the vehicles family in the urban reality.

<sup>1</sup> The word MULO stays for the English MULE; its acronym is "Mobilità Urbana da Lavoro" (in English "Working Urban Mobility")

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

The following text tries to define a feasible strategy to actualize a sustainable mobility project in the urban context, considering the difficulties inherent to the framework inside which the project was born and the complexity of the intervention ambit. In fact it's clear that the project has to grow in a "low-budget" situation and aims to intervene in something (light transport mobility), that involves technical, social and political matters.

The first part of the paper describes synthetically the MULO project: how it was born, which are its characteristics and its potentialities.

The second part focuses on the building of a strategy to actualize the project in a concrete application and to disseminate that.

Finally the text will try to conceptualize the strategy to extrapolate a general model.

## 2 The MULO project

MULO System is a degree thesis started in the 2005 and developed with the **Design and Innovation for Sustainability** research unit (INDACO-Politecnico di Milano).

As said before it has set the goal in proposing a new light transport mobility system able to guarantee environmental benefits to the community, and economic benefits to producers and clients; in other words a system able to combine the actors' satisfaction with the environmental sustainability.

MULO System is a family of light working vehicle, with zero emissions in use phase, thought for the urban context. In particular the vehicle is a four-wheeled hybrid, powered by solar, electric an human power, convertible in four variants: goods' delivery, people's transport, green areas maintenance, and peddling.



Figure 1: Good's delivery version



Figure 2: People transport version



Figure 3: Green areas maintenance version



Figure 4: Peddling version

The service connected with the product, thought for the city of Milan, is synthetically characterized by the presence of some key actors: the municipality, the Politecnico di Milano and some producers. Together they provide the access to the vehicles (the client pays only for the period of time of use), and offer an integrate service of maintenance and repair.

## 2.1 Vehicle's characteristics

The four-wheeled light vehicles that made up the MULO family are moved by an electric motor which is energy provided by two solar panels; the energy from the motor can be integrate with the user's muscular one. That implies that the vehicle doesn't produce any air and noise pollution, and that has costs of use that are near zero.

Concerning performances the vehicle has a maximum speed of 40 km/h and a batteries autonomy of 60 km. It has been calculated that with 3 hours of sun the vehicle is able to travel for 35 km. Vehicle's performances are balanced to the urban context's characteristics; in fact being the average velocity of the urban traffic around 10-15 km/h is unnecessary to have an high maximum velocity.

The vehicle has been designed to be appropriate and to have access in every kind of urban route: normal roads, pedestrian areas, limited traffic areas.

It has been designed to give the driver an high manoeuvrability to move inside the traffic in an easy way; it also has been thought to provide a good confort in use (giving an ergonomic position, an absorber system, a good street visibility and a protection from bad weather).

Technical characteristics	
Dimensions L x W x H	3000 x 1100 x 1800 mm
Pass	1300 mm
Weight	85 kg
Max load (driver excluded)	300 kg
Motor	700 W, 36 V
Batteries	Pb 36 V
Solar panels	200 W
Max speed	40 Km/h
Autonomy	60 km
Autonomy with 3 hours of sun	30 km



Table 1: Vehicle's technical characteristics

## 2.2 Possibilities of use

The family of vehicles has been designed to be used in a wide range of applications; here it is some examples of possible services.

1. **Parcel post delivery.** The vehicle might be used by the parcel post delivery's companies, and in particular it would deliver the goods in the city center, taking advantage of its environmental characteristics (it don't have traffic limitations), and its high manoeuvrability (that permits easy manoeuvre and manoeuvre).
2. **Goods delivery (transit point).** Many cities, in its new mobility plan have decided to adopt a transit point. That is an infrastructure placed near the city center , that functions like a central warehouse. Here the goods entering the city are collected and then delivered with little vans. The designed vehicle has the right characteristics to be used with success in this kind of service.
3. **Shopping delivery.** This kind of service is active in several supermarkets; the designed vehicle could be used in this ambit together with the traditional vans; in other terms the vehicles would be specialized in the delivering inside the city centre, where traffic limitations problems and parking problems make difficult the use of the traditional vehicles.
4. **Meals and medicinals delivery.** The vehicle might be used for social services like meals and medicinals delivery for elderly people. Il veicolo può essere pensato anche per essere utilizzato per servizi sociali come la consegna dei pasti caldi e dei medicinali per gli anziani.
5. **People transport inside the historical center.** It might be a service that gives to persons the possibility to have a tour of the historical center.
6. **Taxi-rickshaw.** The people transport service might be applied in the whole city. The service might function in a similar way of the one of the traditional taxi (without prefixed routes), or vehicles may have predefined paths along the city's nodal points (for examples central station, historical center, fair...). In that last case the municipality could give favored path , for example utilizing cycling tracks. Another parallel possibility is the use of the vehicle during particular events of the city (where it is needed a big demand of mobility).



7. **People transport inside fair centres.** Inside the fair centres that present a big extension, the vehicle could be used to transport persons from a pavilion to another.
8. **Parks and green areas maintenance.** The ordinary maintenance of the park is usually done using motorized vehicle; it could be interesting substitute this polluting and noise vehicle with the designed one.
9. **Private area maintenance.** Another possible application is the maintenance and the cleannes of big private areas, for examples big fairs.
10. **Peddling.** The vehicle can also be used by peddlers



Figure 5: Some possibilities of use of the vehicles

### 2.3 Benefits of the PSS solution

The PSS solution was thought to guarantee a series of advantages both to producer, to clients and to environment; it has therefore to be a “win-win” system, that is to be winning in more directions. This is a fundamental aspect

because a PSS must be environmentally and economically sustainable; able to bring economic benefits for producer and client, and environmental benefits to the entire community.

### 2.3.1 *Environmental benefits*

- The vehicle, being powered by solar and human energies, doesn't have emissions in the use phase.
- The shared use of the product bring that less vehicles are needed to satisfy the same number of clients; therefore there is a vehicles number reduction..
- The maintenance integrated service produces a components life extension and therefore a product life extension; hence the environmental impact of the dismissal and the ones of the manufacturing of new vehicles can be avoided.
- A strategy of components reuse and materials recycling permits a resources saving.
- The up-grading integrated service bring to introduce more frequently the innovations that the market propose; components technologically more advanced determine an higher efficiency in the resources use.

### 2.3.2 *Economical benefits (for the partnership)*

In a strategic level:

- Improvement of the partnership's strategic position; because it anticipate future environmentl restrictions and regulations..
- Stronger relationship with the client; the maintenance and upgrading integrated services bring to develop a more durable relation.
- Image return; the emerging of the critical consumption behaviur, with the carefulness to the environmental and social issues, could be used by the partnership showing the environmental benefits that the PSS bring to.

in a operative level:

- Production and dismissal costs reduction; maintenance, reuse and recycle integrated strategies bring to a lower costs for the service provider because it postpones the dismissal's costs and the ones relative to the manufacturing of new components.

### 2.3.3 *Client benefits*

- Costs of use; the vehicle has zero costs of use.
- Traffic restriction: the vehicle has no traffic restriction and can be used in pedestrian areas and limited traffic areas.
- Acquisition costs; client is not forced to buy the product, but could simply rent it for the period of time necessary; that determines an economic saving.
- Maintenance and dismissal costs; client is free from the problem related to maintenance and dismissal because that is a duty of the service provider.

- In-site maintenance; the in-site maintenance service permits a timely repair, minimizing the client's loss of time (and therefore the economic damage).

### **3 Strategies and actions to actualize MULO project**

As said before MULO project was realized within the **Design and Innovation for Sustainability** research unit (INDACO- Politecnico di Milano). Considering that project a promising one, the research unit decided to define a strategy in order to find one or more concrete vehicle's application.

We are conscious of the difficulties to reach that goal, in particular three are the main obstacles:

- the fact that the project is a low-budget project; we have internally human resources but not funds to invest on it.
- the fact that internally we don't have all the competences and skills necessary to develop and realize these kinds of project.
- the fact that the project aims to intervene in a very complex issue (light urban mobility), in which are interlaced many matters: not only technicals ones, but also (and these are the most problematic), infrastructural, political and normative ones.
- the fact that there isn't yet a diffused market of this kind of vehicles, and therefore there are not companies directly interested on that.

Despite these facts we decide anyhow to try to develop this project with a strategy taking off from the bottom. The following text describes the actions we did and the ones we will do in order to reach the prefixed goal.

#### **3.1 Creating the partnership**

The first step we aimed to do was to review our project idea in order to have a technical feedback and a consequent upgrade; in other words we wanted skip from a pre-engineered project to a totally engineered one.

For these reasons we decided to enlarge the actors involved in the project, firstly engaging the high school IPSIA "A. Ferrari" of Maranello; with that school Politecnico di Milano stipulated a collaboration agreement that brought to a knowledges and experiences exchange. In particular the advantages we got are:

- knowledge exchange regarding solar and human energies applied to mobility; IPSIA has a lot of experience in that issue (it realized several prototypes of this kind), and many human resources.
- technical experience; being a technical school, IPSIA gave us a lot of technical feedback in order to improve the prototype in the mechanical and energetic aspects.
- instruments for prototyping; IPSIA provided spaces, tools, and machineries to support the prototipation.
- DIS research unit shared with IPSIA its competences concerning the designing of low impact products.

Another very positive aspect of this agreement between the two education istitutions was the fact that we had the opportunity to enlarge the network in order to involve some companies. We utilized IPSIA network of

contacts to select some possible interesting companies, and three of them joined us in the partnership. These companies decided to enter in the project because they were concerned with the environmental sustainability aspects of the PSS idea and with the possible develops of the product.

Companies shared their know-hows and experiences, and that was fundamental to develop further the project idea. That brought to reach an high technical design level.

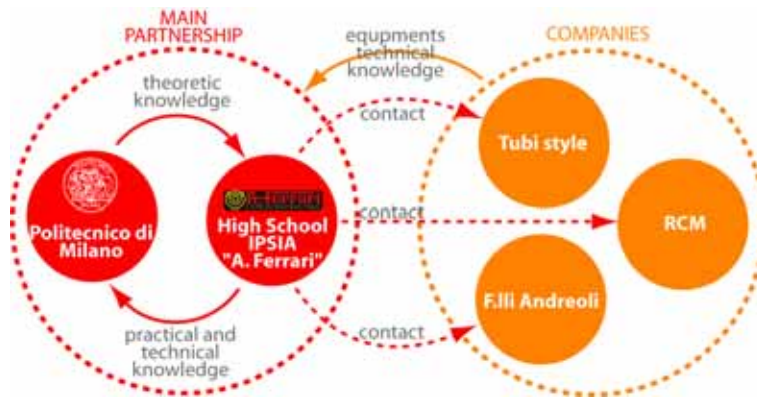


Figure 6: The main partnership in MULO project and the companies networked with it.

### 3.2 Realizing the prototype and giving it visibility

The second step we wanted to achieve was to develop our engineered project into a prototype. A prototype, to be realized needs of know-how, human resources, materials, equipments time, and funds.

To reach this aim we decided to organize an event and utilize its sponsorships to get the financial resources necessary for the prototype's realization. But what kind of event organize? We thought to a 5 days trip, from Rome to Maranello, dedicated to innovative zero emissions vehicles. We made this choice in order to have the possibility to test the vehicle and at the same time to give visibility and risonance to it.

We didn't have all the competences to organize an event like that, so we involved other actors, in particular the Maranello municipality and NAC (Nakanhion Automotive College). Together we organized the event aspects.

The realization of that event, denominated Progetto Levante (Levante Project), brought to three main goals:

- **prototype realization;** we used a part of the sponsorships to get the resources needed to carry out the prototype.
- **prototype testing;** we went through a 591 km trip and so we had the possibility to test the vehicle's several aspects (mechanical, structural, energetic, ergonomic, guidance and so on), and to collect many technical data. We understood which are the product's positive point and which the negative ones that have to be modified.
- **product visibility;** the event was organized thinking also to give risonance to the vehicle and to the PSS solution in general. In fact the Levante Project was managed in order to guarantee, in each cities where the vehicles' caravan passed through, a

meeting with the municipality's representatives and with the press. In other words we had the possibility to give resonance to the initiative (sensibilizing the public opinion regard sustainable mobility), and to create a network of contacts with the municipalities (which are potentially interested in change urban mobility in the direction of sustainability).

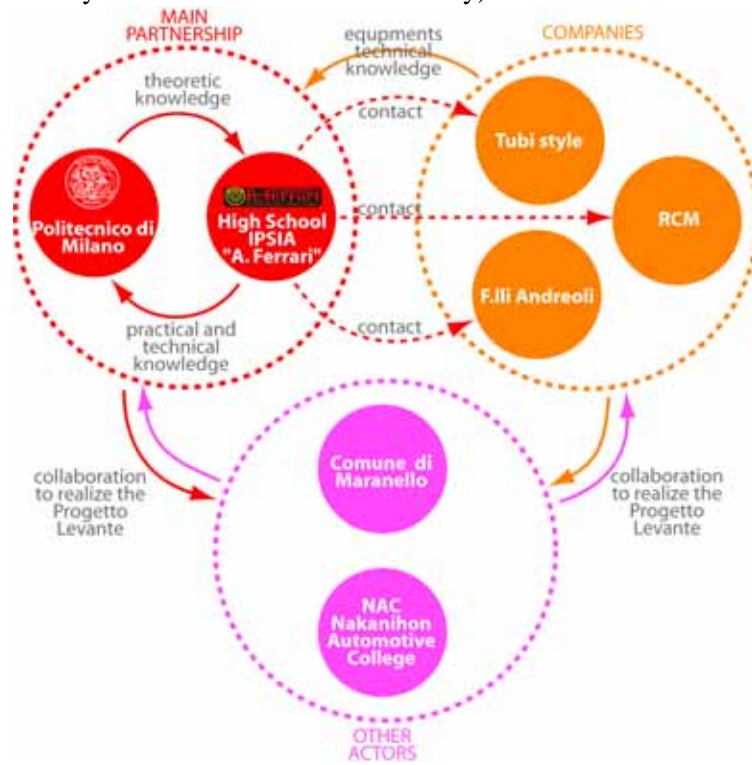


Figure 6: MULO Project network enlargement

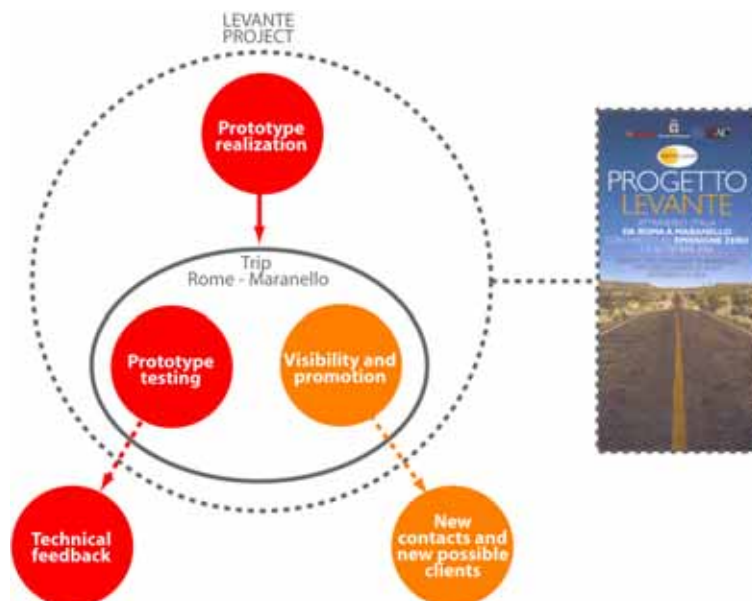


Figure 7: Levante Project's main results

We could say that Levante Project is a good example because it gave us the possibility to concentrate three important targets (prototype realizing, prototype testing and PSS idea visibility), in a short period of time, investing a very low amount of money.



Figure 8: The prototype in action during the Rome-Maranello trip

### 3.3 Next steps

As said before Levante Project gave us many opportunities, in particular the opportunity to have a technical feedback and an high visibility.

Now the next steps are:

- **upgrading the vehicle;** analyse all the data collected during Levante Project and redesign what is uncorrect: in other words improve the product.
- **proposing the PSS solution;** evaluate and select some promising application contexts of the PSS solution and propose it the municipality.

Strengthened by the experience done we have just proposed, in collaboration with the companies which supported us, our PSS solution to the Modena city Municipality, and we have signed an agreement to test a pilot project

In particular we have to provide 2 vehicles which will be used as supporting vehicles for the cleaning and maintenance of the Modena city center.

That will be the first concrete vehicle's application in urban context, and a very important goal for us. It will be a full experience, that will bring:

- the possibility to realise a vehicle's upgrading, in order to eliminate lacks and deficiencies found during the Rome-Maranello trip.

Strategy and actions to actualize sustainable mobility projects

- the possibility to test the vehicle in a real situation, with all the concerning problems, and have feedbacks helpful to improve further the product.
- the possibility to have an high visibility and risonance and so the opportunity to get involved in others pilot project ore something more important.

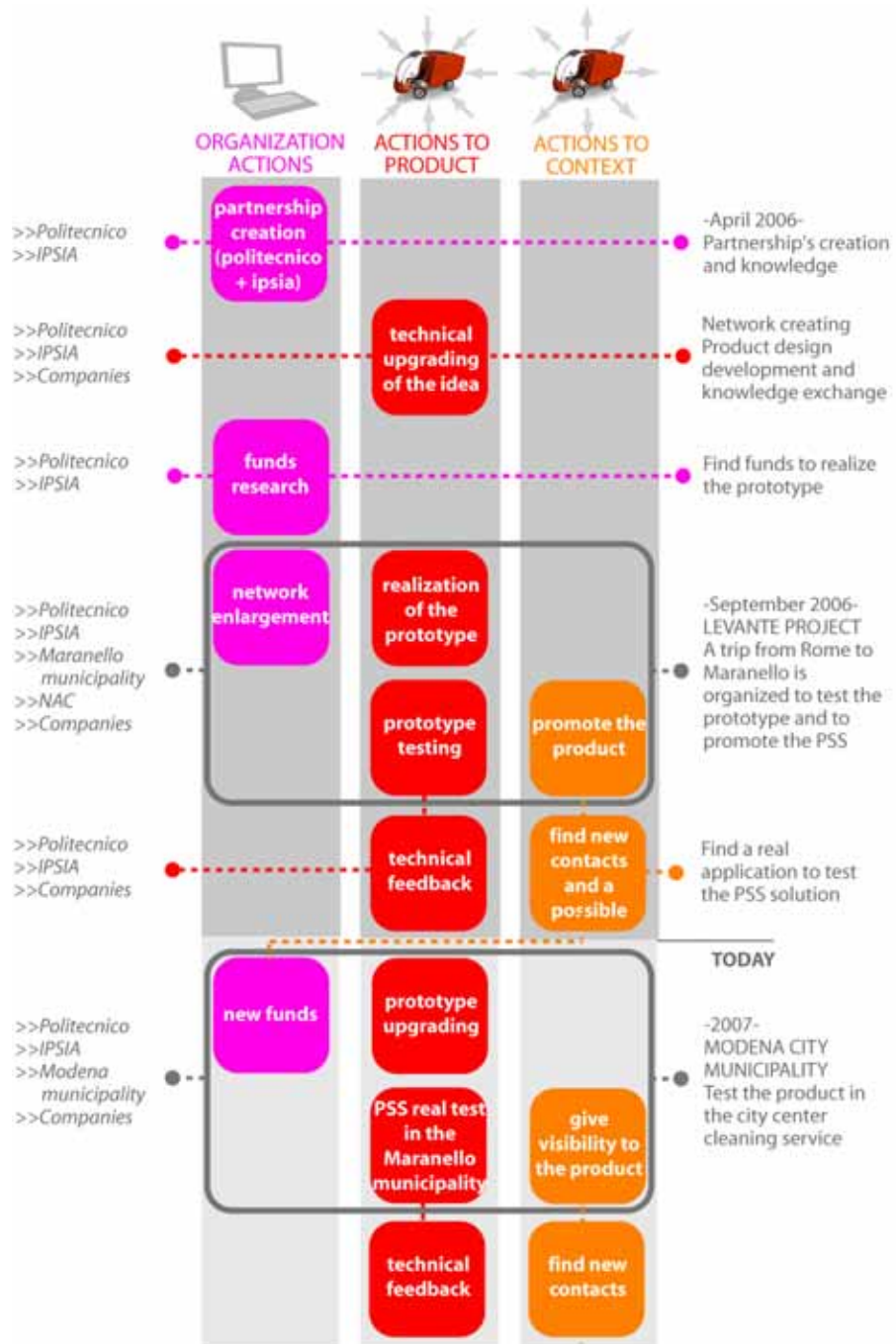


Figure9: Summary of all the actions undertaken in the MULO Project

The idea that we have in mind now is to test much more possible the product, aiming to continue to improve the vehicle and to have visibility and risonance. That has the purpose to realise a dominoes effect in order to succeed in having a real incidence in the urban mobility.

## 4 Conclusions

From the MULO Project experience and the steps done we can first extrapolate a general model to actualize a sustainable mobility project and second reflect on which are the skills needed by a designer to do that.

### 4.1 A general model to actualize a sustainable mobility project in urban contexts



Figure10: A model to actualize a sustainable mobility project in urban contexts



We can summarize a general model in five points:

1. **create a partnership;** with other schools (to share knowledges, skills and thoughts), with companies (to have a technical and economical point of view), with municipalities (to have an institutional point of view and because they are potentially interested in a PSS solution related to urban mobility).
2. **develop and upgrade your PSS idea;** use the knowledges and skills of the created partnership to improve in any aspect your PSS idea. In particular exploit schools' and companies' technical competences.
3. **organize an event in order to realise a prototype of the PSS idea and give visibility to it;** organize an event and utilize its sponsorships to get the financial resources necessary for the prototype's realization. At the same time take the chance to test the prototype and give it resonance and visibility (especially to the actors potentially interested to it).
4. **upgrade your PSS solution and enlarge contacts to find possible clients;** use the done experience to upgrade your PSS solution and use the created resonance to promote it on selected municipalities.
5. **find a real application to test it;** create a collaboration with a municipality in order to have a real and concrete PSS test.

#### 4.2 New designer's skills needed

In that framework, besides the traditional skills, the designer needs some others strategic competences, which can be delineated as follow:

- skills to design an integrated system of product and service;
- skills to communicate your PSS idea in an efficacious way in order to involve new interactions (in particular with companies and municipalities), find new funds and create resonance.
- skills to facilitate participated design between schools, companies and municipalities;
- skills to facilitate new socio-economic interactions and partnerships with companies and municipalities;
- skills to organize events or initiatives in order to give visibility to your PSS idea.

#### References

- D. Bruno, *Progettazione continua. Nuove tecniche di sviluppo dei prodotti industriali*, Maggioli Editore, 1999
- A. Cappelli, A. Luongo, D. Mollano, U. Petrucci, *Strumenti e metodologie per la gestione del sistema stradale urbano*, Franco Angeli Editore, 2000
- B. Cori, *Traffico urbano e qualità della vita in Italia*, Patron Editore, 1988
- EMUDE, *Emerging User Demands for Sustainable Solutions final report*, 6th Framework Programme (priority 3-NMP), European Community, 2006.
- A. Fuad-Luke, *Eco-Design*, Logos Editore, 2003
- V. Hoesle, *Filosofia della crisi ecologica*, Einaudi Editore, 1992
- H. Hoyer, "Indagare sul sistema città", in *Domus* n° 809, novembre 1998

- Istituto di Ricerche Ambiente Italia, *Ambiente Italia 2002. Rapporto annuale di Legambiente*, 2002
- C. Lanzavecchia, *Il fare ecologico. Il prodotto industriale e i suoi requisiti ambientali*, Paravia Editore, 2000
- E. Manzini, "Progettare la sostenibilità", in *Domus* n° 789, gennaio 1997
- Manzini E., *Design, sostenibilità e innovazione sociale. Le scuole di design come agenti del cambiamento*, seminario Formazione, sviluppo sostenibile e design: strumenti e strategie per la decade, Politecnico di Milano, 2005.
- Manzini, E., Jegou, F., *Sustainable everyday. Scenarios of Urban Life*, Edizioni Ambiente, Milan, 2003.
- Manzini E., Vezzoli C., *Lo sviluppo di prodotti sostenibili*, Maggioli editore, Rimini, 1998.
- E. Mari, *Progetto e passione*, Bollati Boringhieri Editore, 2001
- Ministero dell' Ambiente, *Relazioni sullo stato dell'ambiente. L'inquinamento atmosferico e i cambiamenti climatici*, 2001
- M. Singh, *L'energia del sole e il futuro dell'umanità*, Silvana Editoriale, 1998
- UNEP, *Product-Service Systems and Sustainability. Opportunities for sustainable solutions*. United Nations Environment Programme, Division of Technology Industry and Economics, Production and Consumption Branch, Paris, 2002.
- Van Halen C., Vezzoli C., Wimmer R. (edit by), *Methodology for Product Service System. How to develop clean, clever and competitive strategies in companies*, Van Gorcum, Assen, 2005.
- Vezzoli, Manzini, *Design for sustainable consumption*, proceedings, Perspectives on Radical Changes to Sustainable Consumption and Production (SCP), Sustainable Consumption Research Exchange (SCORE!) Network, Copenhagen, 2006.

# POSTER An international multi-lateral didactic activity for the development of furniture systems

Liliane Iten Chaves<sup>a</sup>

*DIS Research Unit, Politecnico di Milano, Italy, liliane.chaves@polimi.it*

*<sup>a</sup>CNPq Scholarship - Brazil<sup>1</sup>*

## 1 Introduction:

It is already known that the transition for sustainability demands more than the redesigning of existing products or incremental innovations. The challenge demands radical and system innovations and for that the furniture sector needs to look for new solutions.

In this sense, a possible route of design for sustainability is to explore new solutions by developing product/service systems. Besides being an argument already solid in the academic field, there is little structured information regarding real examples or methods for its development. This becomes more difficult when the focus is a certain sector such as furniture.

The Life Cycle Design course developed at the Faculty of Design of the *Politecnico di Milano*, whose responsible is Professor Carlo Vezzoli, provided experimental opportunity for the development of news PSSs for furniture sector.

It is necessary to highlight the importance of educational activities for the new designer formation, once the transition towards sustainability demands new capabilities.

The new strategic approaches towards design require the sensitisation and preparation of the new generation of designers. Consequently, all initiatives in the educational approach are interesting workshops both for the search of new sustainable product/service system solutions, as for new educational models. The importance of education for sustainability is highlighted by UNESCO who established the Decade of Education for Sustainable Development<sup>2</sup>.

The paper presents the methodological route used by the course, as well as some examples illustrating these.

<sup>1</sup> *CNPq is the National Brazilian Council for Scientific and Technological Development. It is a foundation linked to the Ministry of Science and Technology to support Brazilian research.*

<sup>2</sup> *UNESCO Decade of Education for Sustainable Development (2005-2014).*

[http://portal.unesco.org/education/en/ev.php-URL\\_ID=51229&URL\\_DO=DO\\_TOPIC&URL\\_SECTION=201.html](http://portal.unesco.org/education/en/ev.php-URL_ID=51229&URL_DO=DO_TOPIC&URL_SECTION=201.html)

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

## **2 The course structure**

The course is an initiative of the Research Unit DIS – Design and Innovation of systems for Sustainability at Politecnico di Milano, which has been developing an informal network of design colleges from emerging countries since 2002. This network was formed as an experimental laboratory “not only to have the universities/institutes as contexts for which sustainable ideas could be designed” (Penin, L. and Vezzoli, C., 2005a, p. 5) but also for experiences and knowledge exchange regarding PSS in the different contexts.

This present course edition was developed from February 2006 to June 2006. The network campuses participants were:

1. Department of Industrial Design Faculty of Architecture King Mongkut's Institute of Technology, Thailand;
2. USP de Sao Paulo, Brazil;
3. Hong Kong Polytechnic University, School of Design, Hong Kong;
4. Indian Institute of Technology Delhi, India;
5. Istanbul Technical University, Dept. of Industrial Product Design, Turkey.

Those Universities sent data regarding their furniture systems to Politecnico di Milano, which were used by the Italian students in a product/service system project for the respective campuses. It has been required of each University to have a responsible professor and assistants, to give answers and feedbacks to the participants. There were two second year groups of students from the Design College. Both groups were subdivided into smaller groups, each one responsible for a country each: Brazil, Italy and Hong Kong. The second one was responsible for Thailand, Turkey and India. It was asked the foreign students to be responsible for the Italian campus.

Bellow is a table of the Professor and Assistants responsible for each campus.

Table 1: Description of campus groups and responsible

Campus	Local contributors and revisers	Number of groups
Hong Kong	Prof. Benny Leong and Prof. Jennifer Hung	10
India	Dr. Amrit Srinivasan and Amruta Ranade	10
Turkey	H. Apay Er, Assoc.Prof.Dr. Ozlem ER, Efe Goktogan and Ceyda Vatan	8
Brazil	Prof. Dr. Maria Cecilia Loschiavo, Regina José e Gustavo Curcio	8
Thailand	Prof. Moi and Pwinn Q Rujikietkhomjron	7
Italy	Carlo Vezzoli and Christian Sabbioni	6

The exercise focuses on work emplacements, so the functional unit<sup>3</sup> used for the exercise was the use of one work emplacement in classroom in each participant campus during one year. The smaller the impact of the furniture the longer the piece will last.

## 2.1 A brief view of PSS on the furniture sector

According to SusProNet<sup>4</sup> network the PSS can be divided into three categories (Tischner, 2004, p. 21):

- Product-oriented PSS: the product is owned by the user/consumer (e.g. service integration, product extension service and vertical integration).
- Use-oriented PSS: product is owned by the service provider who sells functions instead of products, by means of modified distribution and payment systems, e.g. sharing, pooling and leasing.
- Result oriented PSS /system optimisation (e.g. product substituting service, facility management)

Normally in the furniture sector, the system solutions turn around the production or inside the product-oriented PSS category presented above, which is called “add-on” to the product.

Regarding the “add-on product”, the furniture company does not only offer the product in itself, but also some services expected as well as some unexpected ones. In other words, instead of the generic product and expected services such as warranty or payment facilities, the client is surprised with ‘widened product’ like training courses, etc.

Concerning the design for sustainability in the furniture sector, some examples of “add-on products” are cases of take-back for recycling or re-use systems that allows for enlargement the product lifespan. These services are direct or indirectly linked to the company.

The manufacture, in most cases, does not supply *use oriented PSS* category, such as second-hand dealers, leasing or sharing (Bärsch, 2001). The second hand dealer is a well established service in many countries but sharing and leasing are not such a spread service, and requires increasing.

According to Tischner (2006), the development of new PSS achieves most successful PSS results when they started from zero, instead of being linked to old companies businesses. Therefore, the present design exercise has the positive side to be free about production or product, in spite of being restricted to the university campuses.

<sup>3</sup> *The functional unit is not a physical product but the usefulness of analysed system. On other words, it is not necessarily the physical product, but also its function, or the service and its results that will supply. For example, for a coffee machine a functional unit could be a cup of coffee, in this case it is possible to compare the environmental impact of two systems of coffee making: one could be that of an electric machine and the other one that of soluble coffee. The results of these two systems of coffee making are a coffee cup.*

<sup>4</sup> *SusProNet – Sustainable Product-Service System co-design Network is a European Network on Sustainable Product-Service Development.*

## 2.2 Process phases for PSS creation

For achieve the waiting results the course was divided in three phases: set priorities - strategic analysis, orientate concept and check concept

Table 2: Phases of the design route

Phases	Sub-phases	Tools
Set priorities - Strategic Analyses	- Socio-economic - Environmental - Set of priorities (criteria) for environmental sustainability	- Life Cycle Assessment tool – LCA software - SDO-MEPSS <sup>5</sup> – check-list
Orientate concept	Sustainable ideas concept (environmental + socio-ethical)	- SDO-MEPSS – orientate concept - Design for Sustainability Orienting Scenario, SDOS - Story board - Stakeholders’ table of roles - PSS map - Evidences concept rendering
Check concept	Qualitative evaluation (environmental – socio-ethical)	SDO-MEPSS: Environmental and socio-ethical radar

### 2.2.1 Set priorities - Strategic analysis

The first phase, the **strategic analysis**, is where the briefing is defined. Its main function is to carry out the intervention priorities regarding the triple bottom line of sustainability: environmental, economic and social aspects. It is worth mentioning that the course main focus was the environmental aspect.

The **socio-economic analysis** was done through the collection of data containing the general aspects of each campus. It was also sent a format document to collect the specific aspects regarding the furniture systems used.

Table 3: Specific aspects required

Data	General aspects
Existing typology of classrooms	Which are the various classrooms typologies, according to furniture typology (e.g. computer, ordinary courses, drawing)? Which is the most present classroom typology? Which is the most used classroom typology?
Evolution of the furniture system classroom	Is it possible to observe some changes on the furniture typology in the last years? Which is the typology that seems to be more significant in terms of evolution (that will be most used in future)?
Furniture acquisition	How is the acquisition process of furniture in the campus (e.g. is the furniture simply bought? is it in leasing? or is it bought together with its maintenance service? Is there any concern on the use of renewable materials?(e.g. Forest Stewardship Council-FSC, for wooden furniture)? Is there any concern on socio-ethical issues related to the various workers of the furniture chain? How is the furniture maintenance done? Which are the components that go through a major number of maintenance? How is the cleaning done?

<sup>5</sup> PSS Sustainability Design-Orienting is a Toolkit edited by Carlo Vezzoli in the EU project MEPSS – Methodology for PSS. For more information see <http://www.mepss-sdo.polimi.it/mepss/website/mepss.html>

It was required of each campus to choose 1 or 2 typologies of furniture classroom that better represented the system and that made it easier to collect data. The main idea for the work placements choice was that it would be the furniture system that better represented the future demands on the campus. Other information required regarded students quantity in each class and shift, in this case focusing on the furniture system choice. In relation to the chosen system, it was required of them to disassemble the furniture in order to obtain data regarding number of pieces, material, manufacturing process and weight of pieces and components. Other information required regarded transportation, distribution and disposal.

The quantity data was used for the next step of the course: the **environmental assessment**. For that, an abridged LCA was made with the objective was to raise the most impacting material, process and life cycle phase of the furniture system. For the LCA execution it was necessary to create a database for the furniture sector<sup>6</sup>.

The LCA results achieved show that the most environmentally impacting life cycle phases were the pre-production and production.

Knowing the most environmental impacting phases (pre-production and production), it was possible to establish which strategies were prioritized according the design for sustainability approach. The following SDO-MEPSS strategies were used as a basis:

- System life optimisation
- Transportation/distribution reduction
- Resource reduction
- Waste minimisation/valuation
- Conservation/biocompatibility
- Toxic reduction

The impact in pre-production and production phase is directly influenced by the life system optimization strategy. Therefore it will have a high priority. It is considered as medium priority the resource reduction strategy. Some aspects were highlighted for the students, because they could have a direct influence on the optimisation of the system life maintenance/repairation, re-use/remanufacturing, updating/ aesthetics, adaptability/morphology.

According the resource reduction strategy, some aspects that are directly linked would be: dematerialization, use of non toxic materials and process; and use of renewable materials.

<sup>6</sup> *In the furniture case, it was necessary to implement the data base with specific information. For that, it was used the data of a software eVerdEE from eLCA Project financed by EU6. eVerdEE is a web-based software tool that is designed to support the use of LCA by Small and Medium-sized Enterprises (SMEs). The software has a furniture database with the most used materials and allows to do a simplified LCA. The results of eVerdEE LCA are characterized. In other words, the results give the contribution of the product analyzed to the greenhouse effect, to acidification and other environmental problems. For a designer these results are very difficult to interpret, because it is not viable to estipulate a mutual weighing of environmental effects. For this reason, the characterized results of eVerdEE LCA were taken and converted, using ecoindicator 95, in environmental indicators, a weighting method that "has enabled one single score to be calculated for the total environmental impact based on the calculated effects" (Goedkoop, 1996, p.2).*

Using the SDO-MEPSS check list tool, it was made the analysis of the existing system, always considering the prioritized strategies. The students have completed the prioritization radar tool regarding the current system.

### 2.2.2 Orientation of the concept

In the orienting concept phase the sustainable PSS ideas are generated. Diverse were the tools used for ideas concept support. Other tools typologies were used to clarify and to better communicate the developed system.

The first step was to use the ideas table by SDO.MEPSS. Using the brainstorming technique each group generated ideas, to cater for the campus needs and to take into account the sustainability priorities of the product/service system.

The preliminary system ideas were better visualised using *Design for Sustainability Orienting Scenario*, SDOS. In the following figure the scenarios structure is shown.

The scenarios were divided into four quadrants, built using two axes or polarities: user participation and innovation placement.

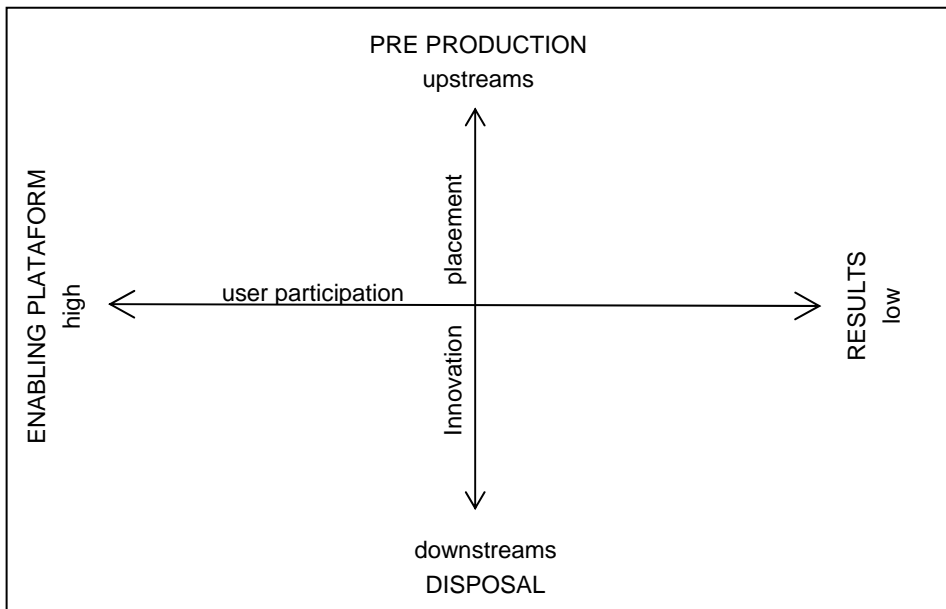


Figure 1: Axes used for scenarios polarities definition

The user participation axis represents the major or minor participation of the user in their own needs satisfaction. On the left side of the axis, the user has a high participation on the service; on the right side his/her participation is low<sup>7</sup>. The vertical axis associates the new concept intervention in all product/service system life cycle<sup>8</sup>. Above is the pre-production phase and below is the disposal.

<sup>7</sup> For example, in a clothing care system, the axes left side represents a kind of service in which the user could wash her/himself clothes, in the other side the user takes her/him dirty clothes and after a time brings clean clothes without participating in the process of washing.

<sup>8</sup> The considered life cycle phases of a product are : pre-production, production, use, transport and disposal.



Some other tools were incorporated to the concept oriented phase for better define and represent the proposed system. They are: story board, stakeholders/roles table and evidences concept rendering. These tools are better described in the next section.

Finally, the new pre-concept was sent to the campus of origin in order to have the professor/assistants' feedbacks. An interactive website was specially designed for the network information exchange<sup>9</sup>. The website proved to be a key interface piece for dialogue among campuses (students/professors, professors/professors and students/students). The website enriched the feedbacks, once all students or professors could visualize the results and give feedbacks regarding all group works.

Based on the feedbacks, the students refined the concept. After that, they evaluated environmental and social-economic quality of the concept using the SDO-MEPSS check list.

### 2.3 The students presentation

The final concepts were presented by each group in an oral presentation. The presentation contents are presented in the table bellow:

Table 4: Presentation contents

Data	General aspects
Poster	It is an image that describes synthetically what is offered by the concept developed. It is formed by visual messages and writings in such a way to make visual the main characteristics of the PSS as if it was a promotional image (publicity).
Concept synthesis	It is a description with 200 words about what the concept offers, who offers it and why it is advantageous.
SDO Scenario	Design-orienting scenario is a tool that allows visualizing the concept ideas according two polarities. The two axes form four actions domains. The axes are previous chose in order to guide the scenario building (Vezzoli at all, 2005; Manzini, 2004).
Story board	It describes the experience as it appears to the users in the time. It is a sequence of static images linked with texts. The images: they are few and they must represent the main situations of the service and the relative advantages, the background delineate a synthetic context. The texts are brief comments regarding what is the consumer doing and why.
Skateholders/roles Table	It describes the stakeholders' configuration of the PSS and their specific roles. It is a list of the various stakeholders, whom supply the service.
PSS map	It is a map of the campus which identifies the locations of the developed PSS concept in the campus map.
Evidences concept rendering	It is a place rendering where the PSS takes place.
Environmental and socio-ethical radar (SDO-MEPSS)	It shows the socio-ethical and environmental advantages for the diverse stakeholders forecast by the PSS concept.

Bellow is presented some examples developed into the course<sup>10</sup>. First example:

<sup>9</sup> For visualise see: [www.lens.polimi.it](http://www.lens.polimi.it)

<sup>10</sup>The results presented here is a description by the paper's author regarding the students projects. The choice of the projects were done following the criteria of final course valuation

### 2.3.1 First example: Your own chair

USP, Brasil was the context in which the group proposed a new product/service system. The group is composed by four members: Burberi, Corvatta, Di Gioia e Franci. They project a system that linked a social cooperative, a furniture manufacturer, the university and the slums context.

A ITCP organizes qualifying courses to anyone wanting to be a worker for the cooperative whose designer designs work emplacements for USP. To produce new products, the cooperative avoids environmental impact processes, use local materials and reuses discarded components dismissed. In collaboration with the cooperative, USP launches a student competition periodically. It aims to redesign furniture parts and products when their life span is expired. The cooperative also invited famous designers to collaborate by developing new products using discarded materials for the slums public spaces. In this case, this non-profit initiative would bring these designers a brand increase.

The environmental advantages are the use of local materials and the life extension of materials and products. The social advantages are:

1. The cooperative generates job to slums residents.
2. The cooperative guarantees good job conditions for workers
3. The slums receive free common goods
4. Famous designers, with their designs, attract international attention to the social problems of slums.

The Economical advantages are:

1. Using local workers from *the* slums, it increases job occupation for needy people.
2. The famous designs increase their brand value.
3. Cooperative makes business.

### 2.3.2 Second example: B. a. S. – Book and Share

B. a. S. – Book and Share is a product service/system developed for India campus context. The students are: Ronnel Ibarra, Diego Longoni, Luca Meroni and Flavio Montali.

The main idea of the concept is a renting service for work emplacements, not only for the University campus but also for other colleges, middle-high schools and public services. These groups of institutions form a cooperative that use a “product-sharing” service offered by the company.

The rent company is responsible for production, warehouse organization, delivery and maintenance of the products. Consequently it will look for a bigger life span, less use of packaging and delivery optimization. As a result, the environmental impact tends to be lower.

Through a website each student books her/his own work emplacement for the classes, by informing a responsible college department which will do the rest. Besides that, the student receives the work emplacement and makes its assembly. Students themselves inform the company using the website when the work emplacement has some kind of problem. Once the course is

---

*and/or are interesting. The examples do not intend to express precise statements, but rather to open a research and educational debate.*

finished, students make the furniture disassembly and make it available using the website.

### *2.3.3 Third example: Students' cooperation*

The concept developed focused on the Turkey campus. Maria Chara Zacchi, Chiara Salabrini and Ivan Puzovio are the group members that have worked on it.

The main idea of the concept is to link the university, design students and local firms through a website. The university promotes a competitive examination for design students that have knowledge regarding design for sustainability. The main idea is to develop work emplacements for the university, leading account sustainable requirements. For the production the university contact cooperatives and local manufactures.

Some preparation lessons will be done with the three first classified groups. The groups work together with professors and local manufacturers' representatives. After the production, the students carry out an assembly.

It is understood that the chosen projects have taken into account environmental requirements and the posterior professors' contribution have optimized the results.

Regarding socio-ethical advantages, the participation of the students in a real project is highlighted. Also the manufactures would be sensitized and have the opportunity to be updated with academic knowledge. On the other hand, students as well as professors have the possibility to keep in touch with the local reality and the manufacturing world.

The university has the economic advantage of getting a discount for the furniture design and assembly from the manufacturers. In addition to that, the furniture could be used as a positive brand both for the university and for the manufacturers. The students receive possible reductions and discounts of the university expenses.

## **3 Overall conclusions**

The three examples were chosen according to their evaluation. According to the categories presented in section 2.1, the examples are classified as:

- a) Product oriented PSS, Your own chair.
- b) Use oriented PSS B. a. S. – Book and Share.

It is necessary to highlight that all concepts revolves around the universities campuses which have particularities that an external context does not have. It does not, however, invalidate the exercise . Based on these exercises, the adaptation of the results to other scenarios is possible.

In this paper, it was not discussed the real possibilities of implementation of the PSS developed. As a design exercise, the educational actitivity achieves its scope, but a real implementation demands a deeper analysis.

The exercises about different contexts permit the new generation of designers to look into cultures and realities. In fact, in the so-called emerging contexts<sup>11</sup> the PSS could be a possibility to increase the access for socio-economic advantages. However in these contexts there are already many examples of PSS.

<sup>11</sup> *“Being aware of the limits of gathering in one category various developing and newly industrialised contexts” the research unit DIS adopted “the expression emerging contexts aiming at some possible general considerations” (Penin, L. and Vezzol, C., 2005b, p. 6).*

It may seem difficult to achieve effective solutions without being part of a context and without experiencing its problems. However, the results of such an experience could be solutions which are not “contaminated” by the context logic or standards.

## References

- Bärsch, J (2001). *The Feasibility of an EU Eco-label for Furniture*. Final report. Umweltbundesamt (Federal Environmental Agency), Berlin, GE.
- Goedkoop, M. at all. *The Eco-indicator 95*. Manual for designers. Prè Consultants, Amersfoort, NL. Available in: <http://www.pre.nl/eco-indicator95/eco-indicator95.htm>.
- Manzini, E.; Bertola, P. (edited by) (2004). *Design Multiverso. Appunti di fenomenologia del design*. Poli.Design, Milano, IT.
- Penin, L.; Vezzoli, C. (2005b). *Design Research and Education for Sustainability in Emerging Countries in Proceedings of the International Conference "Design Education Tradition and Modernity"*, National Institute of Design, Ahmedabad, IN.
- Penin, L.; Vezzoli, C. (2005b). *Designing Sustainable Product-Service Systems for All. Sustainable clothing care concepts for university campuses in emerging contexts*. Libreria Clup, Milano, IT.
- Tischner, U. at all (2004). *Product Service Systems to Offices*. State of the art study. SusProNet Report. Available in: [http://www.suspronet.org/fs\\_reports.htm](http://www.suspronet.org/fs_reports.htm).
- Vezzoli, C; Halen, C. van; Wimmer, R (2004). *Methodology for Product Service System Innovation. How to develop clean, clever and competitive strategies in companies*. Van Gorcum, Assen, the Netherlands.

# POSTER Socio-economic drivers of (non-) sustainable food consumption

*An Analysis for Austria*

Birgit Friedl <sup>a,b</sup>, Ines Omann <sup>c</sup> and Alexandra Pack <sup>b</sup>

<sup>a</sup> *University of Graz, Department of Economics, Graz, Austria*

<sup>b</sup> *Wegener Center for Climate and Global Change, Graz, Austria*

<sup>c</sup> *Sustainable Europe Research Institute (SERI), Vienna, Austria*

## 1 Introduction

In research on sustainability, the focus on household food consumption is relatively new yet very important. The relation of sustainability to the area of consumption was first stressed in Agenda 21, where it is said that unsustainable consumption and production patterns are the main cause for global environmental deterioration. Particular attention is paid to the role of households as consumers and the consequences of their choices (UNSD, 2006). Current trends suggest that the fraction of food consumption in total household expenditures is declining (e.g., for Austria in 2002: 12.1% and 1970: 20%), but the daily calorie intake is increasing as do environmental pressures from food consumption (OECD, 2002a; Payer et al., 2000; EEA, 2005). Within the EU-25, approximately one third of total environmental impacts from households can be related to food and drink consumption (Tukker et al., 2005). Among these impacts are energy use, land use, water and soil pollution, emission of greenhouse gases (see section 4). When including the environmental affects of storing and preparing meals and of out-of-home consumption, figures for food-related environmental impacts rise to more than 40% of the total. In fact, the environmental impact of consumed foods and beverages exceeds the impacts of all other investigated consumption domains, even transport (17% of measured impacts) and housing (7% of measured impacts).

However, environmental impacts differ considerably across food categories, as verified by several studies. According to Tukker et al. (2005), meat and meat products are the most environmental significant sub-category within food consumption for EU-25, with contributions between 9% and 14% to global warming potential, photochemical oxidation and acidification, and even around 24% to total eutrophication.

When comparing different diets in Germany, Taylor (2000) finds the most ecological compatible diet to be the whole food diet of vegetarians, followed by the non-vegetarian type. An exception to this rule, where a

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

vegetarian diet can be more environmental harmful than a meat based one, is singled out in an earlier study by Carlsson-Kanyama (1998) and refers to cases, where the vegetarian diet consists of a high share of exotic foods. Especially rice, salad and tomatoes turn out to have higher CO<sub>2</sub> emissions than other food groups, due to greenhouse production and long distance transportation (Kramer et al., 1998; Jungbluth, 2000).

The aim of the present paper is thus to investigate the sustainability of household food consumption across socio-economic groups, acknowledging that households' preferences for and expenditures on foods differ significantly by household specific characteristics like age, income, education and labor force status, as discussed in more detail in Section 2. Using the Austrian Household Budget Survey 1999/2000, in Section 3 we analyze Austrian household food consumption patterns by focusing on four socio-economic characteristics (age, income, education, labor force status) and three highly relevant food categories in more detail: meat, vegetable and fruit. The selection of these food categories is based on the high environmental impacts of meat relative to vegetable and fruit and, on the other hand, the large differences in environmental impacts within these categories (meat varieties, methods of growing, etc.). Building on these results, we discuss the degree of non-sustainability of Austrian food consumption patterns across socio-economic groups, in particular environmental impacts and health in Section 4. In Section 5, we suggest policy measures to induce sustainable food consumption patterns.

## **2 Food consumption patterns in Austria**

### **2.1 Data base**

The analysis of Austrian food consumption patterns is based on the Austrian Household Budget Survey 1999/2000, which contains a collection of data concerning total household income and expenditures of private households. The survey comprises the expenditure figures (in ATS) of private households according to the COICOP nomenclature, a recognized international list of classifications which groups consumption expenditures by purpose (European Commission and Eurostat, 2006). Apart from expenditures, quantities consumed (in kilogram, litre or units) are available in the 1999/2000 Household Budget Survey for the category of foods and beverages. Furthermore, this survey collects information on socio-economic and demographic characteristics of the households. The characteristic income covers the total household net income whereas the attributes age, gender and education refer to the household head, which is defined as the household member that contributes most to total household net income (Statistik Austria, 2004).

### **2.2 Household expenditures and consumed quantities**

#### *2.2.1 Total household expenditures by COICOP*

Before focusing on food-related expenditures, a short overview of the allocation of total monthly household expenditures (€2,437) of an average Austrian household across COICOP categories is given (Figure 1). The highest share of total household budget is spent on housing, water,

electricity, gas and other fuels (24%), followed by transport which constitutes a share of 15%. In line with the trend of declining household expenditures on nutrition in high income countries (OECD, 2002a), Austrians spend a rather low percentage of their total household budget on foods and beverages (13%). By including expenditures on out-of-home consumption (i.e., expenditures on eating in hotels or restaurants), the share rises by 6% to 19%.

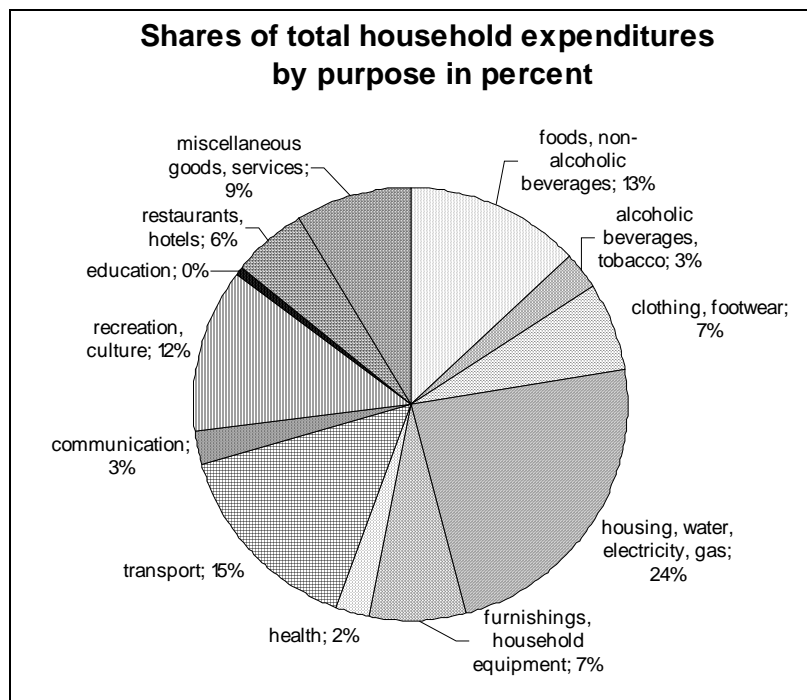


Figure 1: Shares of total household expenditures by purpose (COICOP categories) in percent (STAT, 2004; own calculation)

### 2.2.2 Expenditures on and consumed quantities of foods and beverages

The total household expenditures on foods and non-alcoholic beverages amounts to €321 per month (€289 is spent on foods and €32 on beverages). About one fifth of total expenditures on the aggregate of foods and beverages is attributable to meat expenditures (22%). Bread and cereals account for 15%, milk and milk products for 13%, whereas expenditures on fruits and vegetables each constitute a share of 8%. Relative expenditures on candies and sweets (8%) are as high as on vegetables or fruits. The remaining 26% is attributable to non-alcoholic beverages (10%), fish and seafood (2%), oils and fats (3%) and other foods (12%).

By looking more closely at the consumed quantities of different food and beverage categories (Table 1), Austrian consumption patterns are found to be in line with international trends mentioned by OECD (2002a), for example the shift to increased consumption of vegetables (with a large share of frozen products), fruits, bottled beverages, cereal products (result of higher consumption of fast food, pizza and pasta), and meat (in particular pork and poultry). Animal fats are more and more substituted by vegetable oils. A

decline can be observed in consumption of potatoes and dairy products, except cheese. Another strong trend is the increasing consumption of easy-to-prepare or pre-prepared meals and the increase of out-of-home consumption. There is one special trend in Austria. Due to the increasing share of people over 60 in future, the demand for food will decline, because older people have lower energy requirements.

Concerning out-of-home consumption, the Austrian Household Budget Survey gives only information about monthly expenditures but does not specify amounts or kind of meals consumed. Therefore, consumed quantities out-of-home are not considered in our calculations.

Table 1: Monthly household consumption of and expenditures on selected foods and non-alcoholic beverages of an average Austrian household in kilogram, liter, units and Euro (EUR-ATS) (STAT, 2004; own calculation)

	quantities consumed	expenditures
<b>Foods</b>		<b>in EUR-ATS</b>
carbohydrates (rice, bread, flour, pasta)	12.1 kg	21.3
Vegetables	14.1 kg	18.2
Fruits	13.0 kg	21.4
Meat	9.8 kg	66.4
Fish	0.6 kg	6.7
Yogurt	2.7 kg	6.5
cheese, curd	2.0 kg	14.2
Milk	13.7 l	10.6
Eggs	37.0 units	6.3
animal fats	0.9 kg	4.3
vegetable fats	0.7 kg	2.2
candies (sugar, jam,...)	4.5 kg	6.1
<b>beverages (non-alcoholic)</b>		<b>in EUR-ATS</b>
coffee, tea, cacao	1.6 kg	11.5
mineral water, lemonades, juices	29.0 l	20.2

\*) Expenditure figures are available for all food categories, but for some categories information on consumption data is not available (in total, for 30% of expenditures figures). Therefore, the table shows only expenditure figures for which corresponding quantities are available.

### 3 Socio-economic determinants of household food consumption in Austria

When investigating the influence of socio-economic household characteristics (household size, age, income, educational level and labour force status), we observe the following trends. For expenditures on in-home food consumption, the most influential determinant is the household size: with each additional member household food expenditures increase. Apart from the household size, food expenditures are positively determined by age (in the strict sense expenditures peaking at middle aged groups) and total household net income (results are statistical significant, however show only a weak positive influence). Interestingly, as monthly household expenditures on out-of-home increase, expenditures on foods purchased for consumption at home rise, too. The educational level, however, has no significant influence on food expenditures.



Table 2: Regression of the monthly household expenditures on foods and beverages (STAT, 2004; own calculation)

Independent variables	coefficients*	standard error
Constant	-45.4	10.4
household size (persons)	86.5	2.0
age (head of the household ; in years)	2.1	0.2
out-of-home consumption	0.1	0.01
net income (per household, per month, EUR-ATS)	0.001	0.00
R <sup>2</sup>	0.34**	

\*) Only significant coefficients are displayed. The coefficient *education* does not significantly influence household expenditures on foods and beverages.

\*\*) Approximately 34% of total food expenditures can be explained by the influence of the determinants household size, age, out-of-home consumption and net income.

While Table 2 clearly demonstrates that the household size significantly influences absolute food expenditures, no such size effect can be observed for consumption preferences for different food and beverage categories (in terms of relative and absolute consumed quantities). In contrast, preferences are more determined by age, household income, educational level and labour force status.

For comparing the differences in preference for food and beverage categories across distinct socio-economic household groups, we use equivalence expenditures and equivalence consumption figures in order to eliminate the influence of household size. Equivalence scales assign each household type a value in proportion to its needs depending on the number and age of people living in the household. Standardized figures are obtained by dividing expenditure and consumption figures of each household by the corresponding equivalence value. Thus, the basis of standardization is the one-person household (Statistik Austria, 2004).

### 3.1 Age

According to Hayn et al. (2005), older people are more health orientated whereas younger people adjust their diet more to time constraints. Furthermore, Gossard and York (2003) argue that older people show a trend toward lower meat consumption. Let us investigate this issue for the case of Austria by focusing on consumed quantities of selected food categories.

In general, consumption figures of the main food categories, namely rice, bread, flour and pasta, vegetables, fruits and meat, respond positively as the age of the household head increases. This can be partly explained by the fact that expenditures on out-of-home consumption decrease as the household head becomes older. Vegetable consumption of the oldest age group, for example, is more than twice that of the youngest age group, 10 kg versus 4 kg. The preference for different vegetable categories (in relative figures) is shown in Figure 2. Within the category of vegetables, a strong tendency towards higher potato consumption with increasing age can be observed: Fresh vegetable consumption of the oldest age group is dominated by potatoes (51%), whereas households with heads aged 39 and younger consume a share of 39%. In contrast, younger age groups have a higher share of fruiting and flowering vegetables (29%) and root vegetables (17%). This preference for fruiting and flowering vegetables instead of potatoes can be explained by the time consuming preparation needed for potatoes, and the

preference for foods which can be quickly prepared. Older consumers adhere more to traditional eating habits, which are characterized by a high relative intake of potatoes due to low price, nice taste and their satiating character.

Similarly to vegetable consumption, meat consumption increases with the age of the household head, from 3 kg in the youngest age group to 6 kg in the oldest. The (relative) preference for different meat categories by age is shown in Figure 3. Pork consumption responds positively to increasing age, and constitutes a share of 26% in the 60 and older group. The youngest age group, on the contrary, has only a share of 20% for pork. On the other hand, the youngest age group consumes more than 40% of meats in the form of dried, salted and smoked meat, whereas the oldest group consumes only 32%. Again, the preference for dried, salted and smoked meat within the younger age group results from an increase in snack consumption due to time restrictions for meal preparation. Relative consumption of poultry is rather stable across age groups. Interestingly, the consumption of minced meat accounts for 12% of total meat consumption within the youngest age group, which is more than 5%-points higher than in all other age groups. Again low prices as well as the easy preparation of minced meat may address the needs of younger age groups. Beef and veal consumption is more or less balanced between all age groups. In fact, only households with young heads (29 and younger) show very low figures, 7% of total meat consumption. It may be that the high prices of beef and veal are responsible for this low share.

### 3.2 Income

Several authors argue that lower income results in a preference for cheap and filling foods, whereas dietary habits of high income households are more determined by taste and time constraints (Hayn et al., 2005; Trichopolou et al., 2002). This raises the question how do different income levels affect people's preferences for food?

The analysis for Austria shows that the categories of rice, bread, flour and pasta, vegetables, fruits and meat respond negatively to increases in household income. In particular, the consumption of vegetables declines by one kilogram from low to high income households, however within the category of vegetables preferences change (Figure 4): the relative consumption of potatoes as share of total fresh vegetable consumption decreases considerably as income grows. Potato consumption of low income households constitutes a share of 49% of total fresh vegetable consumption, whereas high-income households consume only 38%. Furthermore, relative figures of fruiting, flowering, leaf vegetables and herbs (as share of total fresh vegetable consumption) become higher as income increases. This trend could be determined by both the price and time effect: potatoes are inexpensive and satiating, but require longer preparation time in comparison to fruiting, flowering and leaf vegetables, which can be consumed without cooking as snacks and in salads.

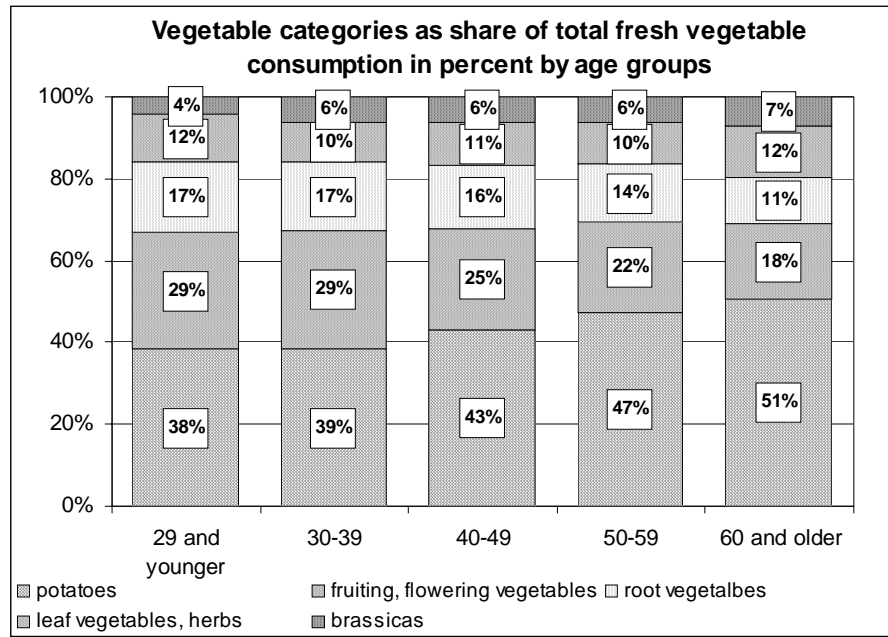


Figure 2: Vegetable categories as share of total fresh vegetable equivalence consumption (in quantities) in percent by age groups (STAT, 2004; own calculation)

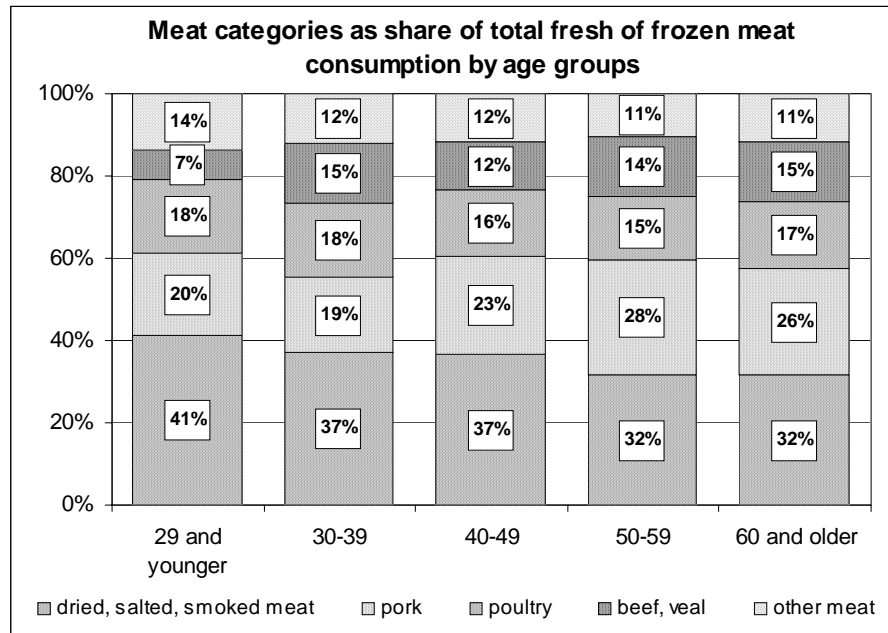


Figure 3: Meat categories as share of total fresh or frozen meat equivalence consumption (in quantities) in percent by age groups (STAT, 2004; own calculation)

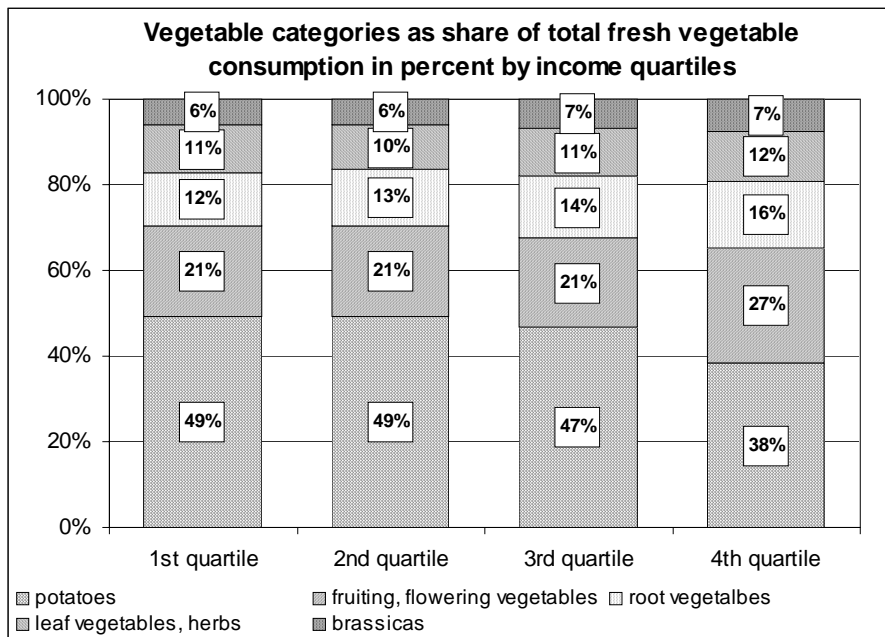


Figure 4: Vegetable categories as share of total fresh vegetable equivalence consumption (in quantities) in percent by income quartiles (STAT, 2004; own calculation)

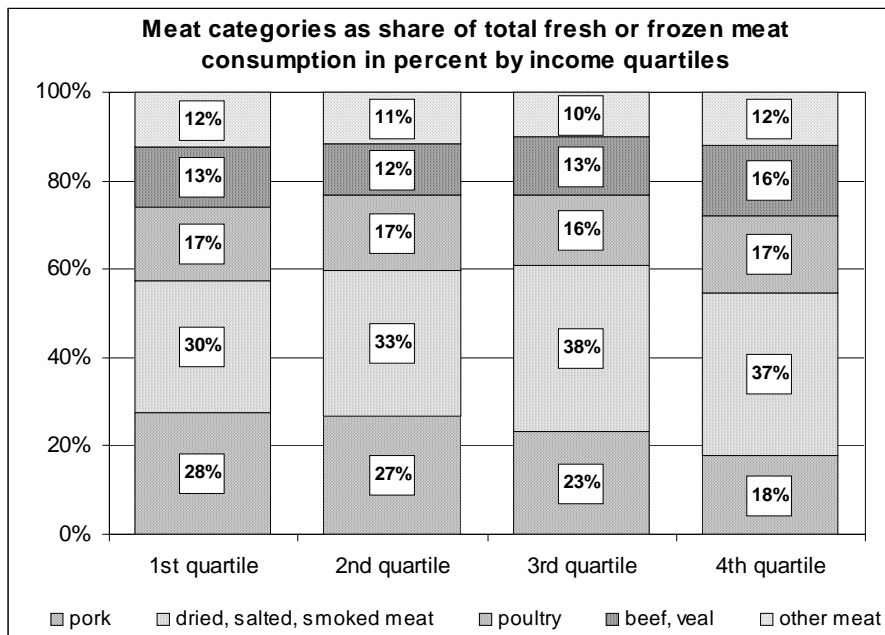


Figure 5: Meat categories as share of total fresh meat equivalence consumption (in quantities) in percent by income quartiles (STAT 2004; own calculation)

Concerning meat consumption, our analysis confirms the results by Gossard and York (2003), who argue that income has no influence on total consumed quantities of meat, which is around 5 kg per month and household, apart from the share of beef. The percentage distribution of various meat types as share of total meat consumption across income quartiles is shown in Figure 5. Indeed, calculations indicate that high income households consume a higher share of beef (16% of total meat consumption), whereas low income households substitute beef (13%) with higher amounts of pork, resulting in 28% pork consumption for low income households versus 18% for high income households. In addition, the category of dried, salted and smoked meat rises significantly from the lowest (30%) to the highest income quartile (37%), due to time scarcity by high income households.

### 3.3 Education

Education is said to be a precondition for the understanding of health and environmental-related information, which in turn affects fundamentally peoples' food choices (Trichopoulou et al., 2002). Several authors agree that a higher educational level results in a reduced consumption of meat but in a higher intake of fruits and vegetables (Gossard and York, 2003; Irala-Estevez et al., 2000; Trichopoulou et al., 2002).

As it was the case with income, all food categories respond negatively to increases in the educational level of the household head. Vegetable consumption of the lowest-educated households, for example, is about 4 kg higher, 9 kg, than that of high-school or college/university-educated households (5 kg). The consumption of meat falls approximately by a half from lowest-educated with 6 kg to the highest educated households with 3 kg. These results can be explained by higher expenditures on out-of-home consumption by high income households, so that needs for food consumed at home are lowered, and because higher educated people have a higher share of vegetarians.

With regard to single categories of vegetables and meat, trends identified in the preceding section appear again: Higher educated household have higher preference for fruiting and flowering vegetables (on account of potatoes), for beef, and for dried, salted and smoked meat (instead of pork). These results can be explained by the positive correlation between education and income, and on the other hand, by time restrictions (the share of people in the labour force is increasing from lower educated to higher educated households).

### 3.4 Labour force status

Differences in consumed quantities of food and beverage categories by selected labour force status groups (farming households, self-employed households and employees, public servants and clerks in low, middle, high or top positions) demonstrate that the group of employees (including public servants and clerks) in middle, high and top positions have the lowest in-home consumption figures for vegetables, fruits, meat and the aggregate of rice, bread, flour and pasta. In contrast, farming households have the highest figures within these categories. In the following, a more detailed description of consumption figures and preferences for vegetables and meat is given.

High numbers for vegetable consumption (in quantities) occur in farming households (10 kg), whereas self-employed households, employees, public servants and clerks consume markedly less, between 6 kg and 7 kg. Regarding the distribution across various vegetable types, potato consumption is particularly high within farming and self-employed households, as well as in those lead by employees in low position, (between 46 and 48%). Employee households substitute fruiting and flowering vegetables (between 25% and 28%) and root vegetables (between 17% and 18%) for potatoes. The highest share in leaf vegetable, herb and brassica consumption, at 14% and 9% respectively, can be found in farming households.

By focusing the analysis on the impact of labour force status on the consumption of various meat categories, at least two trends can be identified. First, pork consumption shows high relative figures in farming (31%) and self-employed households (26%), but shows notably less importance in employee households irrespective of position, where pork consumption accounts for between 15% and 24%. Second, the lower consumption of pork by employee households is compensated for by a higher intake of dried, salted or smoked meat (between 33% and 44%). The consumption of beef, veal and poultry seems to be mostly independent of labour force status. Only the group of employees, public servants and clerks in top positions consumes relatively more beef and veal (17% of total fresh or frozen meat consumption) than the other labour force status groups, due to their higher income level.

#### **4 The sustainability of food consumption by socio-economic groups**

The present section addresses the following question? What is the net effect of age, income, education and labour force status on the environment given that households with younger heads, higher income and educated households, as well as employee and self-employed households, show lower consumption quantities of meat, vegetables and fruits, but prefer foods (beef, dried, salted and smoked meat instead of pork, fruiting and flowering vegetables on account of potatoes, exotic fruits instead of apples and pears) with higher environmental pressure within this categories?

In order to answer this question, we proceed in three steps. First, we discuss the health and environmental impacts of food consumption.<sup>1</sup> Then, we investigate the consequences of socioeconomic preferences on aggregate food consumption patterns. Finally, we calculate the CO<sub>2</sub> equivalent emissions of meat and vegetable consumption across socioeconomic groups, by differentiating quantity effects from preference effects.

<sup>1</sup> The authors are aware that sustainable food consumption addresses more than health and environmental impacts, which are in particular treated in this paper. The paper is based on a project (sufo:trop, see Pack et al., 2006; financed by the Global Change Program of the Austrian Academy of Sciences) which focuses on these two areas. However it is planned to expand the study by other social as well as economic issues in a future project.

#### 4.1 Health and environmental impacts of food consumption

Sustainable or “green” food consumption refers to a diet that has relatively low environmental impacts but requires the amount of nutrients and energy to maintain good health. However, diets that are environmental compatible but are sparse from the nutritional viewpoint lead to malnutrition and deficiencies and could therefore not be called sustainable (Dahlin und Lindeskog, 1999; Duchin, 2004; Erdmann et al., 1999; Hayn et al., 2005; Tanner and Kast, 2003; Wallèn et al., 2004; White, 2000). Accordingly, sustainable food consumption can be defined as the preference for meatless or reduced meat diets, organically, regionally and seasonally produced foods, minimally processed, ecologically packed and tastefully prepared foods as well as foods traded fairly (Leitzmann, 2003).

Duchin (2004) points out that current western diets, especially the American diet, is characterized by a high intake of calories with a large portion of energy from animal fats and added sugars. It leads to obesity, disabilities and chronic diseases and thus cannot be sustainable. According to publications by the FAO and WHO (2003) and by Fonds Gesundes Österreich (2005), a healthy diet consists of a low intake of fat, added sugars and protein from animals, implying a reduction in the consumption of meat and eggs. Substitutes for animal protein can be fish, dairy products and legumes. Indispensable for a sustainable diet is the consumption of wholemeal products, potatoes and, above all, vegetables and fruits, fresh if possible.

EEA (2005) and OECD (2002a) stress the complexity of the interactions between food consumption/production and the environment. We can differentiate among the effects occurring along the food chain and those across the food categories. The scale of environmental impacts from food consumption depends on where and how food is produced, processed, packaged, preserved, distributed, prepared and disposed of. The most significant environmental impacts occur at the beginning of the production chain, in the area of food production (Goodland, 1997; Hofer, 1999; OECD, 2002a). Agricultural production requires 28% of the food sector’s total energy requirement. Together with livestock production, agricultural production is responsible for global deforestation and loss of biodiversity and contributes to soil and water pollution, due to the use pesticides and fertilizers, to greenhouse gas emissions, to fertility loss of soils, and to eutrophication and acidification of water bodies. While fuel combustion is the main source for CO<sub>2</sub> emissions, other important greenhouse gases are methane (CH<sub>4</sub>) from animal husbandry, waste and rice planting, and nitrous oxide (N<sub>2</sub>O) from industry and agricultural soils (Carlsson-Kanyama, 1998).

Although agricultural production accounts for most of the environmental impacts in the food production cycle, the use of energy and water as well as waste production in food processing and packaging play a significant role, too. Transportation, as a process linking the stations along the food chain, has got a series of environmental impacts.

The environmental pressure of household food consumption can be differentiated into direct and indirect impacts. Direct impacts describe environmental consequences of activities like transport, cooking, dish washing and waste disposal (Payer et al., 2000). Indirect impacts of household food consumption refer to individual consumption choices and their impact on the entire production chain.

Concerning environmental effects across the food categories, meat and meat products are identified as one of the most environmental significant sub-categories for all impact categories looked at in this paper and the underlying study (Pack et al. 2006). The fact that meat production requires larger quantities of natural resources, in particular land, energy and water, was confirmed by many studies (Leitzmann, 2003; Gossard and York, 2003; White, 2000; Goodland, 1997; Carlsson-Kanyama and Faist, 2000; OECD, 2001). In fact, the ecological footprint triggered by meat consumption is higher than by vegetarian consumption in all regions (White, 2000). Within the category of meat, pork and poultry are, from an ecological viewpoint, more sustainable than lamb, beef or veal, which cause the worst damage. The second important group of food products are the aggregate of milk, cheese and all kinds of dairy products, the aggregate of bread and cereal products as well as non alcoholic drinks (Tukker et al., 2005).

The impacts from meat consumption are intensive land use for grazing and grain production, water use and pollution. The main results are that meat has higher energy requirements than vegetables. Analogously, the consumption of cereals and flour leads to intensive land use. The impacts of vegetable and fruit consumption comprise water pollution caused by pesticides and fertilizer utilisation, agglomeration of organic waste as well as high energy use for greenhouse production and food transport in order to assure year round availability (OECD, 2001).

As far as product attributes are concerned, greenhouse products have, in general, considerably higher environmental impacts than open-ground production, whereas organically grown foods have the lowest impact. By contrast, locally produced vegetables are the most environmental friendly (Jungbluth, 2000). Concerning material input the highest resource demand is for agricultural production of meat and dairy products (Faist et al., 2001).

Summarising the environmental impacts of food consumption, of all stages of a food product life cycle, agriculture production is responsible for the highest environmental effects. The influence of packaging material and transport is of minor importance compared to other categories. Concerning food categories, the smallest environmental impacts can be expected from seasonable and fresh vegetable products grown in an extensive manner (such as organic agriculture) with little transport and light packaging. Not surprisingly, meat and meat products show the most severe environmental consequences, followed by dairy products and other product groups (such as fats and oils, soft drinks and bread/bread products).

#### **4.2 Relative shares of different food categories across socio-economic groups**

Let us now analyze the relative shares of different food categories (meat, vegetable, and fruit) by the socio-economic factors age, income, and education. In order to verify the validity of the claim that health awareness increases for older people, ratios are calculated by dividing consumed quantities of carbohydrate products (rice, bread, flour and pasta), vegetables and fruits by meat quantities. Table 3 shows the carbohydrate to meat ratio, vegetable to meat ratio and fruit to meat ratio, which indicate the amount of consumed carbohydrates, vegetables and fruits (in kilograms) in proportion to one kilogram of meat.



Table 3: Mean ratios between carbohydrate, vegetable, fruit consumption and meat consumption by age groups (STAT, 2004; own calculation)

age group	carbohydrate to meat ratio	vegetable to meat ratio	fruit to meat ratio
29 and younger	1.4	1.4	1.6
30-39	1.1	1.4	1.4
40-49	1.1	1.3	1.3
50-59	0.8	1.4	1.2
60 and older	0.9	1.7	1.6

In fact, the vegetable to meat and fruit to meat ratio of the oldest age group is higher compared with middle or younger aged households. In other words, the age group of those 60 and older has a more healthy diet, since this group also proportionately consumes more vegetables and fruits. Only the 29 and younger age group compares, also with a high fruit-meat ratio of 1.6. Conversely, the carbohydrate to meat ratio decreases from younger to mature age groups. That decrease may result from a preference of younger people for quick-to-prepare foods (rice, pasta products, bread).

While preference for different meat categories alter with rising income, the carbohydrate to meat ratio, vegetable to meat ratio and fruit to meat ratio do not change significantly. On average households consume 1.5 kg of vegetables, 1.4 kg fruits and 1.3 kg of carbohydrates per one kilogram of meat.

In order to verify claims on rising vegetable and fruit consumption with higher educational level made by several authors cited before, the ratios between fruits, vegetables carbohydrates and meat are calculated across educational levels, too. Indeed, results for Austria confirm not only lower meat consumption, but also higher fruit and vegetable consumption. In particular, we find that the carbohydrate to meat, vegetable to meat and fruit to meat ratios increase with higher educational level. In other words, low educated households (maximum secondary school achievement) consume fewer carbohydrates (1.3), vegetables (1.5) and fruits (1.3) in proportion to one kilogram of meat. Higher educated households (college/university degree), on the contrary, have higher ratios in favour of carbohydrate, vegetable and fruit consumption, 1.6 for carbohydrate, 1.9 for vegetable and 2.1 for fruit consumption. Figure 6 shows the median (framed by the 25% and 75% percentile) vegetable to meat ratio by educational level. On the basis of the Duncan test about mean equivalence, the group means of the vegetable-to-meat ratios differ significantly (error statistic  $p < 0.05$ ), and the same applies to the fruit to meat and carbohydrate to meat ratio.

Regarding labour force status, no general trends can be observed. The carbohydrate to meat ratio is lowest for employees in low position (1.2) and highest for farmers (1.5). Generally speaking, this ratio increases moderately from low to top positions. On the other hand, the vegetable to meat ratio is highest for employees in low positions (1.9) and lowest for farmers and self-employees (1.4 each), with employees in middle and top positions falling in between (1.4). Finally, the fruit to meat ratio is lowest for farm households (1.3) and highest for employees in middle and top positions (1.8).

Based on these differences across socio-economic groups, we will discuss the following socioeconomic groups in more detail: household with heads of age 29 and younger with those with age 60 years and older;

households in the first income quartile with those in the fourth quartile; households with secondary school attainment with those with university; and finally farm households with households of top managers.

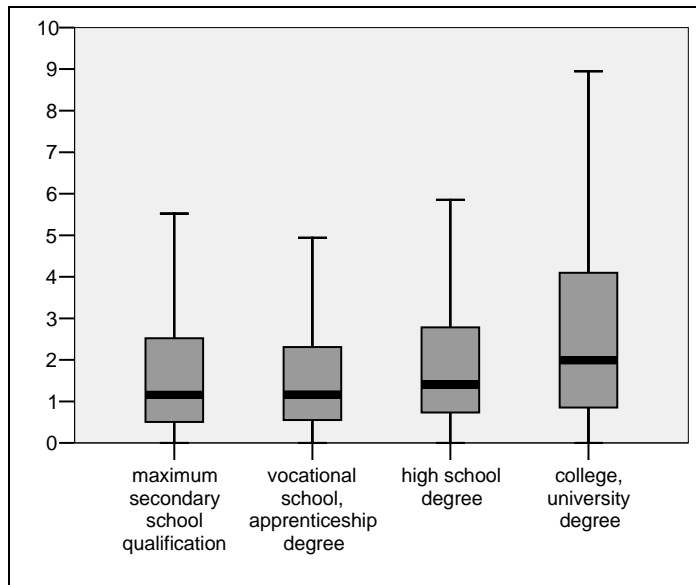


Figure 6: Ratios between vegetable and meat consumption by educational level of the household head (STAT 2004; own calculation)

#### 4.3 Environmental impacts: the effects of income, age and education

In assessing the environmental sustainability of household food consumption by different socio-economic groups, we refer to emissions of CO<sub>2</sub> equivalents generated through production, processing, transportation, retailing and consumption of specific food categories. Environmental effects were calculated from specific emissions in CO<sub>2</sub> equivalents (units in gram per kg food) per food category (for meat and vegetables), based on Taylor (2000). For meat, LCA estimates were available for beef, pork, dried, salted and smoked meat, and poultry. Due to non-availability of data, sheep and goat, minced meat and other meat could not be considered in the analysis. However, the share of these sub-categories is low such that overall results are likely to be unaffected. Since the consumption database does not distinguish organic production from conventional one, we refer to emission coefficients for conventional production. Regarding vegetables, specific emissions are available for potatoes, fruiting and flowering vegetables (as a proxy for fruiting and flowering vegetables we generate a mean emission coefficient from tomatoes, leek, peas and green beans), a selection of root vegetables (mean value is taken for root vegetables), salad and spinach (1/2 each is assumed to contribute to leaf vegetables), selection of brassicas (mean value is taken for brassicas). Concerning tomatoes, we assume that 1/3 is grown on field and 2/3 in glasshouse.

In order to gain CO<sub>2</sub> equivalent emission for meat and vegetable consumption by different socio-economic groups, we multiply these specific

emissions by the consumed quantities in the respective food category. In order to be able to interpret the emissions, we use the average Austrian household as reference point. Thus, we first calculate the difference relative to this average (in %, called the “total effect”). Then, we differentiate for the effect of differences in quantities consumed and in preferences for specific types of meat and vegetables. For the quantity effect, we take the preferences of an average Austrian household and the total quantity consumed by the socio-economic group. For the preference effect, we take the total quantity consumed by an average Austrian household and the preference held by the socio-economic group. Table 4 reports the results for meat and vegetable consumption across socio-economic groups.

The general trends are as follows. First, the highest environmental effects from meat and vegetable consumption can be observed for households with heads of 60 years and older (+17.8% compared to average household), and for farmers (+35%), while the lowest environmental effects emerge for households with university education (-33.5%) and households with heads of 29 years and younger. Moreover, the quantity effect and preference effect always point in opposite directions: for instance, low income households have a positive quantity effect (that causes 6% more emissions than on average) and a negative preference effect (that is responsible for 4.4% less emissions than on average, due to a lower preference for environmental harmful meat and vegetable categories). For meat, for vegetables and for the total effect of both, the quantity and preference effect point in the same direction, except for high educated households and high income households. The latter two have a lower environmental effect from meat consumption than the average household (-4.1% for high income; -34.9% for high education) but a higher environmental effect from vegetable consumption (+1.1% and +4.4% respectively).

Let us now discuss the results in more detail. Starting with the effect of age, older people consume more vegetables and fruits in proportion to meat. Younger ones, on the other hand, have a higher (relative) preference for dried, smoked and salted meat, minced meat, fruiting and flowering vegetables. In addition, older households choose their diet in line with traditional eating habits (potatoes, apples, pork) whereas younger ones compose their diet more diversely (exotic fruits). With respect to the environmental effects of food consumption, older age groups are however less environmental sustainable than younger ones, based on older people’s higher quantities consumed. Their preference for apples, instead of exotic fruits, and potatoes instead of fruiting and flowering vegetables leads to a negative preference effect, which is too weak to compensate the strong positive quantity effect. The magnitude of the quantity effect can be explained by the low share of out of home consumption by older households. The effect of income on sustainability is as follows. Emissions of CO<sub>2</sub> equivalents (in kg) differ only marginal as income grows. While the consumed quantities of vegetables decline by 1.2 kg from the first to the fourth quartile, preferences for fruiting and flowering vegetables (in particular tomatoes) on account of potatoes cause emissions of CO<sub>2</sub> equivalents to fall only by 0.1 kg. As discussed above, total emissions of high income households decline by 3.9%, due to a negative quantity effect and a positive preference effect (more beef, more fruiting and flowering vegetables). Low income households contribute to emissions by 1.7% more

than the average household, despite a strong negative preference effect (-4.4%). With respect to (environmentally) sustainability, we find therefore ambiguous results. While lower quantities of fruiting and flowering vegetables and beef indicate a more sustainable consumption pattern by low income households, on the other hand, high absolute quantities of meat could speak for less sustainable patterns.

Table 4: Change in emissions of CO<sub>2</sub> equivalents (in g) from food and vegetable consumption of selected socio-economic groups relative to average Austrian household

		change in CO <sub>2</sub> emissions relative to average Austrian household		
		quantity effect	preference effect	total effect
<b>Age &lt; 30 years</b>	total (Δ%)	-44.3%	+1.7%	-42.6%
	meat (Δ%)	-44.2%	+1.2%	-43.0%
	vegetable (Δ%)	-46.3%	+14.2%	-32.1%
<b>Age &gt; 60 years</b>	total (Δ%)	+19.7%	-1.9%	+17.8%
	meat (Δ%)	+19.1%	-1.7%	+17.4%
	vegetable (Δ%)	+37.3%	-8.5%	+28.8%
<b>Low income (Q1)</b>	total (Δ%)	+6.0%	-4.4%	+1.7%
	meat (Δ%)	+6.0%	-4.4%	+1.6%
	vegetable (Δ%)	+6.4%	-2.9%	+3.5%
<b>high income (Q4)</b>	total (Δ%)	-10.1%	+6.2%	-3.9%
	meat (Δ%)	-10.1%	+6.0%	-4.1%
	vegetable (Δ%)	-9.5%	+10.6%	+1.1%
<b>Low education</b> (secondary school)	total (Δ%)	+29.1%	-3.9%	+25.2%
	meat (Δ%)	+29.2%	-3.7%	+25.5%
	vegetable (Δ%)	+25.2%	-9.6%	+15.5%
<b>high education</b> (university)	total (Δ%)	-38.5%	+5.0%	-33.5%
	meat (Δ%)	-39.1%	+4.3%	-34.9%
	vegetable (Δ%)	-21.2%	+25.6%	+4.4%
<b>farmers</b>	total (Δ%)	+39.4%	-3.6%	+35.8%
	meat (Δ%)	+39.7%	-3.5%	+36.2%
	vegetable (Δ%)	+31.1%	-8.6%	+22.5%
<b>Top managers</b>	total (Δ%)	-15.5%	+10.7%	-4.8%
	meat (Δ%)	-15.3%	+10.7%	-4.6%
	vegetable (Δ%)	-23.1%	+12.6%	-10.5%

The influence of education on emissions resulting from vegetable consumption is in similar direction as for income, but the magnitude of the effects is stronger. Emissions of CO<sub>2</sub> equivalents of vegetable and meat consumption decrease slightly with increasing educational level (but are above average for both), which is attributable to a strong decline in the quantity effect (from +29.1% for low educated to -38.5% for highly educated households) and a moderate increase in the preference effect (from -3.9% to +5%). The preference effect is particularly strong for vegetables among high educated households (+25.6%), due to a change in preferences (root vegetables, fruiting and flowering vegetables on account of potatoes). The influence of education on emissions resulting from meat consumption is considerable. Emissions resulting from meat consumption fall dramatically:

from +25.5% for the lowest (maximum secondary school) to -34.9% for the highest educational level (college/university). This result can be explained by the strong decline in meat consumption (5.6 kg versus 2.6 kg). When considering that the average emissions of meat consumption are around ten times (e.g., Halberg et al., 2006) that caused by vegetables (with the exception of glasshouse vegetables which cause nearly the same emission as pork), the determinant education plays a major role in reducing environmental impacts from food consumption. However, since the dietary choices of higher educated households generally depend on three factors, (i.e., health and environmental awareness, taste and time scarcity), the total effect of higher education is the net effect of the gains in terms of sustainability, due to a higher awareness of environmental and health issues, and of the loss due to time scarcity and taste.

Finally, the effect of labour force status can be best understood by investigating two groups which are quite different in their food choices: farm households and top manager households. From a sustainability perspective, farm households contribute considerably more to emissions, because of higher total consumption, particularly of meat. On the other hand, top managers contribute far less to emissions from meat and vegetable consumption, due to a higher tendency to out of home consumption. While the quantity effect is thus clearly negative, a preference for more environmentally harmful meat and vegetable categories leads to a lower overall reduction in emissions relative to the average Austrian household.

## **5 Policy options as concluding suggestion**

In order to support the environmental sustainability of food consumption, it is necessary to change the current unsustainable food consumption patterns. There are plenty reports and articles talking about different policy options (OECD, 2001; OECD, 2002a, 2002b; Payer et al., 2000) fostering sustainable consumption in general and for food and beverages in particular. We can divide such options in those addressing all consumers (general trends) and those differentiating between them according to their consumption patterns.

In this paper we analyzed the determinants of socio-economic characteristics for food consumption behaviour. First, age and education are important factors with respect to healthy consumption patterns. The older and the better educated the less is the vegetable to meat and fruit to meat ratio. Second, concerning environmental effects, higher age and education lead to reductions in CO<sub>2</sub> emissions due to negative preference effects whereas the increasing out-of-home and easy-to-prepare-food consumption compensates this positive effect with higher income and higher education. Furthermore, the consumption of organic food is higher the older, better educated and wealthier people are (Hinteregger, 2006). Thus policies aiming at influencing the behaviour of younger and/or less educated people could be a very efficient way of changing the trend (second group of options).

If consumption patterns are to change, the behavioural decisions of consumers, but also producers or retailers have to be changed. Therefore individuals need to have adequate knowledge, a positive attitude to change (willingness) and access to sufficiently attractive<sup>2</sup> alternatives (ability)

(OECD, 2002b). Various types of policy instruments can influence those three factors, coarsely grouped into regulatory, economic and social instruments. According to the policy aim and the addressed group of people, different instruments are appropriate. In general a set of instruments including instruments from different groups is most efficient. Economic instruments usually address consumers, regulatory address producers and social address both groups. Examples for economic instruments are charges or taxes (CO<sub>2</sub> tax, material input tax) and subsidies. Social instruments mainly focus on the knowledge and willingness of people through better education, information campaigns, and labelling, or voluntary agreements by producers for actions beyond legal requirements (an Austrian example are different organic food labels belonging to supermarkets). All instruments are influencing individual choices (OECD, 2002b), which are determined by preferences, which again are determined by various factors such as biological needs and social factors (habits, culture, tradition, socio-economic characteristics). Thus, in order to change behavioural decisions it makes sense to influence preferences and if factors behind those preferences are taken into account, the success of policies can be increased. However, one has to be aware that those changes are of a mid-term to long-term character and cannot happen from one day to the other.

Having said that it makes sense to influence the consumption behaviour in general and those of households, consuming less sustainably, the following instruments are appropriate. Public education via campaigns which promote a more environmentally sustainable diet and inform consumers about the environmental impacts of their food consumption patterns could be one effective measure. These campaigns should specifically focus on young and middle-aged people, for example by involving them in different campaigns. Information in combination with labelling addresses all household types; however, the form of information can vary depending on who should be addressed (different media, in form of exhibitions, school programs, and internet). One label currently in the development phase in Austria is the FUTURO indicating a sustainability value in form of a prize (Jakubowicz, 2004).

Furthermore, consumer behaviour is strongly driven by convenience, time constraints and taste. Therefore, it is desirable to increase the supply of sustainable products fulfilling those criteria, both for in-home and out-of-home consumption. Here the behaviour of producers and retailers has to be addressed by regulatory instruments (bans), economic instruments (subsidies, taxes) or social instruments (voluntary agreements). With respect to out-of-home consumption, a more sustainable food supply by canteens of public institutions (ministries, schools, universities) could set a good example in achieving sustainability.

Thus, in order to change the currently unsustainable trend in food consumption a lot of policy instruments are available to choose from. Best is a set of instruments, economic, social and regulatory ones, aiming at all consumers on the one hand and on households with socio-economic characteristics determining higher negative sustainability impacts on the other hand.

## References

- Carlsson-Kanyama, A. (1998), *Climate change and dietary choices—how can emissions of greenhouse gases from food consumption be reduced?* Food Policy 23: 277–293
- Carlsson-Kanyama, A. and Faist, M. (2001), *Energy use in the food sector: a data survey*. A joint study by Stockholm University, Department of Systems Ecology and the Swiss Federal Institute of Technology, Department of Civil and Environmental Engineering, Zurich, 36p.
- Duchin, F. (2004), *Sustainable Consumption of Food*. Thesis, Rensselaer Polytechnic Institute, Department of Economics, New York
- Dahlin, I. and Lindeskog, P. (1999), *A first step towards sustainable dietary habits*. Stockholms Läns Landsting, Centrum för Tillämpad Näringslära, Stockholm
- Erdmann, L., Sohr, S., Behrendt, S. and Kreibich, R. (2003), *Nachhaltigkeit und Ernährung*. Werkstattbericht Nr. 57, Institut für Zukunftsstudien und Technologiebewertung, Berlin
- European Environmental Agency (EEA) (2005), *Household consumption and the environment*. EEA Report, No 11/2005, Copenhagen, 68p.
- European Commission and Eurostat (2006), Eurostat's classification server (RAMON): *Classification of Individual Consumption by Purpose (2000) – COICOP*. [http://europa.eu.int/comm/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=DSP\\_NO\\_M\\_DTL\\_VIEW&StrNom=HICP\\_2000&StrLanguageCode=EN&IntPcKey=3035434&IntKey=3035457&IntCurrentPage=1](http://europa.eu.int/comm/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=DSP_NO_M_DTL_VIEW&StrNom=HICP_2000&StrLanguageCode=EN&IntPcKey=3035434&IntKey=3035457&IntCurrentPage=1); downloaded in April 2006
- Faist, M., Kytzia, S. and Baccini, P. (2001), *The impact of household food consumption on resource and energy management*. Environment and Pollution, 15(2): 183–199
- FAO (Food and Agriculture Organization) and WHO (World Health Organization) (2003), *Diet, nutrition and the prevention of chronic diseases: a report of a joint WHO/FAO expert consultation*. WHO technical report series 916, Geneva, 149p.
- Fond Gesundes Österreich (2005), *Die Ernährungspyramide baut auf*. [http://www.gesundesleben.at/index\\_.cfm?bid=3&tid=74&uid=401&sid=7919&tabelle=beiratrag](http://www.gesundesleben.at/index_.cfm?bid=3&tid=74&uid=401&sid=7919&tabelle=beiratrag); downloaded in December 2005
- Goodland, R., (1997), *Environmental sustainability in agriculture: Diet matters*. Ecological Economics 23 (3): 189-200
- Gossard, M. H. and York, R. (2003), *Social Structural Influences on Meat Consumption*. Human Ecology Review 10(1): 1-9
- Halberg, N., Dalgaard, R. and Rasmussen, M. D. (2006), *Miljøvurdering af konventionel og økologisk avl af grøntsager. Livscyklusvurdering af produktion i væksthuse og på friland: Tomater, agurker, løg, gulerødder*. Arbejdsbericht Nr. 5 des dänischen Ministeriums für Umweltschutz, Copenhagen
- Hayn, D., Empacher, C. and Halbes S. (2005), *Trends und Entwicklung von Ernährung im Alltag. Ergebnisse einer Literaturrecherche*. Materialienband Nr. 2, Institut für sozial-ökologische Forschung (ISOE), Frankfurt am Main
- Hinteregger, E. (2006), *Organic food in Austria: Production and Consumption Patterns*. SERI Background Paper, Nr. 9. Vienna
- Hofer, K. (1999), *Ernährung und Nachhaltigkeit: Entwicklungsprozesse- Probleme- Lösungsansätze*. Arbeitsbericht NR. 135, Geographische Institut der Universität Bern.
- Irala-Estevéz D. J., Groth, M., Johansson, L., Oltersdorf, U., Prättälä, R. and Martínez-Gonzalez, A. (2000), *Systematic review of socio-economic differences in food habits in Europe: consumption of fruits and vegetables*. European Journal of Clinical Nutrition 54: 706-714
- Jakubowicz D., Supper S., and Bußwald P. (2004), *FUTURO, der Nachhaltigkeitspreis*, Sustainable Austria Nr. 28, [http://www.akaryon.com/docs/FUTURO\\_dez2004.pdf](http://www.akaryon.com/docs/FUTURO_dez2004.pdf), downloaded in December 2004
- Jungbluth, N. (2000), *Umweltfolgen des Nahrungsmittelkonsums: Beurteilung von Produktmerkmalen auf Grundlage einer modularen Ökobilanz*. PhD Thesis, ETH Zurich
- Kramer, K. J., Moll, H. C., Nonhebel, S. and Wilting, H. C. (1998), *Greenhouse gas emissions related to Dutch food consumption*. Energy Policy 27: 203-216
- Leitzmann, C. (2003), *Nutrition ecology: The contribution of vegetarian diets*. Am. J. Clinical Nutrition: 78 (3): 657-659
- OECD (2001), *Household food consumption: trends, environmental impacts and policy responses*. Paris: OECD (ENV/EPOC/WPNEP(2001)13)
- OECD (2002a), *Towards sustainable household consumption: trends and policies in OECD countries*. Paris

- OECD (2002b), *Policies to promote sustainable consumption: An Overview*. Policy Case Study Series. Paris: IECD (ENV/EPOC/WPNEP(2001)18/FINAL)
- Pack, A., Friedl, B., Lorek, S., Jäger, J., Omann, I. and Stocker, A. (2006), *Sustainable Food Consumption: Trends and Opportunities*. Sufo.trop. Interim Report. Graz and Vienna
- Payer, H., Burger, P. and Lorek, S. (2000), *Food Consumption in Austria: Driving Forces and Environmental Impacts*. National case study for the OECD Programme on Sustainable Consumption, Vienna
- Roos, G., Johansson, L., Kasmel, A., Klumbienä, J. and Prättälä, R. (2001), *Disparities in vegetable and fruit consumption: European cases from the north to the south*. Public Health Nutrition 4(1): 35-43
- Statistik Austria (2004), *Standard-Dokumentation Metainformationen (Definitionen, Erläuterungen, Methoden, Qualität) zur Konsumerhebung 1999/2000*. Vienna
- Taylor, C. (2000), *Ökologische Bewertung von Ernährungsweisen anhand ausgewählter Indikatoren*. Inauguraldissertation, Justus-Liebig Universität Gießen  
<http://geb.uni-giessen.de/geb/volltexte/2000/273/pdf/d000074.pdf>, downloaded in July 2005
- Tanner, C. and Kast, S. W. (2003), *Promoting Sustainable Consumption: Determinants of Green Purchases by Swiss Consumers*. Psychology and Marketing 20(10): 883-902
- Trichopoulou, A., Naska, A. and Costacou, T. (2002), *Disparities in food habits across Europe*. Proceedings of the Nutrition Society 61: 553-558
- Tukker, A., Huppes, G., Geerken, T. and Nielsen, P. (2005), *Environmental impact of products (EIPRO)*. Draft report of the Institute for Prospective Technological Studies (IPTS) and the European Science and Technology Observatory (ESTO), Brussels
- United Nations Division for sustainable development (UNSD), Documents, February 2006: *Agenda 21*. <http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm>
- Wallén, A., Brandt, N. and Wennersten, R. (2004), *Does the Swedish consumer's choice of food influence greenhouse gas emissions?* Environmental Science and Policy 7: 525-535
- White, T. (2000), *Diet and the distribution of environmental impact*. Ecological Economics 34 (234): 145-153



# POSTER Prioritizing sustainable consumption patterns

*Key decisions, key actors and potential improvements of the environmental balance*

Josef Kaenzig<sup>a</sup> and Olivier Jolliet<sup>b</sup>

<sup>a</sup> University of St. Gallen, Switzerland. josef.kaenzig(at)unisg.ch

<sup>b</sup> University of Michigan, USA. ojolliet(at)umich.edu

## 1 Introduction

### 1.1 Context and Research questions

How does one improve the personal environmental balance as a consumer? Numerous are those who would like to know how to respect the environment and at the same time take advantage of the benefits of the consumer society. The aim of this paper is twofold, starting with an overview on the most important environmental impacts, the paper focuses on decisions in order to identify priorities of action. Secondly, the paper proposes a palette of consumption patterns to illustrate an environmentally sound behaviour and the potential improvement of the personal annual balance of a consumer. The financial side is also considered and the scenario results are compared to the total impact per person and year, so as to highlight the priorities for action. By adopting a series of scenarios coinciding as closely as possible with the present Western European lifestyle, the environmental impact of a consumer can be reduced by one third, at no extra cost.

The research questions are the following:

- What is the relative share of housing, private mobility, consumer goods and services, nutrition, public services and insurance in different environmental impacts?
- What are the key decisions, key actors, and savings potentials of environmentally sound consumption patterns in each consumption domain?
- What are the conclusions and implications for consumers, policy makers and companies?

### 1.2 Account of the state of research in the field

There exist a lot of studies asking how to improve the environmental balance and how to consume in a sustainable way; consumers are inundated

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

with reams of recommendations. Many studies present results on very specific aspects or single products and do not put them into the global context of the total environmental impacts of consumption. The number of studies addressing the total environmental load caused by various consumption activities is increasing (Wilting et al., 2002, Labouze et al., 2003, Nijdam et al., 2005, Munksgaard et al., 2005, Voet van der et al, 2006, Weidema et al., 2005). The number of studies looking at energy consumption and carbon dioxide emissions is even higher (for Switzerland: Jochem, 2004, Ecospeed, 2004). For a detailed review on studies on the environmental impact of products refer to Tukker and Jansen (2006). The increasing number of studies provides a more and more coherent and complete overview on the most important environmental impacts (see also Tukker, 2006). Both macro-level and micro-level, top-down, bottom-up and hybrid approaches are useful for a progressive identification of hot-spots (Tukker et al., 2006). The work described in this paper is based on previous research taking into account the total (direct and indirect) environmental impact (references cf. Figure 1). In order to increase the accuracy, the results of studies using different approaches are compared (Figure 1). Where data for Switzerland has been missing it was complemented by using above allecoinvent (2005) and national statistics in combination with consumer expenses. However identifying hot spots of environmental impacts is not sufficient. Consumption alternatives offering an important potential for improvement of the environmental balance need to be identified in order to choose priorities of action. There are few studies focussing on the potential improvement of the environmental balance rather than on absolute environmental impacts. Some of the studies analyzing environmental impacts of products outline the potential improvement of alternative consumption patterns but they do not prioritize.

The low hanging and mellow fruits leading to substantial improvement of the environmental balance need to be identified. It would make sense to pick them first. Low hanging fruits are consumption alternatives that enable an important improvement of the environmental balance and that are potentially adopted by consumers or by companies. This article clearly focuses on the joint numerical evaluation of environmental and financial tradeoffs of different consumption alternatives. The question on how behavioural change and the adoption of sustainable consumption patterns can be achieved is out of the scope of this paper but it is an important step for future research. The following chapters will show that prioritizing consumption alternatives leads to different priorities than prioritizing environmental impacts or hot spots.

## **2 Approach and methods**

The paper is based on extracts of a recently published study for the Swiss Federal Office for the Environment (Kaenzig and Jolliet, 2006), which assesses the environmental impact linked to consumption and aims to identify key decisions and actors for the improvement of the global environmental balance. It takes the perspective of consumers, illustrating with scenarios the potential environmental benefits and personal advantages of a series of environmentally sound consumption patterns. The unit of analysis, which is called a functional unit in the field of life cycle assessment (LCA), is the quantity  $Q$  of products needed to fulfil the demand of Swiss

consumers per year. The analysis is mostly carried out on a country or national level and then reported as an average consumption of one person per year. It is a kind of macro life cycle assessment combining both product-based life cycle assessment and input/output-based life cycle assessment.

The environmental impact was assessed using two different methods: the Ecoscarcity method<sup>1</sup>, that weights all impacts in order to get a single indicator and a recently developed method called "IMPACT 2002+"<sup>2</sup>, whose endpoint categories are human health, climate change, ecosystem quality and resources.

The overall approach and the structure of this paper can be divided in three complementary steps:

1. Assessment of the environmental impact per capita with life-cycle approaches.
2. Analysis and identification of key factors, decisions and actors in regard to environmentally sound consumption.
3. Drawing up of environmentally sound consumption patterns presenting important benefits for the environment.

### **3 Environmental impact of consumption domains and per capita**

The diversity of products and services requires an aggregation of consumption activities in order to facilitate the analysis and the comprehensibility of results. Different options to classify environmentally sound consumption are listed in Hertwich et al. (2004). For the current study the UNEP proposal to use functions to classify consumption domains was followed where possible. Five consumption domains have been defined: housing, private mobility, consumer goods and services, nutrition and public services and insurance.

Housing: construction and demolition, maintenance and heating, water consumption, hot-water heating and waste water treatment and electricity used for activities at home (e.g. using household appliances or cooking).

Private mobility: all means of transport (train, car, plane etc.). Construction, operation, maintenance and disposal of the vehicle as well as the infrastructure are taken into account. Commuting is included but not distances travelled at work (they are attributed to the respective consumption domains).

Nutrition: production and consumption of food. Energy consumed for cooking at home is attributed to housing, meals consumed in restaurants and canteens account for the nutrition consumption domain. Spoilage is taken into account (evaluations are based on the quantities bought and not on quantities effectively ingested).

Consumer goods and services: all products and services consumed by Swiss residents that are not considered in the four other consumption domains defined for this study. Manufacturing, use and end of life are taken into account. Only the direct energy consumption of household appliances such as washing machines and televisions are comprised in the domain housing.

<sup>1</sup> Cf. Braunschweig et al. (1997). The life cycle impact assessment method Ecoscarcity measures the environmental impact with environmental impact points (UBP).

<sup>2</sup> Cf. Jolliet et al. (2003).

Public services and insurance: public services as well as mandatory health and social insurance. This domain has not been evaluated as closely as the other consumption domains because consumers can not directly influence its impact. The impact has been evenly allocated to the residents of the country.

The following section is based on the analysis of a selection of life cycle assessment studies on a country or European level. Quantitative results were aggregated to the five consumption domains defined in order to make them comparable. Figure 1 summarizes results from selected studies specifying non-renewable primary energy consumption, carbon dioxide emissions and different environmental impact categories caused by consumption in Switzerland.

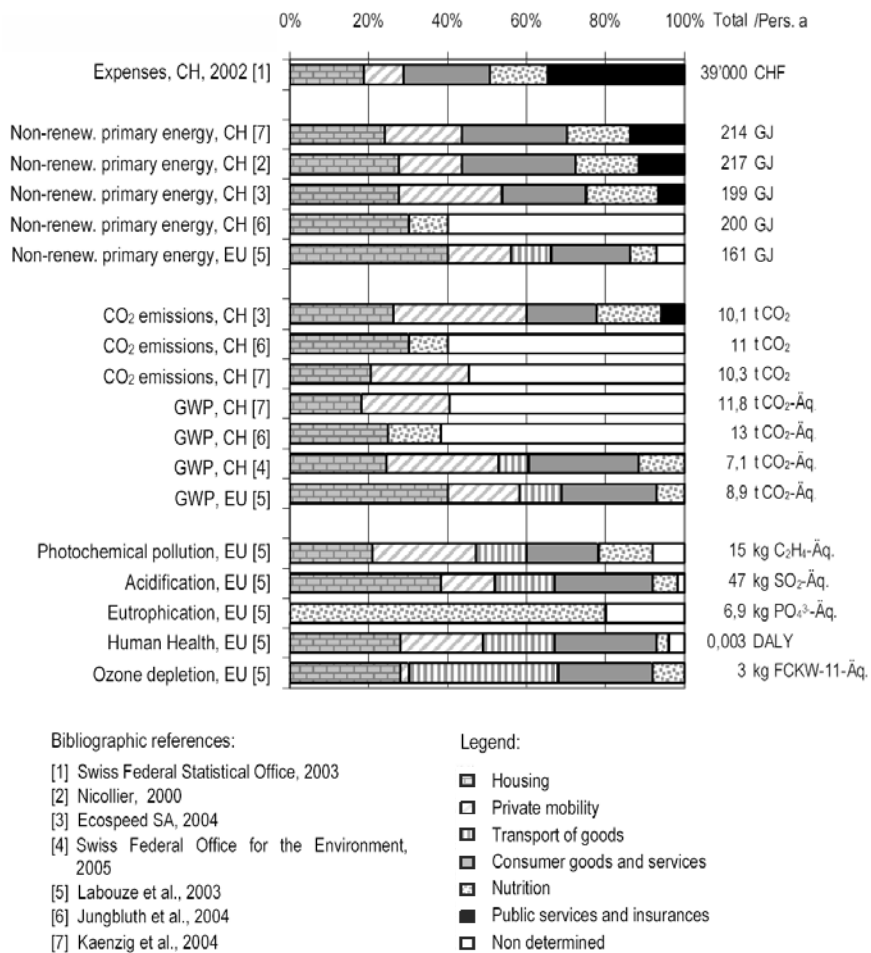


Figure 1: Environmental impact of five consumption domains (per capita and per year). Comparison of the results of selected studies.

The figure is supplemented with the consumer expenditures in Switzerland in 2002 and results of a European study. It may enable to evaluate the importance of a certain environmental impact in comparison to the total environmental impact per capita and year.

The quantitative assessments carried out by different authors show similar tendencies for the environmental impact and the non-renewable

energy consumption per capita and year. The distribution of the expenses on the five consumption domains is not directly correlated to their primary energy consumption and their environmental impact. National statistics such as greenhouse gas inventories do not take into account the environmental load due to imported products and result in lower total environmental loads than macro-life cycle assessments.

Further analysis by the authors and the comparison of different studies and databases (ecoinvent 1.2, 2005, Nicollier, 2000, Labouze et al., 2003, Ecospeed, 2004, Wilting et al., 2002) reveal that private mobility, housing and active products generate a majority of the environmental impacts in the use stage. Consumer goods and services are responsible for high impacts through the whole life cycle while the main impact of nutrition is to be found in the agricultural production stage. The end-of life treatment and the disposal becomes only the most important life cycle stage in terms of environmental impact if the product or service implies toxic substances or if there is no adequate treatment.

#### **4 Key factors, key decisions and key actors**

Consumer demand shapes the offer, the amounts of production and consequently the waste to eliminate. For consumption activities three steps can be distinguished: Purchase, use and disposal. The decisions taken at each step influence the environmental impact along the life cycle of a product considerably: purchase or rent, frequent use or not, long or short lifetime, end of life treatment or disposal. Life cycle impacts from extraction of raw materials, production, use and disposal are separately assessed in order to identify key actors and decisions.

The following paragraph contains a summary of environmental-influence-matrices that were compiled for each consumption domain. The environmental influence matrices inventories decisions. The potential influence of each decision is reported horizontally and detailed for different life cycle stages. Table 1 shows to what extent decisions taken in different life cycle stages influence the environmental balance and specifies key decisions and key actors in regard to environmentally sound consumption. The description of the influence ranges from high influence to no influence. High influence means that decisions do have a high influence on the environmental balance.

The key factors for housing are the living space occupied per person, the thermal quality of buildings, the energy sources and energy technologies, the behaviour of consumers (e.g. room temperature, quantity of hot-water consumption) as well as the location, which determines the kilometres travelled per day to go to work, shopping and leisure. Beside the key decisions taken in the planning phase, the decisions concerning living space and thermal quality when buying or renting a house are crucial. The key actors are the architect, the builder-owner, the government, which influences the general conditions with urban and regional planning and financial incentives (e.g. subsidies and taxes). The remaining key decisions concerning room temperature, airing and hot water consumption in the use stage are taken by the occupant or the facility manager.

Table 1: Key decisions and key actors for an environmentally sound consumption. The influence of key decisions<sup>3</sup> for the global environmental balance specified for different life cycle stages.

Domain	Key phase <sup>1</sup>				Key decisions	Key actors
	Decisions taken during production	Purchasing decisions	Decisions taken during the use stage	Decisions concerning end of life treatment and disposal		
Housing	▼	▼	▼	▼	<ul style="list-style-type: none"> <li>• Thermal quality (insulation etc.)</li> <li>• Choice of building materials, building site</li> <li>• Living space (m2/capita)</li> <li>• Energy sources</li> <li>• Consumer behavior (°C, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>• Builder-owner, architect</li> <li>• Government (regulation, financial incentives)</li> <li>• Buyer-consumer</li> </ul>
Private mobility	▼	▼	▼	▼	<ul style="list-style-type: none"> <li>• Mode of transport</li> <li>• Vehicle type and motor technology</li> <li>• Distances traveled (km)</li> <li>• Occupancy</li> </ul>	<ul style="list-style-type: none"> <li>• Government (provision of infrastructure, regulation, financial incentives)</li> <li>• Buyer-consumer</li> </ul>
Consumer goods and services	▼	▼	▼	▼	<ul style="list-style-type: none"> <li>• Amount of products and services purchased</li> <li>• Quality, Eco-design / Label</li> <li>• Energy and resource use efficiency of products</li> <li>• Useful time</li> <li>• Recycling rate</li> </ul>	<ul style="list-style-type: none"> <li>• Government (regulation, financial incentives)</li> <li>• Producer</li> <li>• Buyer-consumer</li> </ul>
Nutrition	▼	▼	▼	▼	<ul style="list-style-type: none"> <li>• Production and land use</li> <li>• Consumption of cereals and milk products instead of meat products</li> <li>• Season (green house), origin (air transport), etc.</li> </ul>	<ul style="list-style-type: none"> <li>• Government (regulation, financial incentives)</li> <li>• Producer</li> <li>• Buyer-consumer</li> </ul>
<b>Legend:</b>	High influence		Medium influence		Little influence	

The distance travelled is by far the most important factor for private mobility, followed by the mode of transport and the occupancy. The choice of a certain type of vehicle implies the choice of a motor technology, which determines the emission level. The provision of infrastructure for private mobility is normally a public affair. Key decisions taken by policy-makers determine for instance the level of infrastructure and of financial incentives. The important decisions taken by the consumer, which is the most important actor as far as the environmental impact of private mobility is concerned, start with buying or renting vehicles or using transports services. As the environmental impact is very directly dependent on kilometres travelled, the choice of destinations and distances travelled is crucial.

<sup>3</sup> A key phase in the context of this paper is a phase in the life cycle of products and services in which key decisions influencing considerably the global environmental balance are taken.

A majority of the environmental impacts due to nutrition occurs in the agricultural production phase and is correlated to decisions taken by the producer concerning the type of cultivation and land use for instance. Consumers are key actors for the global environmental impact reduction of nutrition. The most influencing decision concerns the partial substitution of meat consumption by vegetables and dairy products, which decreases at the same time water, and energy consumption, land use and photochemical pollution. But consumers' behaviour also influences the range of products offered; privileging food that was not transported by airfreight and not grown in heated greenhouses improves the environmental balance of nutrition.

As the environmental impact is more or less constant per unit produced, a key factor for all type of products in the domain of consumer goods and services is the amount of products and services purchased. For the analysis of other key factors and decisions, it is necessary to distinguish active, mobile, transported and passive products. As far as products are concerned that do not consume important quantities of energy or resources during use (passive products) the environmental impact is mainly due to production and disposal. Consequently the product designer and producer are key actors. Products that consume a significant amount of energy resources in the use stage (active products) such as washing machines or transported and mobile products cause an important impact in the use stage. But consumer attitudes, choosing quality products and an appropriate maintenance level for instance, determines market offers, increases the useful lifetime of a product and reduces the global environmental impact of products, especially of passive products. The useful lifetime and the end of life treatment (reuse, recycling, disposal) are key factors of passive products. Eco-design and labels are tools for producers to promote environmentally sound products. Energy and resource efficiency is a key factor for active products and weight is a key factor for mobile and transported products such as car parts and furniture.

In summary, for each consumption domain, the decision concerning disposal and end of life treatment influence the global environmental balance but normally not as much as decisions taken in the production stage purchase and use stage. This shows the importance of prioritizing measures early in the life cycle of products rather than at the end of the pipe.

The government and above all consumers are key actors for the environmental impact of all consumption domains. The role of companies and its potential for improvements is found amongst other in eco-efficiency and innovation of new environmentally sound products and services.

## **5 Environmentally sound consumption patterns and potential improvements**

The study evaluates the environmental benefits of thirteen scenarios illustrating environmentally sound and financially viable consumption patterns compared to the average consumption per capita in Switzerland. Financial trade-offs are taken into account and discussed with the potential environmental benefits using the concept of E2-vectors (environmental indicator versus expenses, Goedkoop, 1999).

To provide an example, figure 2 illustrates potential and cumulative energy and cost savings per capita and year, adopting eight scenarios that can be cumulated.

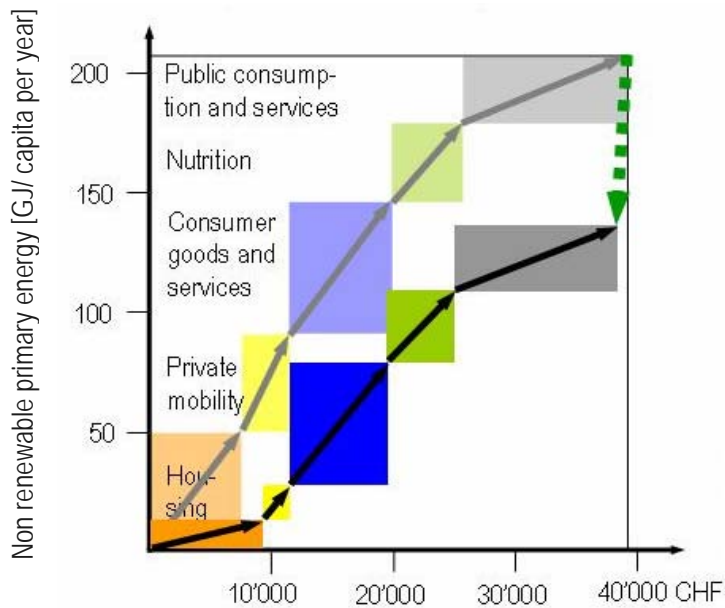


Figure 2: Potential energy and cost savings per capita and year adopting eight environmentally sound consumption patterns.

The environmentally sound consumption patterns considered in figure 2 are: living in a low energy flat, the optimization of the room temperature, buying wind power instead of the conventional Swiss electricity mix, using energy efficient household appliances and lighting carrying the energy efficiency label A, using public transport, travelling abroad by train instead of air-plane, a ten per cent prolongation of the use of passive consumer goods and a fifty per cent reduction of the meat consumption.

The potential energy savings per capita and year with these eight selected scenarios are about 66 GJ of the total non renewable primary energy consumption (cf. figure 2). This corresponds to a reduction of energy consumption of about one third. There is a similar high potential for reduction of the environmental impact and also an interesting potential for financial savings thanks to energy savings e.g.. In Switzerland the total non-renewable primary energy consumption amounts to about 214 GJ per capita and year, which is about five time higher than the average consumption in China and about 45% lower than the average consumption in the USA.

The scenarios illustrating environmentally sound consumption patterns considered in the study normally provide the same utility and functions as the consumption patterns they substitute. Some of them imply advantages or disadvantages compared to the status quo. For some consumers scenarios might require renouncing to a certain level of comfort for instance when travelling by train instead of travelling by airplane, other scenarios provide advantages such as the improved acoustic insulation that comes along with a low energy house. The choice and the adoption of scenarios depend on personal preferences and weighting.



## **6 Discussion and Conclusions**

### **6.1 Validity of the evaluations**

The study at the basis of this paper has been carried out assuming Swiss conditions, however much of the data used for the computations is valid for most western European countries. For instance the environmental impact data for automobiles used in this study correspond to the impacts of a generic European passenger vehicle. Some of the scenarios are depending on public infrastructure e.g. public transport and have to be adapted before they can be adopted in countries where the public infrastructure is more or less developed. In general the key factors and decisions, the main conclusions and tendencies and the priorities identified are valid for other industrialized countries. The most important difference concerns energy supply: the electricity consumed in Switzerland contains a higher share of hydro-electricity than the average electricity mix. This implies that the scenarios would be even more favourable for the environment if they are adopted in other countries with a more fossil and nuclear based electricity supply mix.

Note: The comparison of costs focuses mainly on energy, because other natural resources such as air and water are free or generate just marginal costs for individuals in many industrialized countries. However this does not mean that only energy consumption is relevant.

### **6.2 General findings**

At present consumers as well as managers are inundated with pieces of information on how to consume in a sustainable way. It is the aim of this study to gain an overview and provide a basis for comparison of the environmental impact. The evaluations allow describing priorities of action by putting specific environmental impact into the global context. One possible way of doing this is a relative comparison using inhabitant equivalents and another possibility is a comparison of the absolute impact of different consumption activities. An example for the latter comparison is to rank environmentally sound consumption patterns using indicators such as the "environmental-impact-points" (assessed with the Ecoscarcity method). To provide an example, the environmental impact of a journey of 650 kilometres by train is about five times smaller than that of the journey by plane.

Often it is easier to only evaluate the differences between consumption alternatives instead of evaluating the whole system. Another general finding illustrated by figure 2 is that it is more promising to focus on important decisions that can help to avoid environmental impacts rather than to focus on the main impacts itself. The consumption domain "consumer goods and services" for instance causes quite a high environmental impact but the potential improvements are not as easy to tap by consumers who want to maintain their level of consumption, as for instance in the private mobility or housing domain. Therefore it does not make sense that consumers provide as much effort for the domain "consumer goods and services" as for "housing" for instance. Furthermore Kempton et al. (1992) found that in general it is

easier to achieve one-time changes in behaviour than to alter and maintain repetitive behaviour changes. This is another reason why improvement potentials of the environmental balance in the housing and private mobility domain, where investments are rather high but not very often, can be considered low hanging fruits in comparison with improvement potentials in the nutrition and consumer goods and services domain. The study therefore suggests focusing efforts on key factors, key actors and key decisions as they are summarized in chapter 4 and table 1.

### 6.3 Consumers' perspective

The potential energy savings and the potential improvement of the environmental balance with small changes in lifestyle are about one third. Savings achieved thanks to reduced energy consumption e.g. can be reinvested in sustainable products such as low energy houses and renewable energy to further improve the environmental balance. As time and budget and capability to adopt new behaviours are limited, prioritizing of consumption patterns and alternatives that can make a significant difference is crucial. Consumers willing to improve their personal environmental balance should pay attention to rebound effects. Financial savings achieved with energy efficiency improvements for instance should not be used to finance holiday trips by airplane.

As a conclusion it can be stated that the environmental impact per capita can be reduced very significantly by adopting a few realistic scenarios, which overall do not cost more than the average consumption and might imply advantages in other levels such as health, ethics, convenience, prestige, and aesthetics.

### 6.4 Implications for companies and policy makers

Several findings might also be of interest for companies. The applicability of results is depending on the economic sector and the life cycle stage considered. On the level of a production site or service centre findings on housing, renewable energy use, mobility and consumer goods can directly be adopted to offices, heating, power supply, vehicle fleet, the choice of means of transport, and producer goods. For companies different contributions to more environmentally sound consumption are possible. For instance, these might include direct measures to increase eco-efficiency on-site and within the supply chain, or rather indirect influence by developing environmentally sound products.

Policy makers such as governments were identified as key actors in this study but also by Jackson (2005) and McKenzie (2000). Their role for more environmentally sound consumption can be the promotion with label-packets such as Minergie<sup>4</sup> for low energy houses, in order to avoid rebound effects and to achieve maximum environmental benefits. Governments' role should also be to legislate and set targets to promote the reinvestment of economic savings in additional environmental improvements. Marketing utilizing appealing images and positive terms is probably a key factor for the

<sup>4</sup> "Minergie" is a Swiss label for low energy houses defining an upper limit for energy consumption for heating, warm water and electricity use for ventilation ([www.minergie.ch](http://www.minergie.ch)).

successful implementation and broad adoption of environmentally sound consumption patterns. Tools and knowledge from business economics are waiting to be used for this end.

The authors hope that the study at the basis of this article is of interest to consumers, policy makers as well as managers, and that it may help to prioritize and to select areas of action for more environmentally sound consumption.

The article is based on a two year SCP-research project commissioned by the Swiss Federal Office for the Environment. Full reports are published in German and French (Kaenzig and Jolliet, 2006).

## 7 References

- Braunschweig, A., Bär, P., Rentsch, C., Schmid, L., Wüest, G. (1998). *Methode der ökologischen Knappheit – Ökofaktoren 1997. Methode für die Gewichtung in Ökobilanzen*. BUWAL, Bern, 107 p.
- Corbière-Nicollier, T. (2005). *Integrated sustainability assessment for local projects: Environmental impacts and their connections with economic and social field*. Dissertation n°3180, Swiss Federal Institute of Technology Lausanne
- ecoinvent (2005). *Database 1.2*. Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland
- ecoinvent (2004). *ecoinvent reports*. Swiss Centre for Life Cycle Inventories, Dübendorf, Switzerland
- Ecospeed SA (2004). *ECO<sub>2</sub>-Privat*. Internetbasierte Datenbank und Berechnungstool. Ecospeed SA, Zürich.  
<http://www.ecospeed.ch/ie/f/privat.html> (30.07.2004)
- Federal Office for the Environment (2005). *Switzerland's Greenhouse Gas Inventory 1999–2003 – National Inventory Report*. Bern, 208 p.
- Goedkoop, M., van Halen, C., te Riele, H., Rommens, P. (1999). *Product Service systems, Ecological and Economic Basics*. Ministère de VROM et EZ
- Hertwich E. (2005). *Life Cycle Approaches to Sustainable Consumption: A Critical Review*. Environmental Science & Technology, 39(13): 4673–4684
- Hertwich, E., Katzmayr, M. (2004). *Examples of sustainable consumption: Review, Classification and Analysis*. Norwegian University of Science and Technology (NTNU), Industrial Ecology Programme (IndEcol), Report no. 5/2004
- Jackson, T. (2005). *Motivating Sustainable Consumption - a review of evidence on consumer behaviour and behavioural change*. A report to the Sustainable Development Research Network, Centre for Environmental Strategy, University of Surrey
- Jochem, E., Andersson, G., Favrat, D., Gutscher, H., Hungerbühler, K., Rudolph von Rohr, P., Spreng, D., Wokaun, A. and Zimmermann, M. (2004): *Steps towards a sustainable development – A White Book for R&D of energy-efficient technologies*. Zürich (ISBN 3 9522705 0 4).
- Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer, G., Rosenbaum, R., (2004). *Characterization Factors for IMPACT 2002+ – Version 1.1*. Swiss Federal Institute of Technology Lausanne.  
<http://www.epfl.ch/impact> (20.02.04)
- Jolliet O., Margni M., Charles R., Humbert S., Payet J., Rebitzer G., Rosenbaum R., (2003). *IMPACT 2002+: A New Life Cycle Impact Assessment Methodology*. International Journal of LCA 8 (6): 324–330.
- Jungbluth, N., Faist Emmenegger, M., Frischknecht, R., (2004). *Gesamtpotential für die Reduktion von Umweltbelastungen im Bereich Ernährung und Wohnen*. Report for the WWF Schweiz, ESU-Services, Uster, 33 p.
- Kaenzig, J., Jolliet, O. (2006). *Umweltbewusster Konsum: Schlüsselenstheide, Akteure und Konsummodelle / Consommation respectueuse de l'environnement: décisions et acteurs clés, modèles de consommation*. Umwelt-Wissen Nr. 0616 / Connaissance de l'environnement n° 0616. Swiss Federal Office for the Environment, Bern. 114 p. (<http://www.umwelt-schweiz.ch/publikationen>)

- Kempton, W., Darley, J.M., Stern, P.C. (1992). *Psychological research for the new energy problems: Strategies and opportunities*. *American Psychologist*, 47, 1213-1223.
- Labouze, E., Monier, V., Le Guern Y., Puyou J.-B. (2003). *Study on external environmental effects related to the life cycle of products and services*. Final report version 2. Paris, France: European commission, Directorate General Environment, BIO Intelligence Service/O2 France, 163 S. & Appendixes
- Loerincik, Y., Kaenzig, J., Jolliet, O. (2005). *Life Cycle Approaches for Sustainable Consumption*, *International Journal of Life Cycle Assessment*. 10(3): 228 – 229
- McKenzie-Mohr, D. (2000). *Promoting Sustainable Behaviour: An Introduction to Community-Based Social Marketing*. *Journal of Social Issues*, 56(3): 543-554
- Munksgaard, J., Wier, M., Lenzen, M., Dey, C. (2005). *Using Input-Output Analysis to Measure the Environmental Pressure of Consumption at Different Spatial Levels*. *Journal of Industrial Ecology*, 9(1/2): 169-186
- Nicollier, T., 2000: *Présentation d'un outil permettant d'évaluer la dépense énergétique de divers choix quotidiens et du concept d'esclave énergétique*. Lausanne: Ecole Polytechnique Fédérale de Lausanne, 19 S. + appendixes
- Nijdam, D. S., Wilting, H. C., Goedkoop, M. J., Madsen, J. (2005). *Environmental Load from Dutch Private Consumption: How Much Damage Takes Place Abroad?* *Journal of Industrial Ecology*, 9(1/2): 147-168
- Tukker, A. (2006). *Identifying Priorities for Environmental Product Policy*. *Journal of Industrial Ecology*, 11(3): 1-4
- Voet van der, E., Oers van, L., Moll, S., Schütz, H., Bringezu, S., Bruyn, de S., Sevenster, M., Warringa, G. (2005). *Policy Review on Decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries*. Institute of Environmental Sciences (Leiden University); Wuppertal Institute for Climate, Environment and Energy; CE Solutions for Environment, Economy and Technology; commissioned by European Commission, DG Environment
- Weidema, B., Nielsen, A.-M., Christiansen, K., Norris, G., Notten, P., Suh, S., Madsen, J., (2005). *Prioritisation within the Integrated Product Policy*. Danish Ministry of the Environment
- Wilting, H.-C. (2002). *The Effects of Dutch Production and Consumption on the Environment in the Netherlands and Abroad*. Fourteenth International Conference on Input-Output Techniques, 10–15 Octobre, 2002, Montreal, Canada

# POSTER Organizational and institutional innovation in companies for resource productivity

Kora Kristof, Volker Türk, Katharina Walliczek and Jola Welfens

*Wuppertal Institute for Climate, Environment, Energy*

## 1 Background

Natural resources are the basis of all economic activities. Thus, an optimal and efficient use of resources can increase the welfare of a society. Especially the management of natural resources has lately become a challenge. The continuous growth of the world population, as well as the increase of production worldwide and price increases for energy and raw materials create an urgent need for long-term adaptation as regards efficiency increases in the use of natural resources.

The project “Resource Productivity as Core Strategy for Sustainable Development”, supported by the German Federal Ministry of Education and Research, aims at demonstrating how organizational and sectoral strategies can create market conditions that lead to significant increases in resource productivity ([www.ressourcenproduktivitaet.de](http://www.ressourcenproduktivitaet.de)). One of the projects research question is: What are central starting points in management for organisational and institutional innovations that can lead to a successful increase of resource productivity? This paper outlines the strategy used in order to answer this question and presents a summary for the results.

Following a literature study on current management approaches and instruments about 20 were identified, which focus on a (parts of) sustainable and/or excellent management. The chosen approaches were screened with a consistent raster, covering:

- Basic data: name, literature / web links
- Intention: main idea, intention, target group
- Operating mode and effectiveness: design and operating mode, impact on resource productivity
- Realization: facts and figures about realization, best practice stories, general conditions / supporting und hindering conditions
- Evaluation: strengths and weaknesses, needs and opportunities for further development

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

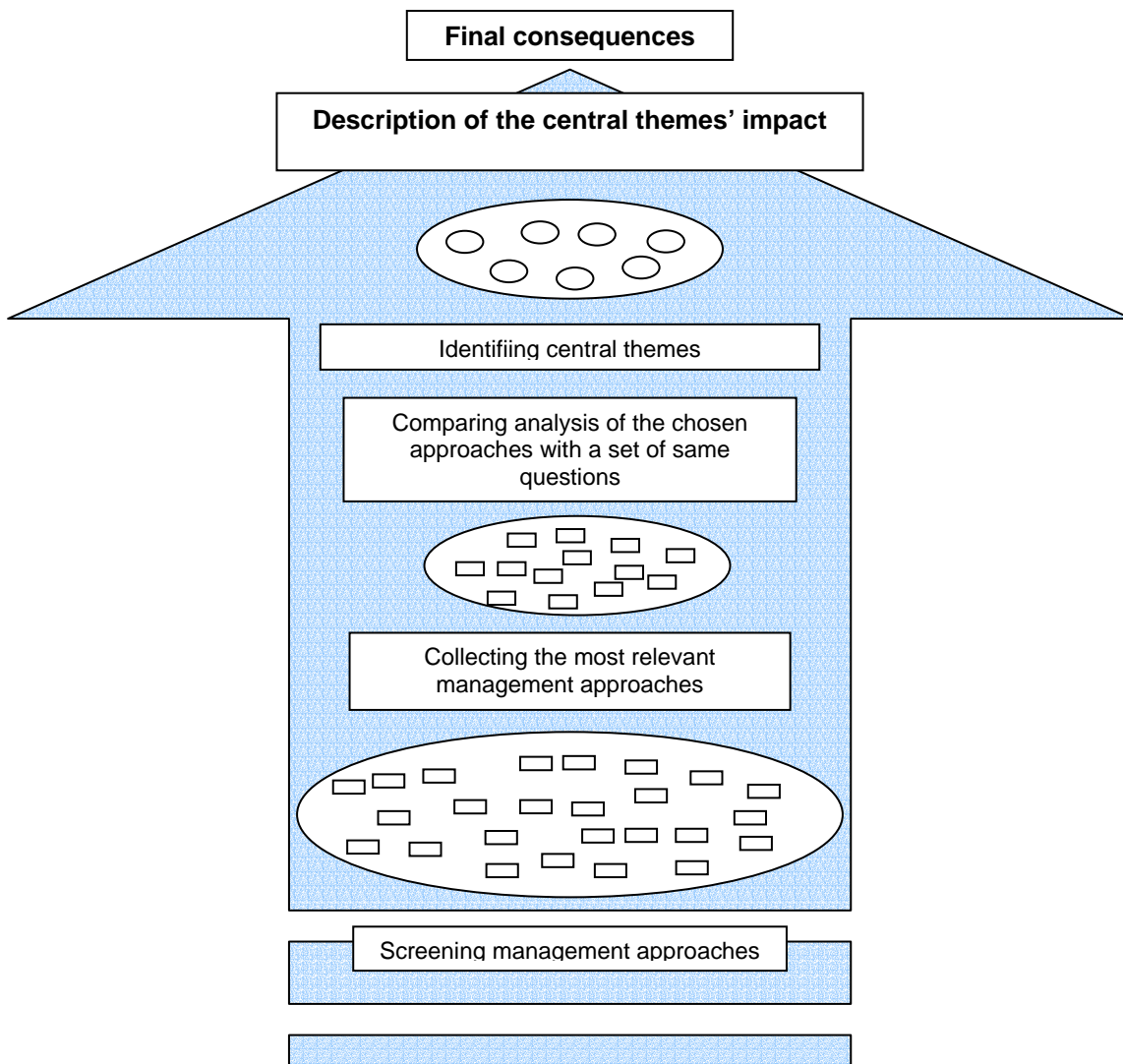


Fig. 1: Strategy

Based on the raster, the approaches and instruments were analysed and compared, and grouped according to central entry points or “themes” common to more than one instrument. The following seven themes resulted from the comparative analysis:

- Theme 1: action oriented status quo analysis,
- Theme 2: continuous data based information management,
- Theme 3: target definition,
- Theme 4: product / service analysis and development,
- Theme 5: quality management,
- Theme 6: external and internal learning processes of the companies,
- Theme 7: sustainability oriented holistic management systems.

For the themes, the **main idea** and the central starting point as well as the operating modes were described. Having understood the way things work,

the concrete impact on resource efficiency can be inferred – whether their influence is direct or indirect and for which task and in which sector they can be used most effectively. Furthermore it was possible to assess the **impact on resource efficiency**. Since the themes are non-technical, quantitative conclusions on the overall impact were not possible, but only qualitative conclusions (e.g. addressing the theme is a „necessary, but not sufficient condition“, a „basic condition“ etc.). In the end, the **development potentials** of the seven themes are analysed, i.e. what changes can substantially increase the impact on resource productivity substantially and what **further research** is necessary.

## **2 Summary of Results**

The **overall interpretation of the research** leads to the following conclusion:

- Many instruments and approaches developed and used for sustainable as well as excellence management, are capable of initiating an increase in resource productivity – mainly within the company, but sometimes also in the supply chain -, although many do not seem to directly address resource efficiency at a first glance (e.g. quality management, sustainability reporting etc.).
- Among these instruments, seven important themes, which mark the seven most important starting points for increasing resource productivity, were identified:
  - o **Theme 1 – Action-oriented Status-Quo-Analysis:** The approaches in this group start with analysing the status quo and then show adequate reactions. They are based on the idea that realizing the status-quo and the respective problems, disadvantages and unused opportunities makes you strive for improvement and thereby leads to action.
  - o **Theme 2 – Continuous Data Based Information Management:** The basic idea of this approach is to continuously provide decision makers with processed information on the environmental impacts and efficiency potentials of organizations, processes or products and services.
  - o **Theme 3 – Target Definition:** Here, the basic idea is the voluntary commitment of companies to reach goals that go beyond the respective legal minimum standards. Often, the enterprise intention is to provide an alternative to legal regulations, because they seem to be less flexible and more cost-intensive.
  - o **Theme 4 – Product / Service Evaluation and Development:** The impact of products and services on the environment has to be examined, so that ways of improvement can carefully be derived. Theme 4 therefore addresses the core competency of the company.
  - o **Theme 5 – Quality Management:** This theme aims at improving the quality of processes and products/ services. This can refer to production and product quality as well as to consumer orientation or quality management itself.

- **Theme 6 – Internal and External Learning Processes of the Companies:** In order to use the potentials of employees and company networks effectively, learning potentials in and around the company have to be discovered.
- **Theme 7 – Sustainability-Oriented Holistic Management Systems:** The goal is to integrate management systems into enterprises or to optimize existing integrated management systems, which aim at effectiveness and efficiency of industrial supply chains – while at the same time minimizing negative effects on the environment.
- Qualitative and partially quantitative statements about impacts on resource efficiency are possible for all seven themes and can be used for models and scenarios (e.g. ordinal approaches). Tab. 1 provides an aggregated overview on the impact on resource efficiency; Tab. 2 provides information on whether resource efficiency is directly or indirectly addressed as well as the starting points for the instruments, i.e. where exactly they have impacts on the companies or company networks.
- Although the majority of the approaches have potentials for an increase of resource efficiency, very few do it explicitly and initiate action. The potentials of the seven themes have therefore to be carefully developed.
- In order to increase the potentials, corporate culture and strategy have to be geared towards supporting and enabling successful approaches. The employees have to be enabled and supported to recognise and implement respective options.
- Considering the differences and the different starting points of the themes in general and of the underlying approaches in particular, the existing portfolio of instruments seems broad enough to successfully implement instruments aiming at an increase of resource efficiency in the enterprises. Yet, a company-specific selection of the adequate instruments is necessary.



Tab. 1: Impact on resource efficiency of the seven themes

<b>Theme</b>	<b>Impact on resource efficiency</b>
Action oriented status quo analysis	Necessary, but not sufficient condition, because the recognition, that something has to be done, and the wish to do is, are not automatically connected with recognising, what to do and how to do it.
Continual data based information management	Necessary, but not sufficient condition, since the representation of material and energy flows, environmental figures and environmental impacts as well as identifying improvement potentials are a condition for a systematic and continuous improvement of resource productivity.
Target definition	The impact depends on the definition of resource efficiency as a target beyond the “business-as-usual” and on the effectiveness of the target realization.
Product / service evaluation and development	The impact depends on the definition of resource efficiency as optimization variable and on a life-cycle-wide optimization; Due to considering design, production process, use and recycling / disposal, a high interference width and depth is possible, if the consumer’s demand is secured.
Quality management	The impact depends on the explicit roll of resource efficiency and on the optimization throughout the supply chain; the efficiency potentials are estimated to be low, because resource efficiency is only an unpopular topic in the quality management of most enterprises.
Internal and external learning processes of the companies	Necessary but not sufficient condition, because without learning processes a systematic and strategic development and long-term realization of resource efficiency is not possible.
Sustainability oriented holistic management systems	The impact can be very high, if the use of resources is identified as a strategic variable – in enterprise and supply chain – and if the integration of management systems is successful

Tab. 2: Comparing overview over the main starting points for operational modes of particular instruments

<b>Instrument / Concepts</b>	<b>Direct / Indirect Impact</b>	<b>Starting Points</b>		
		<b>Production</b> (incl. Supply chain)	<b>Product</b> (incl. use)	<b>Human</b> (incl. culture, interaction)
Action oriented status quo analysis	indirect			X
Continual data based information management	indirect	X	X	
Target definition	indirect			X
Product / service evaluation and development	direct		X	
Quality management	direct	X	X	
Internal and external learning processes of the company	indirect			X
Sustainability oriented holistic management systems	direct	X	X	X

### **3 Needs of research**

Further research need has been identified in the following areas:

- The seven themes' modes of impact on increasing resource efficiency has to be examined in detail – so that the mode of impact and the potentials for improvement can be better understood and gaps are recognized and shut. At this point, the different target groups in companies and networks have to be considered as well as the external factors and actors (e.g. politics, federations, other intermediates) that can have positive or negative influence (**Research on institutional and management innovations**).
- Additionally, the possibilities are to be examined, how to improve the use of the seven themes by integrating the day-to-day processes of the companies and the instruments that are already activated in organizations, so that the increase of resource efficiency can be implemented (**Diffusion research as regards institutions and management**).
- Considering the fact that the analysed instruments and approaches are primarily used internally, their potentials for use within the entire supply chain as well as the use phase should be analysed (**Research on supply chain management**).
- Another important research question is, how actors within the company or company networks can be enabled to recognize and realize the existing potentials. The role of qualification measures is to be examined and steps at conceptualizing such measures should be taken (**Qualification research**).

## POSTER How to investigate and how to reduce the natural resource consumption caused by private households?

Satu Lähteenoja<sup>a</sup>, Michael Lettenmeier<sup>b</sup> and Tiina Moisio<sup>c</sup>

<sup>a</sup> *The Finnish Association for Nature Conservation, Helsinki, Finland, satu.lahteenoja@sll.fi*

<sup>b</sup> *The Finnish Association for Nature Conservation, Kurhila, Finland*

<sup>c</sup> *The Finnish Association for Nature Conservation, Helsinki, Finland*

### 1 Introduction

Sustainable consumption and production (SCP) was identified as a renewed global policy focus at the World Summit on Sustainable Development in Johannesburg in 2002 (United Nations, 2002). Redirecting our consumption behaviour towards sustainability is a task that requires changes from all actors of society. Households are one of the major actors in SCP: they have an important role in a production-consumption chain which causes many environmental pressures. That is to say, it is the consumers who make the final choice of goods and services consumed, although this choice is influenced by many external background factors. This is why reliable and easily understandable information on the effects of household behaviours is crucial.

According to the OECD, household consumption is defined as the consumption of various goods and services by households. It includes the selection, purchase, use, maintenance repair and disposal of any product or service (OECD, 2002). However, it does not include consumption by the public sector or intermediate consumption of products and services in the productive sector. Public sector consumption is also ultimately consumed by private consumers in the form of public services.

Household consumption has grown and changed its form tremendously in the past few decades. Income grows year by year alongside GDP over the whole of Europe and there is more and more to be consumed. Household consumption expenditure in the EU-15 increased by almost one third per person between 1990 and 2002. At the same time households are becoming smaller and are tending to use more energy and water, as well as generating more waste per person (EEA, 2005).

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

The environmental effects of household consumption have mostly been studied either on a highly aggregated level of activities (e.g. Lorek & Spangenberg, 2001; Mäenpää, 2004) or on a product level with a relatively narrow scope in terms of different consumption activities (e.g. Nissinen et al., 2005; von Geibler et al., 2003; Grönroos & Seppälä, 2000). Tukker et al. (2006) approach consumption on both macro and product level from the viewpoint of integrated product policy (IPP). This paper is based on a research project, which focuses on households' material intensity and on the possibilities to reduce it under a wide scope of different products and activities and with an actor centered approach.

The Finnish Association for Nature Conservation is conducting a research project called FIN-MIPS Household – Promoting Sustainable Consumption in 2006-2008. The purpose of the project is to test the application of the MIPS concept for increasing the sustainability of private households. The project consists of two stages. In the first stage, the material input data relevant to households will be gathered and new data on the basis of the needs will be generated and discovered. In the second stage, the material input data produced will be used by 20 Finnish households to assess the relevance of different fields of consumption and to develop options for the dematerialisation of household activities. Based on this, a means for social intervention will be proposed. Also PR materials for promoting sustainable consumption will be produced.

The aim of this article is to discuss how to form a holistic picture and how to approach a relevant improvement of the sustainability of private household consumption. The question of the most appropriate level of presenting the data on resource consumption to households is addressed. Different data collection methods used in other household studies are introduced. Some case studies are discussed in order to give an impression of the methods used for households to assess their own behaviour and to help in identifying the most appropriate methods for the FIN-MIPS Household project.

One aspect of the research is to obtain an impression of the material flows related to all the goods that households possess. When the most appropriate level of data has been recognised, households will be able to use the data for making estimations of their own consumption of goods and the possibilities for reducing it. This partial study is used as an example in some sections of this paper. The research questions of this partial study are:

- How much natural resources are needed to produce all the goods and gear in the households and how could the natural resource consumption be reduced?
- What are the factors influencing the magnitude of consumption?
- What should be the nuance of generalisation that the information should be presented?

## 2 MIPS as an indicator for the quantitative data basis

There is no 'one and only' method for studying the everyday behaviour of households. Qualitative methods such as interviews and participative observation are often used in studies relating to everyday life (e.g. Timonen, 2002). However, with quantitative methods it is possible to obtain specific and comparable information on e.g. how different behaviour causes environmental pressure. According to Massa and Ahonen (2006), at its best research combines quantitative and qualitative methods. In the FIN-MIPS Household research qualitative methods are being used in the second phase of the project to evaluate the potential of quantitative material produced in the first phase.

### 2.1 MIPS – Material Input per Service unit

The quantitative part of the study is based on the MIPS method, which stands for Material Input per Service unit. The method was developed at the German Wuppertal Institute for Climate, Environment, Energy in the early 1990s. MIPS is a tool for measuring and managing the human-induced material flows. The MIPS value relates the natural resources consumed by a product during its entire life cycle to the overall benefit derived from it. It can be calculated for all final products that provide a service. It is a rough indicator but nevertheless provides an indicative approximation of a product's environmental pressure. The smaller the MIPS value, the less natural resources it consumes in relation to the amount of service it produces. (Schmidt-Bleek, 1994)

The bases of MIPS-figures are the ecological rucksacks accounting for different goods or commodities. The ecological rucksack is the sum of natural resources moved away from their original place in the ecosphere during the whole life cycle of a certain raw material, product or activity, including also indirect resource use. (Ritthoff et al., 2002)

According to the MIPS method, the material input (MI) is divided into five different categories: abiotic natural resources, biotic natural resources, water, air, and what is termed 'earth movement in agriculture and forestry'. Thus, these five different MIPS values can be calculated for any product. The service unit (S) is defined separately in each case so that it represents the real service provided. Defining service unit for a product challenges the traditional thinking of products as being valuable in themselves. In the MIPS concept, the value of a product is considered through the service it provides.

A controversially discussed aspect of the MIPS indicator is the link between the mass flow of resources and the environmental impacts caused by it (e.g. Koskinen, 2001). Traditional environmental policy has focused on the impacts of hazardous substances rather than on the impacts of mass flows. The ecological impacts of mass flows are still not considered as severe as toxicity (Hooke, 2000). In addition, holistic indicators and indices

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

tend to face the possibility of contradictory messages in relation to some of the numerous detailed individual indicators. However, this is rather an argument for still considering also traditional indicators than for rejecting holistic indicators.

Material flows have been used as indicators for sustainable household consumption e.g. by Lorek and Spangenberg (2001), Mäenpää (2005) and SERI (2002). However, MIPS has not been used before for illustrating to households the magnitude of their own natural resource consumption and the possibilities of reducing it on a holistic basis at a still sufficiently detailed level. In this study, the potential of the method for this purpose will be tested and demonstrated.

## 2.2 Motivation for choosing MIPS as the indicator

MIPS is one method among many others evaluating environmental impacts. In this section, some other possible approaches are briefly introduced and reasons for using the MIPS approach are given. Bringezu (2002) has pointed out that the environmental impact potential of anthropogenic material flows is generally determined by the volume of the flow times the specific impacts per unit of flow. The specific impacts per unit of flow are unknown for most of the materials released to the environment, whereas the volume or weight used can be known for nearly any material handled, so it may be used to indicate a generic environmental impact potential (Bringezu, 2002).

The direct material input of products or activities (e.g. the product itself or the fuel consumed for transport) cannot be considered a sufficient measure of environmental impacts as the life cycle aspect is missing when only direct material flows are taken into account. For instance, the direct material input (DMI) of the Finnish national economy has not substantially grown since the seventies. However, the total material requirement (TMR) has grown more than 50% because unused extraction (“hidden material flows”) from abroad has grown four-fold (Mäenpää et al., 2000). Thus, direct material input as an indicator for the Finnish economy would neglect the problems caused by the hidden flows related to imported goods and materials.

Energy consumption is often used to describe the environmental effects of a household (e.g. Lorek & Spangenberg, 2001). However, environmental impacts are related more to material flows than to the energy itself (Schmidt-Bleek, 1994). Material flows are correlate better with several environmental impacts than they do with energy use (Mäenpää, 2003).

The ecological footprint is a resource management tool that measures the amount of productive land and water area required for the resources consumed and wastes and emissions absorbed to obtain e.g. goods, activities, lifestyles or economies (Ecological Footprint Network, 2006). Ecological footprint tests can promote behaviour change at different levels. The ecological footprint helps to illustrate how shifting consumption to less resource intensive items reduces the environmental impact and thus may work as an incentive to change personal consumption patterns (e.g. Earth Day Network, 2002).

Ecological footprint values thus represent life cycle wide surface and energy use. These are remarkable resource inputs of human activities. In particular, the surface use could be an appreciable addition to the resource categories of the MIPS concept. However, as the concepts have been developed separately from each other, their combination would at least double the work at the present state of the art.

Life cycle assessment (LCA) is one popular method for evaluating the environmental impacts of e.g. products or consumer decisions. It includes the calculation of different kinds of emissions to air and discharges to water and soil, and the use of natural resources. Even though LCA has become an increasingly popular method, the question of how to present its results to consumers has remained a challenge. Finnish LCA researchers gave one option for this by launching the Eco-Benchmark tool (Figure 1). This can be used to determine the scale of the environmental impacts of different products and services. It gives rough-level estimations, for example, to questions on the relevance of doing laundry compared to overall consumption or on the difference between taking the bus or using one's own car (Nissinen et al., 2005). Although the Eco-Benchmark provides an appreciable step forward to illustrating LCA results to consumers by putting the environmental impacts of different products in visible relation to each other, it does not totally overcome the abstractness of LCA results. Thus, MIPS values can still be considered as more concrete and understandable despite their not providing so detailed information on certain environmental impacts.



Figure 1. The Eco-Benchmark tool (Nissinen et al., 2005).

### 2.3 The availability of relevant MI(PS)-data

To create a holistic view of households' natural resource consumption and to be able to give recommendations on how to reduce it, a large amount of material input or ecological rucksack data is required.

In the starting phase of the FIN-MIPS Household project, the availability of MI(PS) data has been studied for the different sectors of household consumption. The available MIPS and other relevant data of private consumption is very heterogeneous because the field of study is wide and the matter has been studied for many purposes. Good or at least adequate data was found at least for the sectors of transport (e.g. Lettenmeier et al., 2006; Saari et al., 2006; Vihermaa et al., 2006; Nieminen et al., 2006), housing

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

(e.g. Nieminen et al., 2006; Salo & Lettenmeier, 2006) with the exception of construction, clothing (e.g. Pütz, 1999 and Üffing, 1999) and telecommunication (e.g. v. Geibler et al., 2003; Türk et al., 2003; Federico et al., 2001).

In the case of the goods possessed and used by households, it is necessary to make some calculations of the missing data. The amount of goods possessed by households is thousands of items per person. This is the reason why each item cannot be calculated and why rough estimations are needed. On the other hand, it is not sufficient to take into account only the goods purchased during a relatively short time of observation.

One question is how the data used should or could be valid also in Finnish circumstances, since the project focuses on Finnish households. For example, housing and construction differs between Finland and Germany even because of the climate. Similarly, food produced in Finland can have quite different MI values compared to food produced elsewhere in Europe. This needs to be taken into account and evaluated before using e.g. German or Austrian data in this project.

Detailed data is available only for very accurate products and services. For example, a few studies have been carried out on electronic devices, which are a significant group of household goods from the environmental point of view. Electronic devices are a challenging group when observing environmental impacts from “cradle to grave” because they consist of a large amount of different components and sub-components that are produced in numerous countries, often by different manufacturers. Von Geibler et al. (2003) have carried out a case study with HP concerning the environmental impacts of mobile computing. The purpose of their study was to describe the function of handheld devices and analyse which physical function they substitute and then to investigate the environmental impacts associated with handheld computing devices compared with products providing similar services. For the environmental comparison, a handheld device (Jordana 565) and a notebook (Omnibook 500) were selected. The material intensity analysis was examined in different phases, viz. material intensity of components and their manufacturing, material intensity of transport and distribution and material intensity in the use phase.

Despite its valuable results, the study by von Geibler et al. (2003) showed that it is hardly possible to calculate exact MI(PS) values for a larger number of electronic devices. On the other hand, studies like this can be used for a rough estimation of the material intensity of electronic devices. For instance, Nieminen et al. (2005) used the data provided by von Geibler et al. (2003) on a kg/kg basis for the estimation of the material intensity of the electronic equipment of aircraft as no detailed information neither on the material intensity nor even on the composition of this equipment was available.

Also for services, there are some detailed studies covering limited parts of the consumption. In the Digital Europe project, for instance, a study conducted with EMI Music attempted to recognise the environmental and social impacts of digital music. EMI stands for electrical and musical industries and it is the world's largest independent music company, operating directly in 50 countries (Türk et al., 2003).



The study focused on analysing three different scenarios for delivering music to a customer. The first scenario was the traditional one where music is produced, transported and purchased on a CD. The second scenario was an online option where a CD is produced in the traditional way but the distribution part varies because the CD is purchased on the internet. The last scenario was based on a digital delivery and the entire trading transaction is conducted on the internet. A scenario where downloaded files are being burned to an empty CD has also been evaluated. The service unit has been defined in this study as "Provision of 56 minutes of music to the consumer".

Table 1. Summary overview of the three highest contributors to the abiotic resource consumption (Türk et al., 2003).

	Physical retail	Online shopping	Digital distribution(partial capacity)	Digital distribution (alternative settings)
	abiotic (kg)	abiotic (kg)	abiotic (kg)	abiotic (kg)
CD/CD-R	0,77	0,77	0,05	0,05
Production site				
NDC/Warehouse				
CD shop/Retailer shop	0,43			
Transport goods				
Transport by consumer	0,28			
Consumer PC materials		0,14	0,14	1,28
Download		0,25	0,46	4,14
CD burning				
Disposal				
<i>Total</i>	<i>1,56</i>	<i>1,31</i>	<i>0,67</i>	<i>5,5</i>

The comparison of the results is shown in Table 1. According to the results, digital distribution seems to be the most beneficial option, with about 50 percent less resource consumption than the other two scenarios. The impact of the digital distribution scenario is dependent on the underlying assumptions e.g. the slow internet connection can lead to a much larger impact than the physical counterparts. The online shopping is a slightly less material intensive operation in comparison with the physical retail. When examining the results, it must be noted that only abiotic raw materials are taken into consideration in this comparison. (Türk et al., 2003).

The kind of data presented above is useful when confronting consumers with partial aspects of their consumption, like SERI (2002) has done on its website. However, calculating MI(PS) values on this level is so labour intensive that there are no resources for it in the holistic framework of this project.

## 2.4 The relevance of different consumption areas

In contrast to the very detailed data shown in the previous section, there is also data on a very general level. From sectoral MFA-studies (e.g. Mäenpää, 2005) the relevance and importance of different sectors can be seen (Table 2). Lorek and Spangenberg (2001) have introduced 14 indicators to identify the most significant potentials for reducing resource consumption in the three most significant clusters. The identification of the most important clusters can be utilised in the FIN-MIPS Household study to help to find those areas having the largest potential for reducing resource consumption. However, the data used in these studies is very aggregated, i.e. it is almost impossible to derive MI values that are sufficiently detailed for working with households on the evaluation of their consumption.

Table 2. The total material requirement of Finnish households in 1999 (1000 t) (Mäenpää, 2004)

Consumption commodity groups	TMR
Food and non-alcoholic beverages	10,114
Alcoholic beverages and tobacco	1,438
Clothing and footwear	1,803
Housing	19,105
Housing (electricity and fuels)	11,228
Furnishing and household maintenance	4,008
Health	1,264
Purchase of vehicles	1,460
Operation of personal transport equipment	6,272
Transport services	1,443
Communication	1,977
Recreation and culture	7,619
Education	135
Hotels, cafes and restaurants	3,671
Miscellaneous goods and services	28,923
<i>TOTAL</i>	<i>100,459</i>

In order to change household consumption patterns, it is crucial to measure the magnitude of consumption and to identify the most environmentally relevant clusters of consumption. Michaelis and Lorek (2004), for instance, identified food, construction, housing and transport as the consumption categories that have the greatest environmental impacts in Europe. The total material requirement of these three clusters covers up to about 70% of total material extraction and each of these clusters represents more than 15% of the total energy and material consumption (Lorek 2002).

According to the OECD (2002), (i) food, (ii) tourism and travel, (iii) energy, (iv) water and (v) waste generation are the areas of consumption responsible for the highest environmental impacts. Based on these and other reports, EEA identified (i) food and drink, (ii) housing, (iii) personal travel and mobility and (iv) tourism as a major categories forming a large part of our total consumption and for which the environmental effects are either great or increasing rapidly (EEA, 2005).

Using several approaches on macro and product level, Tukker et al. (2006) concluded that food and drinks, passenger transport and housing (incl. buildings, furniture, domestic appliances and heating energy) are responsible for 70 – 80% of the environmental impact of consumption.

The Danish Ministry of the Environment has carried out a research study concerning the environmental load of Danish households (Dall et al., 2002). A comparison is made with the former study "The family's environmental impact" carried out in 1996. The main notion is that furnishing the residence with furniture and entertainment electronics has gained increasing environmental impact. The overall level of consumption and the use of products has increased since the former study. The importance of updating the database is also highlighted. For example, the application of new electricity and heating data has resulted in considerable changes to the result.

Based on the observations presented in sections 2.3 and 2.4, the FIN-MIPS Household research will generate additional data, preferably for Finnish conditions, for the following sectors:

- (i) construction,
- (ii) food and drinks,
- (iii) tourism,
- (iv) leisure time and
- (v) goods possessed by households.

Sectoral studies of each of these sectors are made in order to furnish a holistic though sufficiently detailed picture of all the relevant sectors.

In the FIN-MIPS Household research public services like education and health care are left out. These are the areas where households cannot make a difference as they can at home. The OECD definition of household consumption (OECD, 2002) also leaves public services out of picture.

### **3 Approaching the households**

#### **3.1 How to use the MIPS approach**

Household consumption has usually been defined either on the basis of the macro-economic approach or on the micro-level by domestic science analysis. The macro-economic approach analyses the private consumption on the basis of the statistical national accounts (SNA) while the micro-level approach focuses on the private behaviour of households by counting the household equipment and its consumption of energy and water. There have been quite a few attempts to combine these two approaches but the environmental relevance of such attempts has not been clarified. For example, the equipment level of households is recorded alongside with the average per capita energy consumption. (Lorek & Spangenberg, 2001)

The FIN-MIPS Household study is also endeavouring to bridge the gap between the micro and macro level approaches, e.g. by using an actor-

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

centred approach. Lorek and Spangenberg (2001) define an actor-centred approach as an approach that considers the real influence of consumers. When considering the patterns of consumption from the consumers' side, the most relevant clusters of consumption can be defined.

The problem with an actor-centred approach is that consumers' behaviour cannot be observed as being stable because consumer influence is dependent on number of factors differing between sectors, products/services, consumption clusters and social groupings. All these factors influence household behaviour and this is why it is important to take different consumer types into consideration (Lorek & Spangenberg, 2001).

One problem in the FIN-MIPS Household research is to find the appropriate level of detail to calculate MIPS values to households' personal activities and goods in order to obtain an impression of their total environmental impact. The importance of finding an appropriate level of aggregation can be highlighted when undertaking a part study of the goods possessed by a household. It would be an impossible task to calculate material flows for all the products households possess due to their massive amount. This problem has to be overcome by, for example, identifying the most environmentally relevant goods and by making the MIPS calculation or estimation only for those products.

The most suitable aggregation level for calculation can vary with different groups of products and activities and must be considered without losing the important features of a household's resource consumption. The data also has to be presented in a way that the comparison between different choices and households can be made and suggestions can be given on how to reduce the natural resource consumption.

### 3.2 The collection of household data

To give an impression of how the data acquisition has been carried out in other Finnish household studies, the methods used by Statistics Finland will be outlined. The most commonly used methods for collecting data from households are interviews (Statistics Finland, 2006). When studying households' behaviour, interviews can be accompanied by recording methods in which the households are asked to record their own activities, e.g. time use survey or collection of receipts. In a time use survey participating households keep a diary of their time use over a two-day period, in addition to which the daily and weekly rhythms of time use are also analysed. (Statistics Finland, 2006)

The Swedish research project "Urban households and consumption related resource use" (Shanahan et al., 2002) furnishes an example of an approach that has been used to study households. This study is also an example of one way of data acquisition. The aim of the study was to produce applicable data for households to encourage them to change and to reduce the life cycle wide energy flows related to their food consumption. Ten participating households were supposed to plan and implement new, less energy intensive food habits on the basis of a manual that was created giving examples of low energy food habits (Carlsson-Kanyama, 2003).

The data collection method for this particular study was multidimensional and it could act as an example on the method of collecting data and on how much effort the participating households are willing to put into the data collection. In this particular study, households kept records on a number of things. They were asked to record all the food eaten, the time, preparation method, number of portions and storage. Households were also asked to weigh all the waste they generated and the amount of waste sorted. Receipts were kept in order to check whether green-labelled products were purchased. On top of these recordings, households marked down their time use, activities, places, social dimension and transportation using the time-geographic method. After the experiment had run for a year, households were interviewed with the purpose of exploring the long-term effects of the experiment. As a result, households were capable of reducing the life-cycle energy inputs of their food habits by at least a third. Moreover, involving households in experiments with alternative lifestyles has proven to produce longer lasting results. (Carlsson-Kanyama, 2003). As stated by Hobson (2003), behavioural practices are not changed through scientific knowledge per se, but through individuals making connections between forms of knowledge that link their own experimental and everyday environment to broader environmental concerns (Hobson, 2003).

However, if we want to make large-scale progress, we should involve more than 15 households. In addition, one must investigate which measures can be taken to guide households towards sustainable lifestyles on a broader basis. One aim of the FIN-MIPS Household research is to investigate the interventions required for making household activities more sustainable with less intensive informational approach than in a project like this.

### 3.3 The assessment of household behaviour

Methods used in other studies for households to assess and change their own behaviour are introduced here by giving examples of two different studies, viz. the Eco-team project and ecological footprint tests.

The Global Action Plan for the Earth (GAP) is an international environmental organisation which has introduced the Eco-Team Program. The primary goal of the program is to reduce resource consumption at the household level by promoting a change in individual behaviour. The idea of the program is to set up groups of people, consisting of six to ten households, which gather together once a month for the time-period of eight months. They follow a step-by-step workbook in order to create a more environmentally sustainable lifestyle. Team results in terms of savings in gas, waste, energy and water are recorded and sent to a national database. The Eco-Team Program has now been launched in ten countries and about 30,000 households have been involved so far (GAP Finland, 2006). The long-term effectiveness of the program in a Dutch context has been analysed by Harland and Staats (2006). According to their findings, Eco-Team

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

participants have succeeded in reducing their consumption of environmental resources and they have even increased the savings in some areas of evaluation (Harland & Staats, 2006).

A wide range of different tests and games have been developed for households to assess their environmental impact. The ecological footprint quiz by Earth Day Network (2002) is an example of ecological footprint tests. It can be considered as a multi-cultural test offered in various languages and taking the country of origin into consideration. The test consists of 15 questions and after answering them, the personal ecological footprint is given at a very rough level and it is then compared with the average ecological footprint of the country. (Earth Day Network, 2002).

The Sustainable Europe Research Institute has launched a web-based consumption test based on material flow data (SERI, 2002). The test is informative and illustrative for consumers, but its approach is only partial and thus not directly adaptable to the needs of this research.

## **4 Discussion**

Understanding household consumption patterns means above all understanding human behaviour. Consumption is an important part of our everyday life and it is deeply rooted in our modern lifestyles. Consumption also plays a significant role in shaping our identities (Heinonen et al., 2005) which indicates the importance it has in our lives. At an individual level consumption behaviour is shaped by our needs, abilities and opportunities. On the society level important are e.g. the way our economy works (taxes, subsidies), what kind of products the industry is able and allowed (environmental regulation, the level of technology) to make and how accessible more environmentally sound products are to consumers.

Although it has already been recognised by the United Nations (1993) that the unsustainable pattern of consumption and production is a major cause of the continued degradation of the environment, sustainable consumption still has not achieved the political, social and economical attention it requires. In order to be able to change our consumption patterns, the starting point is to make our consumption visible through measuring it and also taking all the "hidden flows" into account. It is also important to understand the underlying reasons for our consumption patterns: Why do we consume and what drives us to behave the way we do?

The FIN-MIPS Household study aims to encourage Finnish households to consider the overall environmental burden they create through life cycle wide material flows. This can be done by offering tools for households to calculate and understand the patterns of their own resource consumption by using the MIPS method. As Spangenberg (2002) stated, "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".

The most appropriate level of producing and presenting information about households' material consumption is an important question which probably

has a strong effect on the forthcoming results of the study. The macro-level approach is useful for identifying the most environmentally relevant consumption clusters whereas the micro-level approach is best for calculating the product specific MI-values for selected products. As noted earlier, the real influence of households lies somewhere between these two levels and the challenge for the FIN-MIPS Household study is to combine these levels in a most suitable manner.

Lorek and Spangenberg (2001) have approached the question of how to reach sustainable consumption by thinking of it from the consumer's point-of-view, i.e. where can households make a difference and which actors are involved in its making? This actor-centred approach (Lorek & Spangenberg, 2001) could also be a starting point in the FIN-MIPS Household study. The appropriate level of presenting the data is the one where households really see the impacts of their behaviour while still not being too laborious to calculate the resource consumption.

In the case study of household goods, using the actor-centred approach would mean that the relevant patterns of consumption are condensed into a survey of approximately 20 questions for the households involved. The questions of a survey cover the most material-intensive products in households, meaning those commodities households should pay attention to if they want to make a difference. Based on the questions selected for the survey, the required MI(PS)-data is produced.

One challenge that has to be faced when using the MIPS method for material flow calculation is that MIPS is calculated in five different categories. Thus, for each product and activity, five different MIPS values are given as a result. In the FIN-MIPS Household study, MI data is produced for all five categories and the importance of each category will be analysed before presenting the data to the households.

Household consumption cannot be observed separately as there is a wide range of other actors affecting to it. Almost all consumption decisions taken by households are influenced by other social and economic actors (Lorek & Spangenberg, 2001). Achieving sustainable consumption and production patterns is a challenge that needs to be addressed by all relevant actors, including public authorities, business and consumers (EEA, 2005).

## References:

- Bringezu, S. (2002). *Towards Sustainable Resource Management in the European Union*. Wuppertal Papers 121. 50 pp. Wuppertal Institute, Wuppertal, Germany
- Carlsson-Kanyama, K. (2003). Promoting sustainable consumption: Possibilities and limitations for private households to use life cycle based environmental information. 12.10.2006. <http://www.infra.kth.se/fms/pdf/UNEPtalk.pdf>
- Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

*Satu Lähteenoja, Michael Lettenmeier and Tiina Moisio*

- Dall, O. Toft, J. & Andersen, T. (2002). Danske husholdningers miljøbelastning. Arbejdsrapport fra Miljøstyrelsen Nr. 13. Danish Ministry of Environment.
- EEA (2005). Household consumption and the environment. EEA Report No 11/2005. European Environmental Agency, Copenhagen.
- Earth Day Network (2002). Ecological footprint quiz. 14.10.2006.  
<http://www.earthday.net/Footprint/index.asp>
- Ecological Footprint Network (2006). Ecological footprint: Overview. 14.10.2006.  
<[http://www.footprintnetwork.org/gfn\\_sub.php?content=footprint\\_overview](http://www.footprintnetwork.org/gfn_sub.php?content=footprint_overview)>
- Federico, A., Musmeci, F. & Proietti Mancini, D. (2001). *MIPS of the Italian Mobile Telephone Network*. Paper presented at the Conference Challenges of a Changing Earth, Amsterdam 10-13 July 2001. ENEA Casaccia: Progetto Sviluppo Sostenibile, Roma, Italy
- GAP Finland (2006). <<http://www.nic.fi/~369123/ekoframeset-2.html>> 22.10.2006
- Grönroos, J. & Seppälä, J. (2006). Maatalouden tuotantotavat ja ympäristö. [Agricultural production methods and the environment.] Suomen ympäristö 431. Finnish Environment Institute, Helsinki, Finland
- Harland, P. & H. Staats (2006). Behavior change program research. 22.10.2006.  
[http://www.empowermentinstitute.net/files/Leiden\\_study.html](http://www.empowermentinstitute.net/files/Leiden_study.html)
- Heinonen, V., Raijas, A., Hyvönen, K., Leskinen, J., Litmala, M., Panzar, M., Römer-Pakkanen, T., Timonen, P. (2005). *Kuluttajaekonomia – Kotitalous ja kulutus*. [Consumer economy – Households and consumption.] Werner Söderström Osakeyhtiö, Helsinki.
- Hobson, K. (2003). Thinking habits into action: the role of knowledge and process in questioning household consumption practices. 22.10.2006.  
<http://ctsi.anu.edu.au/publications/nontaxpubs/KH.thinking%20habits.pdf>
- Hooke, R.LeB., 2000, *On the history of humans as geomorphic agents*. *Geology* 28: 843-846
- Koskinen, H., 2001, *MIPS ja ekologinen selkäreppu tuotteiden potentiaalisten ympäristövaikutusten vertailun menetelmänä – ongelmakohtien tarkastelu*. [MIPS and the ecological rucksack as methods for comparing the potential environmental impacts of products – examination of problems.] Ympäristönsuojelutieteen pro gradu –työ. <<http://ethesis.helsinki.fi/julkaisut/maa/limno/pg/koskinen>>. University of Helsinki, Helsinki, Finland
- Lettenmeier, M., Lähteenoja, S. & Saari, A. (2006). How to achieve factor X improvements in transport? Lessons learnt from the FIN-MIPS Transport project. Paper presented at the SCORE conference 23.-25.11.2006. Wuppertal, Germany
- Lorek, S. & J.H. Spangenberg (2001). Environmentally Sustainable Household Consumption. From Aggregate Environmental Pressures to Indicators for Priority Fields of Action. Wuppertal Papers No. 117. Wuppertal Institute for Climate, Environment, Energy, Germany.
- Lorek, S. (2002). Indicators for Environmentally Sound Household Consumption. In Workshop Lifecycle Approaches to Sustainable Consumption, November 22nd 2002. IIASA, Luxemburg, Austria.
- Massa, I. & S. Ahonen (toim.) (2006). *Arkielämän ympäristöpolitiikka*. Gaudeamus, Helsinki.
- Michaelis, L. and S.Lorek (2004). Consumption and the environment in Europe – trends and futures. Danish Environmental Protection Agency, Environmental Project No. 904 2004, Copenhagen, Denmark
- Mäenpää, I., A. Juutinen, K. Puustinen, J. Rintala, H. Risku-Norja, S. Veijalainen & M. Viitanen (2000): *Luonnonvarojen kokonaiskäyttö Suomessa*. [Natural resource use of Finland.] Suomen ympäristö 428, Helsinki.
- Mäenpää, I. (2003). *Material flows and economic properties of production*. Workshop “Quo Vadis MFA”. Wuppertal Institute, 8.-10.10.2003.
- Mäenpää, I. (2004). Kulutuksen ympäristökuormitus. Oulun yliopisto, Thule-instituutti, Oulu.
- Mäenpää, I. (2005). *Kansantalouden ainevirtatilinpito, Laskentamenetelmät ja käsitteet. Suomen ainetaseet 1999. Tilastokeskus ja Thule-instituutti*. Helsinki.
- Nieminen, A., Lettenmeier, M. & Saari, A. (2005). *Luonnonvarojen kulutus Suomen lentoliikenteessä (LentoMIPS)*. [Natural Resource Consumption in Finnish Air Transport (Flying MIPS)]. Liikenne- ja viestintäministeriön julkaisuja 57/2005. Ministry of Transport and Communications, Helsinki, Finland. Available from:  
<<http://www.mintc.fi/julkaisut>>



- Nissinen, A., Grönroos, J., Heiskanen, E., Honkanen, A., Katajajuuri, J.-M., Kettunen, J., Kurppa, S., Mäkinen, T., Seppälä, J., Silvenius, F., Timonen, P., Virtanen, Y., Voutilainen, P. (2005). Development of benchmarking for the environmental impacts of different products, services and consumption patterns. In: Sustainable Consumption: The Contribution of Research, Workshop 10-12 February 2005, Gabels Hus, Oslo, p.98-114. Norwegian University for Science and Technology (NTNU), Industrial Ecology program, Report 1/2005, Trondheim, Norway.
- OECD (2002). Towards Sustainable Household Consumption, Paris.
- Pütz, S. (1999). *Materialintensitätsanalyse der Hess Natur- spezifischen Produktlinie "Wolle" am Beispiel "Long-Life-Strickbluse"*. Abschlussarbeit für die Diplomprüfung von Ingenieuren
- Ritthoff, M., Rohn, H., Liedtke, C. & Merten, T. (2002). *Calculating MIPS. Resource productivity of products and services*. Wuppertal Special 27e. Available from: <[www.mips-online.info](http://www.mips-online.info)>
- Saari, A., Lettenmeier, M., Pusenius, K. & Hakkarainen, E. (2006). *Influence of vehicle type and road category on the natural resource consumption in road transport*. Transportation Research Part D. In press.
- Salo, V. & Lettenmeier, M. (2006). *SähkölaiteMIPS. Käyttöiän ja energiatehokkuuden vaikutus sähkölaitteiden aiheuttamaan materiaalipanokseen*. [EEE-MIPS. Influence of service life and energy efficiency on the material input caused by electrical and electronic equipment.] Helsinki Reuse Centre, Helsinki, Finland
- Schmidt-Bleek F (1994). *Wieviel Umwelt braucht der Mensch? MIPS—das Mass für ökologisches Wirtschaften*. Birkhäuser Verlag, Berlin, Germany
- SERI, Sustainable Europe Research Institute (2002). How much nature do you consume? Welcome to our online questionnaire. 21.10.2006. <<http://www.umweltbildung.at/cgi-bin/cms/af.pl?contentid=1429>>
- Shanahan, H. , Carlsson-Kanyama, A., & Ekström, M. (2002). Exploring opportunities for eco-sound food habits: households and researchers in partnership. 20.10.2006. <http://www.kon.org/archives/forum/14-1/shanahan.html>
- Spangenberg, J. (2002). An environmental space based approach to assessing the environmental impact of household consumption. In Workshop Lifecycle Approaches to Sustainable Consumption, November 22nd 2002. IIASA, Laxenburg, Austria.
- Statistic Finland (2006). Kotitaloustiedonkeruut. 14.10.2006. <http://www.stat.fi/keruu/kotitalous.html>
- Timonen, P. (2002). *Pyykillä–arkinen järkeily ja ympäristövastuullisuus kuluttajien valinnoissa..* Väitöskirja. [Doing the laundry – mundane reasoning and environmentally responsible choices. Dissertation.] Kerava: Kuluttajatutkimuskeskus. (Helsinki: National Consumer Research Centre).
- Tukker, A., Huppel, G., Guinée, J., Heijungs, R., de Koning, A., van Oers, L., Suh, S., Geerken, T., van Holderbeke, M., Jansen, B. & Nielsen, P. (2006). *Environmental Impact of Products (EIPRO). Analysis of the life cycle environmental impacts related to the final consumption of the EU-25. Main report. IPTS/ESTO project*. Technical Report EUR 22284 EN. European Commission, Joint Research Centre (DG JRC), Institute for Prospective Technological Studies. <[http://ec.europa.eu/environment/ipp/pdf/eipro\\_report.pdf](http://ec.europa.eu/environment/ipp/pdf/eipro_report.pdf)>
- Türk, V., Alakeson, V., Kuhndt, M. & Ritthoff, M. (2003). The environmental and social impacts of digital music a case study with EMI; final report ; Digital Europe. - Wuppertal [u.a.] : Wuppertal Inst. für Klima, Umwelt, Energie [u.a.]
- Üffing, A.(1999). *Materialintensitätsanalyse der Hess natur spezifischen Produktlinie "Baumwolle" am Beispiel "Long-Life – T-shirt"*. Abschlussarbeit für die Diplomprüfung von Ingenieuren.
- United Nations, Ed. (1993). Earth Summit: Agenda 21, the United Nations programme of action from Rio. United Nations, New York.
- United Nations (2002). Report of the World Summit on Sustainable Development in Johannesburg, New York. <<http://www.johannesburgsummit.org>>
- Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

*Satu Lähteenoja, Michael Lettenmeier and Tiina Moisio*

- Vihermaa, L., Lettenmeier, M. & Saari, A. (2006). *Natural resource consumption in rail transport: A note analysing two Finnish railway lines*. Transportation Research Part D 11: 227-232
- Von Geibler, J., Kuhndt, M. & Türk, V. (2003). *The environmental impacts of mobile computing. A case study with Hewlett Packard. Final report*. Digital Europe: ebusiness and sustainable development. Wuppertal Institute for Climate, Energy, Environment, Wuppertal, Germany.  
<[http://www.forumforthefuture.org.uk/uploadstore/HP\\_case\\_study.pdf](http://www.forumforthefuture.org.uk/uploadstore/HP_case_study.pdf)>

# POSTER How to Achieve Factor X Improvements in Transport?

*Lessons learned from the FIN-MIPS Transport project*

Michael Lettenmeier<sup>a</sup>, Satu Lähteenoja<sup>b</sup> and Arto Saari<sup>c</sup>

<sup>a</sup>*The Finnish Association for Nature Conservation, Kurhila, Finland, m.l@iki.fi*

<sup>b</sup>*The Finnish Association for Nature Conservation, Helsinki, Finland*

<sup>c</sup>*Laboratory of Construction Economics and Management, Helsinki University of Technology, Espoo, Finland*

## 1 Introduction

Transport plays an essential role in modern life. We can hardly imagine any product or activity that would not require transport to make it readily available. The amount of transport has been steadily growing for decades, almost without even a temporary decline. In Finland, for instance, passenger traffic increased more than 5-fold and goods transport nearly 4-fold from 1960 to 2005 (Finnish Road Administration, 2006).

If sustainability is to become a reality, a tremendous increase in resource efficiency is required. One target for sustainable production and consumption has been the reduction of material flows in the industrialised countries by a factor of 10 up to the middle of this century. This would make possible a worldwide cut in material flows by half, while doubling worldwide prosperity, i.e. an increase in worldwide resource productivity by a factor of four (Schmidt-Bleek, 1993; Schmidt-Bleek, 1998; von Weizsäcker, Lovins & Lovins, 1997). Meadows et al. (2003) propose, amongst other means, an increase in eco-efficiency by 4% p.a. in order to achieve sustainability. This corresponds to a factor 8 increase in resource productivity.

The purpose of this paper is to discuss the potential for factor X improvements in the resource efficiency of transport. The basis for the discussion are the results of the FIN-MIPS Transport research project. The discussion includes activities by different actors on the micro level as well as the transport system on the macro level.

## **2 MIPS values as an indicator for the resource efficiency of transport**

### **2.1 Background and methodology of the FIN-MIPS Transport research**

#### *2.1.1 Motivation and objective of the research project*

The promotion of sustainability requires appropriate indicators. Changes in technology and consumption patterns must be measurable, e.g. in relation to the Factor 10 target. In 1992, the Wuppertal Institute for Climate, Energy and Environment proposed the amount of natural resources used to provide a certain benefit (Material Input per Unit Service, MIPS or MI/S ) as a basic measure for assessing and comparing the ecological pressure caused by products and services. MIPS constitutes a tool for assessing and systematically reducing the resource consumption of products or activities. The bases of MIPS values are the ecological rucksacks calculated for different goods or commodities. The ecological rucksack is the sum of natural resources moved away from their original place in the ecosphere during the entire life cycle of a certain raw material, product or activity, including indirect resource use as well. (Ritthoff et al., 2002.)

The MIPS approach concentrates on the material input of products and activities. It differs from a life cycle assessment (LCA) in that it does not provide detailed results on certain emissions and other output factors. However, the use of the MIPS concept is less time and cost intensive than the use of, for instance, LCA based methods. In addition, the MIPS concept is easily communicated to a non-expert. Kilograms and tonnes of resources are understandable concepts for guiding consumer decisions, as well as product development and macro-economic considerations. The wide potential for the application of the MIPS-concept (product, service, household, company, municipality, region, national and global economy) promotes the understanding of the links between local activities and global sustainability.

As transport services are part of the life cycle of any product or activity, data on the material intensity of transport services are useful for the MIPS calculation of products and activities. The FIN-MIPS Transport research project was established in order to provide material input data for MIPS calculations made by Finnish companies and other institutions. Other objectives were to study the contribution of transport to the overall natural resource use in Finland and to consider potentials for increasing eco-efficiency and decreasing resource use.

#### *2.1.2 Scope and methodology*

The research project covered the Finnish transport system, including road, rail, bicycle, air, and maritime transport. Transport on inland waterways was excluded as it represents only a small part of the transport volume. Private navigation, private aviation and walking were also excluded. MIPS values were calculated for the consumption of abiotic resources, water and air. Biotic resources and earth movement in agriculture and forestry were excluded from the final calculations as transport turned out to cause only a minimal consumption of these resource categories.

In the first stage, the material intensity of the different transport modes was investigated based on case studies for typical parts of the infrastructure (see Vihermaa et al., 2006; Saari et al., 2006; Nieminen et al., 2005; Lindqvist et al., 2005; Hänninen et al., 2005).

In co-operation with the infrastructure authorities and transport companies involved, the data obtained from the case studies was then generalised to average Finnish conditions by assumptions made on, e.g., the average service life of infrastructure and vehicles, the average amounts of traffic on different infrastructures, and the average ridership.

The MIPS values for transport include the life cycle wide material input of infrastructure and means of transport. This material input is divided by the service obtained, i.e. the amount of transport, expressed in passenger kilometres and tonne kilometres. The calculation of MIPS values for transport requires the allocation of the material input of the infrastructure between passenger and goods traffic, both using the same infrastructure.

## 2.2 Material intensity of the Finnish transport system

### 2.2.1 Passenger transport

The average material intensity of passenger transport within Finland is shown in Table 1. Travel by metro, bus and bicycle consumes the least abiotic resources, travel by van most. Water is consumed least by bus travel and most by using the tramway. Air consumption is the lowest for bicycle travel and the highest for domestic aircraft travel.

Table 1. Average MIPS values for domestic passenger transport in Finland (km / passenger kilometre).

Means of transport	Abiotic	Water	Air
Private car	1.44	12.4	0.14
Van	2.16	20.0	0.28
Bicycle	0.38	12.1	0.02
Bus	0.32	2.8	0.06
Train	1.37	29.3	0.04
Metro	0.29	29.4	0.04
Tramway	0.66	48.1	0.07
Aircraft	0.56	26.6	0.28

Table 2 shows the average material intensity of passenger transport between Finland and abroad. The material intensity decreases with growing distance because the contribution of infrastructure to the material input decreases. Maritime travel consumes fewer resources than air travel mainly because of the lower fuel consumption per passenger kilometre. However, growing distance decreases the difference.

Table 2. MIPS values for international passenger transport from or to Finland (kg / passenger kilometre).

Means of transport	Destination	Abiotic	Water	Air
Ship	Nearby areas	0.26	2.42	0.31

Ship	Germany	0.13	1.44	0.21
Ship	Overseas	0.12	1.42	0.21
Aircraft	Nearby areas	0.47	18.90	0.34
Aircraft	Europe	0.11	3.36	0.14
Aircraft	Overseas	0.06	0.91	0.13

### 2.2.2 Goods transport

The average material intensity of goods transport within Finland is shown in Table 3. Transport by full trailer lorry consumes the least abiotic resources and water, transport by train the least air. Most abiotic resources are consumed when transporting by van, most water and air when transporting by aircraft.

Table 3. Average MIPS values for domestic freight transport in Finland (kg / tonne kilometre).

Means of transport	Abiotic	Water	Air
Van	10.78	100.2	1.39
Light lorry	0.58	5.0	0.07
Semi trailer lorry	0.44	3.8	0.07
Full trailer lorry	0.23	1.7	0.04
Average road transport	0.52	4.4	0.09
Avg road transport without van	0.37	3.1	0.07
Train	0.54	15.3	0.02
Aircraft	5.60	266.5	2.80

Table 4 shows the average MIPS values for cargo transport between Finland and abroad. Air transport consumes more resources than maritime transport. Growing distances decrease the material input per tonne kilometre because less infrastructure is needed per service unit, in air transport also less fuel.

Table 4. Average MIPS values for international cargo transport from or to Finland (kg / tonne kilometre).

Means of transport	Destination	Abiotic	Water	Air
Aircraft	Nearby areas	4.70	189.0	3.4
Aircraft	Europe	1.10	33.6	1.4
Aircraft	Overseas	0.60	9.1	1.3
Ship	Nearby areas	0.75	3.1	0.1
Ship	Europe	0.12	0.7	0.1
Ship	Overseas	0.08	0.6	0.1

### 2.2.3 Resource use on the national level

According to the methodology and assumptions of this study, the Finnish transport system consumes a total of approximately 130 million tonnes of abiotic natural resources, 1.46 billion tonnes of water, and 16.3 million tonnes of air, per year. Per capita this amounts to 25 tonnes of abiotic natural

resources, 280 tonnes of water, and 3 tonnes of air, per year (Tables 5, 6 and 7). Based on the methods used, 72% of the abiotic natural resource consumption by the transport system is attributable to passenger traffic and 28% to goods traffic.

Table 5. Average amount and division of the abiotic natural resource consumption by the Finnish transport system in one year.

Mode of transport	Infra (mill. t)	Traffic (mill. t)	Total (mill. t)	Per capita (t)
Public roads	84.52	5.70	90.22	17.3
Private roads	10.93	0.16	11.09	2.1
Municipal streets	9.18	2.78	11.96	2.3
Cycling	0.43	0.06	0.49	0.1
Rail	4.62	0.67	5.29	1.0
Air	0.91	0.34	1.24	0.2
Maritime	8.56	1.56	10.11	1.9
<i>Total</i>	<i>119</i>	<i>11</i>	<i>130</i>	<i>25.0</i>

Table 6. Average amount and division of the water consumption by the Finnish transport system in one year.

Mode of transport	Infra (mill. t)	Traffic (mill. t)	Total (mill. t)	Per capita (t)
Public roads	462.85	77.12	540.0	103.4
Private roads	244.38	2.18	246.6	47.2
Municipal streets	139.53	27.93	167.5	32.1
Cycling	10.10	5.59	15.7	3.0
Rail	51.43	234.37	285.8	54.8
Air	67.60	2.43	70.0	13.4
Maritime	28.85	11.97	40.8	7.8
<i>Total</i>	<i>1 005</i>	<i>362</i>	<i>1 366</i>	<i>261.7</i>

Table 7. Average amount and division of the air consumption by the Finnish transport system in one year.

Mode of transport	Infra (mill. t)	Traffic (mill. t)	Total (mill. t)	Per capita (t)
Public roads	0.71	7.50	8.21	1.6
Private roads	0.11	0.21	0.32	0.1
Municipal streets	0.26	3.33	3.59	0.7
Cycling	0.002	0.02	0.02	0.0
Rail	0.08	0.27	0.35	0.1
Air	0.07	0.80	0.87	0.2
Maritime	0.30	2.66	2.97	0.6
<i>Total</i>	<i>1.5</i>	<i>15</i>	<i>16.3</i>	<i>3.1</i>

A significant percentage of abiotic natural resource consumption by the transport system comes from infrastructure provision. The contribution of the infrastructure to the traffic's abiotic MIPS values varied between 73% in the case of domestic air traffic and 99% in the case of private roads. The

abiotic natural resource consumption primarily reveals the amount of earthworks and construction undertaken on behalf of the traffic.

The abiotic natural resource consumption is equivalent to around 25% of Finland's Total Material Requirement (TMR). In the study by Mäenpää et al. (2005) the calculated contribution of traffic to the total consumption of natural resources is appreciably smaller. The high figure obtained in this study is influenced by the fact that the previously constructed infrastructure is evenly applied across all the years of use. The amount of traffic infrastructure construction nowadays is, however, less than one might think from the average figures calculated in this study.

The most important factors regarding water consumption are rainwater diverted from its normal route, and electricity consumption. With air consumption, approximately 90% was due (with the exception of bicycle traffic) to energy consumption.

### 2.3 Analysis of the MIPS values

In order to assess the potential for a factor X reduction in resource use, it is necessary to analyse the values given in section 2.2.

One aspect affecting the final range of the values presented in Tables 1-4 is the allocation of the material inputs for the infrastructure to the different users. For instance, the abiotic resource consumption per passenger kilometre can be slightly smaller for car traffic than for bus traffic when allocating the infrastructure input according to the gross weight of the traffic, or 8.7 times higher for car traffic than for bus traffic when allocating on the basis of the number of vehicles using the roads (Saari et al., 2006). However, as the total material consumption of the transport system is not dependent on allocation methods and as the values of Tables 1-4 are based on very profound discussions and decisions with Finnish infrastructure experts, the allocation of the material input for infrastructure is not discussed any further in this paper.

#### 2.3.1 Factors influencing the material input

The factors influencing the material input values for transport differ for the different resource categories. The material input from infrastructure dominates abiotic resource consumption of domestic transport. The share of infrastructure varies between 73% for air transport and 99% for private roads (see Table 5). Air transport has a limited need for infrastructure and a relatively high resource consumption during the period of use of aircraft whereas private roads form a widely spread and relatively heavy infrastructure with only small amounts of vehicles using them. Most of the material input for infrastructure is attributable to the construction of infrastructure, which causes huge direct shifts of material.

The abiotic material input of the traffic (without infrastructure) is dominated by the use phase, i.e. mostly energy consumption, in the case of rail, air and maritime transport. For road and street traffic, the material input for the production of the vehicles is roughly equal to that of the use of vehicles. In the case of bicycle traffic, the production of the bicycle is dominant.



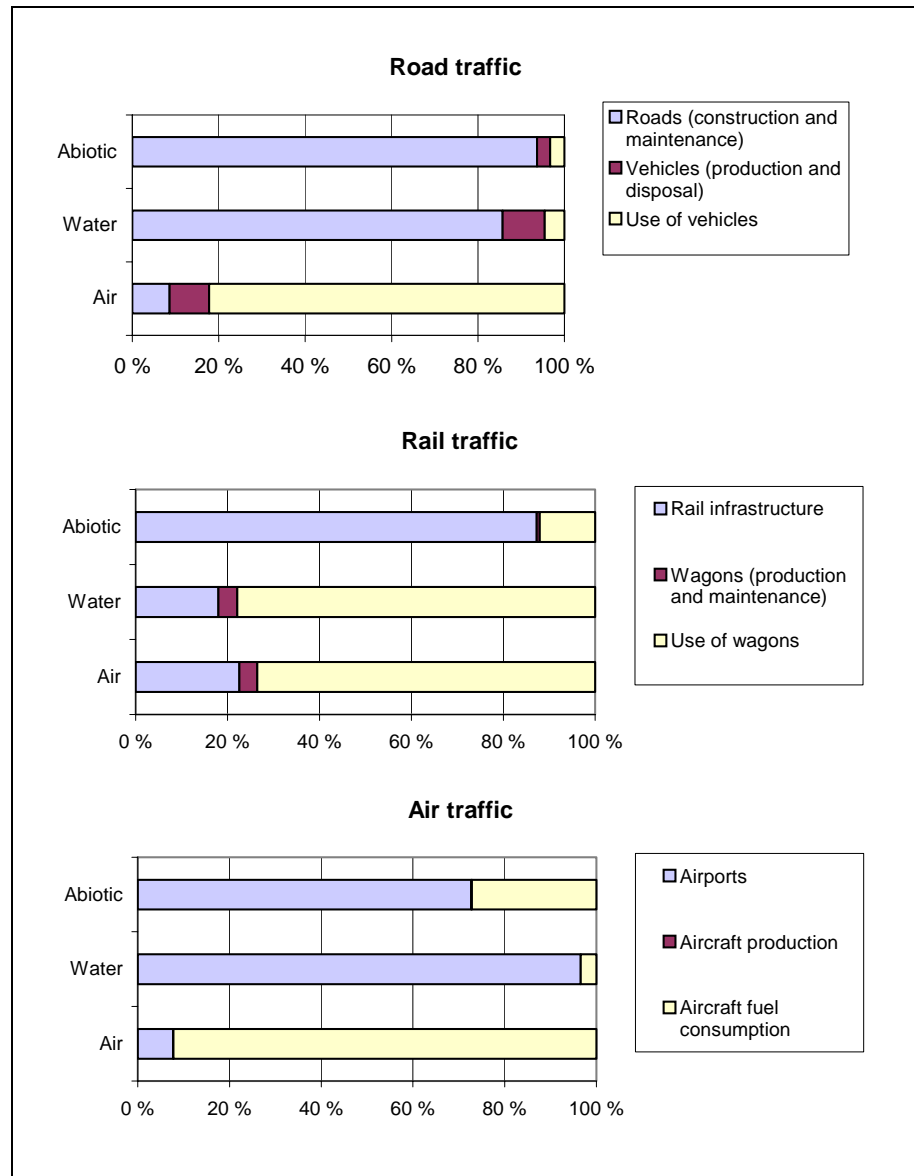


Figure 1. Division of natural resource consumption between traffic and infrastructure.

Infrastructure is also the dominant factor for water consumption as 75% of the water consumption of the transport system is due to infrastructure. The water consumption is mainly caused by two factors, (i) the rainwater diverted from sealed surfaces and (ii) the water input for electricity consumption. In Finland, the latter is highly affected by the proportion of waterpower in the electricity production. Whereas diverted rainwater accounts for a lot of the water consumption for vehicle, maritime and short distance air transport, the water consumption of rail transport is dominated by the water input for the electricity consumed.

With air consumption, approximately 90% was due (with the exception of bicycle traffic) to energy consumption.

2.3.2 Factors influencing the service unit

In addition to the material input (MI), MIPS values are influenced by the amount of service (S) provided as a result of consuming natural resources. In the case of transport, the service provided to the final consumer are the person-kilometres travelled and the tonne-kilometres transported, because the service in question is the transportation of people and goods.

Also, the calculation of the service unit for transport includes the two aspects of infrastructure use on the one hand (means of transport/people/freight tonnage using the infrastructure during its service life) and the use of the means of transport on the other (service life of the means of transport and the passenger and freight tonnage transported in them). The service unit calculation required an analysis of the average person and freight amount transported based on the average traffic volumes for different infrastructures.

The major assumptions for the use of infrastructure and means of transport are shown in Table 8.

Table 8. Major assumptions concerning the use of infrastructure and means of transport.

Means of transport	Service life of infrastructure years	Capacity use of infrastructure	Service life of means of transport	Capacity use
Car	60	Average daily traffic (ADT) of different road and street categories, 26 ... 38,600 vehicles/day	270 000 km	1.4 persons
Bus	60		1 000 000 km	13 persons
Van	60		400 000 km	1 person or 200 kg
Lorry	60		1 000 000 km	7, 14 or 21 tonnes (app. 50%)
Bicycle	60	ADT 300 bikes/day	20 a	1 person
Cargo train	100	0.5 - 3 M. tonnes/a	14 000 000 km	50%
Long distance train	100	0.05 - 5 M. pass. trips/a	14 000 000 km	20 – 60%, depending on rail traffic
Local train	100	ADT 11,000 pass./km	Based on long distance trains	Based on yearly passenger amounts
Metro	100	ADT 52,500 pass./km		
Tramway	60	ADT 3,800 pass./km		
Aircraft	100	Based on the real amount of operations	30 a ( depending on aircraft type, 20 – 110 M. km)	53 – 89%, depending on the route
Passenger ferry	50		30 a., express boats 15 a	2000 persons (pass.ferry) 300 persons (express boat)
Freight ship	50		30 a	2100 – 2200 t. (Roro-ship) 8300 t. (oil tanker)

The assumptions for the use of infrastructure and means of transport have a noticeable impact on the resulting MIPS values. The lowest impact was observed for the lifespan of the means of transport as the material input of the means of transport has only a slight influence on the final MIPS results (cf. 2.3.1). Only with bicycles (Hakkarainen et al., 2005) and express boats (Lindqvist et al., 2005) does a change in the service life have a visible influence on the MIPS values.

The capacity use of the means of transport plays a relevant role. Despite its shorter distance, a transeuropean charter flight consumes less abiotic resources and air per passenger kilometre than an intercontinental flight

because its capacity use (76% instead of 57%) is higher (Nieminen et al., 2005). Travelling in a van causes a high resource consumption per passenger kilometre (Table 1) because there is usually only 1 person travelling in a van instead of an average of 1.4 persons in a car. With goods transportation, an average of only 200 kg is transported in a van whereas lorries carry an average of 7 tonnes at least, which leads to deliberately higher MIPS values (Table 3). Transporting by full trailer lorries consumes fewer resources than transporting by lighter lorries (Table 3) because full trailer lorries transport on average 2 or 3 times more freight than lighter lorries, while their difference in material input remains lower.

Also the presumed service life of the infrastructure influences MIPS values appreciably. There is no generally agreed life for infrastructure. Roads even hardly ever cease to exist. If a larger road is built alongside an existing one, the original road is usually left in place and used as a lower category facility. In the FIN-MIPS Transport research, the service life of the infrastructure (see Table 8) was estimated in close co-operation with the responsible authorities. On short distance flights, for instance, the reduction of the presumed service life of the airside infrastructure of airports from 100 to 50 years, would increase the abiotic MIPS values of short distance flights 38 – 65% whereas the values for water and air consumption remain nearly constant (Nieminen et al., 2005). Similar observations were made when varying the service life for harbours (Lindqvist et al., 2005) and bicycle lanes (Hakkarainen et al., 2005).

The capacity use of infrastructure has the greatest service-unit related influence on the MIPS values. The abiotic MIPS value for travelling by car on a motorway is lower by a factor of 3 than on a lower class connecting road, although the abiotic material input per kilometre of road exceeds the MI of the connecting road by a factor of 20. This is due to the fact that the average daily amount on motorways is 63 times higher than on connecting roads. For water consumption, the differences between the road categories are even bigger, but for air consumption they are considerably smaller.

Similar observations can be made for other modes of transport. For bicycle travel, there is a factor 2.1 difference in abiotic MIPS and a factor 1.6 difference in water consumption between an average bicycle lane in Finland and in Helsinki, the latter having smaller values because of higher traffic density (Talja et al., 2006). Travelling on a single-tracked railway used by 50,000 passengers per year exceeds the MIPS values for a similar track used by 5 million passengers per year by factors of 64, 10, and 9 for abiotic resource consumption, water, and air, respectively. MIPS values for air travel from Helsinki to low frequency airports at a similar distance can be even 4 times higher than for travelling to similar but higher frequency airports.

### *2.3.3 Variation of average MIPS values due to different circumstances*

In addition to the differences between average values, attention has to be drawn to the fact that average values cover noteworthy variations between different circumstances.

The material input of infrastructure is strongly determined by the ground and local topography the infrastructure has been built on. Vihermaa et al. (2005) observed differences of up to a factor of 17, 10, and 4 in abiotic

resources, water, and air consumption, respectively, in the material input values for the construction of one metre of modern, double-tracked railway, depending on the bearing capacity of the soil and the local topography. Hänninen et al. (2005) have stated potential differences by a factor of 40 in the abiotic resource consumption for the construction of one square metre of municipal street, depending on the bearing capacity of the soil, the soil stabilisation method and the amount of traffic expected.

The amount of traffic using a certain infrastructure has a strong influence on the MIPS values obtained for using this infrastructure. Talja et al. (2006) report a factor 3 difference in abiotic MIPS values for car traffic on private roads due to variations in average daily traffic.

The origin of the electricity used by rail traffic has a noticeable influence on the MIPS values. For instance, the use of electricity produced by Helsinki Energy instead of the average national electricity mix increases the material input per passenger kilometre in metro transport by 10% (factor 1.1) for abiotic resources and a factor of 1.75 for air, but decreases the MIPS value for water consumption by a factor of 6 (Talja et al., 2006). Wind power as an electricity source for railway transport has a considerably reducing effect on water and air consumption, but is visible also on the abiotic resource side (Vihermaa et al., 2005).

#### 2.3.4 *Factors influencing the national material consumption*

Figure 2 shows the distribution of the total consumption of natural resources between the different modes of transport in Finland.

When the division of natural resource consumption is compared to the amounts of passenger and goods traffic, the results can be considered logical. 94% of passenger traffic and 68% of goods traffic comprise road and street traffic, through which 87% of the abiotic natural resources, 71% of the water and 75% of the air are consumed. Vehicular traffic is thus the transport mode mostly affecting natural resource consumption by transport.

In order to draw conclusions about reduction in resource use, it is worth analysing the factors behind the consumption of resources in transport.

The consumption of abiotic natural resources first and foremost reveals the infrastructure mass demanded by the particular mode of transport, this mass being determined by surface area and thickness. Thus, for instance harbours, which are of massive construction, consume more abiotic natural resources than private roads, despite the latter having a larger surface area. Similarly, while airports have larger surface areas than harbours, their abiotic natural resource consumption is markedly less than that of harbours.

The distribution of water consumption is primarily correlated with the surface area required by the mode of transport, since an appreciable fraction of water consumption is due to rainwater diverging from its original route. The contribution of private roads to water consumption is greater than the contribution of maritime traffic. The use of water by rail traffic, on the other hand, is linked to the utilisation of water for electricity generation. Consequently, the contribution of rail traffic towards water consumption by the traffic system is greater than its surface area contribution.

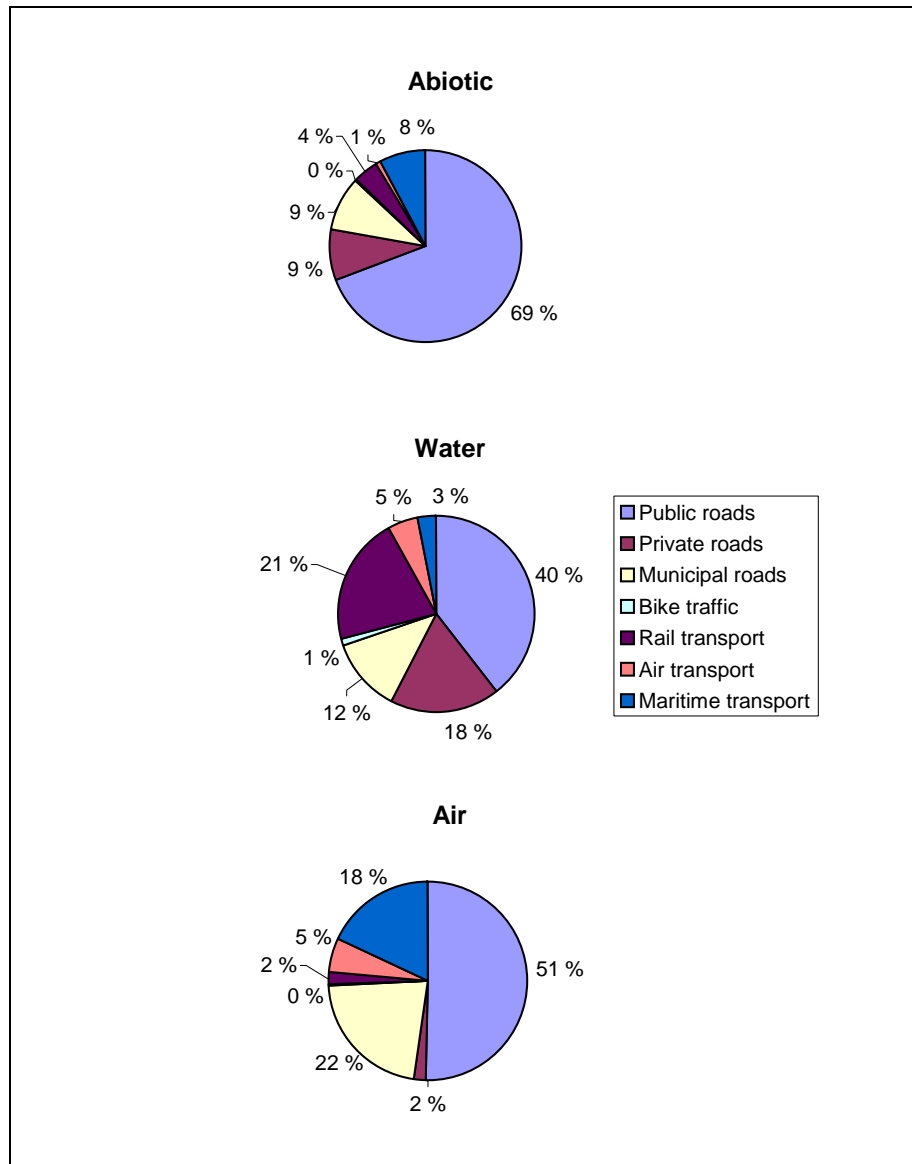


Figure 2: Distribution of natural resource consumption between different modes of transport in Finland.

Air consumption is in almost direct relationship to the amount of traffic, since it is primarily based on the use of fuel. Here rail traffic forms an exception, too. The contribution of rail traffic to the amount of traffic is greater than the contribution of rail traffic to air consumption. This is influenced by, firstly, the energy efficiency of rail traffic and, secondly, the proportion of electricity generated by means other than combustion in relation to the overall electricity consumed.

The MIPS values presented in sections 2.2.1 and 2.2.2 do not tell us anything about the amount of traffic as the material input is set against the amount of service output. As an example, bicycle traffic, the MIPS value for which may be surprising in the case of abiotic resources (Table 1) and water (Table 2), constitutes only 0.4% of the abiotic material input and 1.1% of the water consumption of the whole transport system.

2.3.5 Application of the MIPS values in different transport cases

The MIPS values calculated can be applied to distinct examples for travelling or transporting goods. In this section, three different examples for passenger traffic and two examples for goods transport are shown:

- (i) a trip from Helsinki to St. Petersburg,
- (ii) a commuting trip to work in the Helsinki region,
- (iii) a trip to school in the countryside,
- (iv) an average letter sent in Finland, and
- (v) a comparison of express consignments.

When travelling from Helsinki to St. Petersburg, five different modes of transport can be used (Table 9). The calculations do not include journeys between the harbour, airport or railway station and the city centre. There are differences between the least and the most consuming travel of factors of 8, 9, and 18 for the consumption of abiotic resources, water, and air, respectively. However, the results differ in the different categories of resources. From the standpoint of the consumption of abiotic natural resources and water on this journey the best alternative is the passenger car ferry. The coach consumes almost as little, but in terms of air consumption the coach is an appreciably better option than the passenger car ferry. The train uses the least amount of air, but from the water consumption standpoint the train is the worst alternative. From the overall point of view, the best option would appear, based on this calculation, to be the coach.

Table 9. Natural resource consumption per person on the Helsinki to St. Petersburg route, kg/journey

Modes of transport	Abiotic	Water	Air
Passenger car	794	7990	75
Coach	128	1116	24
Train	568	8089	10
Passenger car ferry	96	895	115
Jet	111	895	177

A commuter’s work trip within the Helsinki Metropolitan Area, with a length of approximately 15-19 km, depending on the mode of transport, was examined for six modes of travel. The different means of travel are named according to the most common form of transport on the journey (Table 10). Between the different options, there are differences by a factor of 9, 43, and 18 in the consumption of abiotic resources, water, and air, respectively. On this trip the bicycle is the best option in terms of abiotic resource and air consumption. From the water consumption perspective, the best alternative is the bus. Water consumption is affected mainly by diverted rainwater and by the use of electricity. Electricity for the metro, as also the tram, has been calculated according to the average national electricity mix, thereby emphasising the contribution of hydropower. From the standpoint of abiotic resource and air consumption the passenger car is far and away the worst alternative.

Table 10. Natural resource consumption of a work trip (Espoo-Helsinki) per person using different modes of transport (kg/journey).

Modes of transport	Abiotic	Water	Air
Passenger car	25,5	228	3,6
Bus	3,2	13	1,1
Bicycle	2,7	111	0,2
Metro	5,6	560	0,9
Bus + tram	5,4	346	1,2
Bus + metro	4,2	128	1,0

The natural resource consumption of a child's 4-km school trip one way in a sparsely populated part of the countryside is considered using four different travel variations. For car travel, the length of the journey in both directions has been calculated. In this case the service applies to the passengers, i.e. the driver has not been taken into account in the total number of people being transported. Thus, the consumption due to transporting one child has been calculated on the basis of the passenger car's vehicle kilometres. With three children on board 1.5 kilometres of extra driving at the start of the trip has been calculated and the vehicle kilometres have then been divided by three. The biggest differences between the options are as high as factor 41, 63, and 17 for abiotic resource, water, and air consumption, respectively (Table 11). The bicycle and coach/bus are appreciably more eco-efficient alternatives than the passenger car, even with several children on board.

Table 11. Natural resource consumption per passenger of children's school journeys using different modes of transport in a rural area (kg/person/trip).

Modes of transport	Abiotic	Water	Air
Cycle	0.9	37	0.1
Taken by car, one child aboard	37	564	1.7
Taken by car, 3 children aboard	19	286	0.8
Coach	1.3	9	0.2

Based on the results of this study it was calculated how much transporting a letter in Finland on average consumes natural resources. The basic data were supplied by the Finnish Post Corporation (Suomen Posti Oyj). Most of Finland's 'letter kilometres' take place by passenger car. Journeys between sorting offices are made by lorry. The most urgent long distance mail goes by air, while vans are used mainly for deliveries to companies and for emptying public mailboxes, so that the contribution of these to the overall transportation is minimal. For calculating the material input of transporting a letter, the average MIPS values for the vehicles were used. The calculations adopted the material intensity values of Sinivuori and Saari (2006) for university buildings to the buildings used by the post corporation.

On average, transporting a letter consumes 190 g of abiotic natural resources, 7.8 kg of water, and 34 g of air. Around 77% of the consumption of abiotic natural resources, 29% of the water consumption, and 74% of the air consumption was attributable to vehicles. Most of the water consumption

was due to the hydropower needed for the electricity supply to the buildings. From the standpoint of its abiotic natural resource consumption, sending a letter in Finland is equivalent to a journey of well over 100 metres by passenger car. Transporting a letter to a letterbox by passenger car over a one-way distance of 1 kilometre multiplies the consumption of abiotic resources, water, and air by a factor of 21, 5, and 11, respectively.

The results of the study were also applied to the calculation of natural resource consumption by TNT's transport operations with the aid of a few examples. TNT Finland Ltd. assisted in making the calculations. To compare the natural resource consumption of different routes and consignments of varying sizes, the results for the different consignments were converted to consumption per tonne kilometre. In the case of transportation within Finland, the actual number of kilometres driven was divided by the total load for each section of the route. The case consignments transported abroad both went from Finland to Germany, one being sent by air, the other by road. Information on the distribution contribution was not as precise as with deliveries in Finland, so that distribution was calculated only as a one-way direct journey to the recipient. In natural resource consumption for foreign route sections in Sweden the MIPS values from this study were used, and in Denmark and Germany, the German values (Schmidt-Bleek, 1998). For the purpose of the calculations only transportation was taken into account and not, for example, buildings as in the previous example.

Table 12. Natural resource consumption of case consignments (kg/tonne km)

Route	Collection and distribution, km	Main route, km	Means of transport	Abiotic	Water	Air
Turku-Rauma	190	—	Van + Lorry	9	54	1.3
Tuusula-Nurmes	196	617	Van + Lorry	0.7	6.5	0.09
Järvenpää-Mannheim	42	2020	Van + Aircraft	1.1	49	0.5
Kotka-Bremen	172	1642	Lorry + Ferry	0.2	0.84	0.02

The natural resource consumption of a 4.4 kg consignment from Turku to Rauma was compared to a delivery made from Tuusula to Nurmes and weighed 80 kg. Taking the consignment from Tuusula to Nurmes consumed in terms of tonne kilometres less abiotic resources, water, and air by a factor of 13, 8, and 14, respectively. An express delivery taken from Järvenpää to Mannheim by air in one night consumed more resources per tonne kilometre than a consignment from Kotka to Bremen taken by road, mainly using a semi-trailer lorry. The difference was a factor of 5.5, 58, and 25, for the consumption of abiotic natural resources, water, and air, respectively.

When the results were examined, it was found that the degree to which vehicles are filled vastly affects the consumption of natural resources. In main route point to point transportation, large amounts of goods are transported from depot to depot in full vehicles, thus not markedly raising the material input in the overall transportation, but reducing the material input of the delivery in relation to the tonne kilometres. The case calculations differ radically from each other in regard to what component of the delivery consumed the most natural resources. The results calculated per tonne kilometre in the examples supported the results of the study regarding the size category of the average MIPS values, even though the fluctuating



goods volumes at the same time indicated that there may be appreciable differences in the eco-efficiency of natural resource consumption between individual cases. Among the domestic consignments the difference is primarily due to the fact that the Turku-Rauma route does not include any main point to point transportation, but comprises solely collection and distribution journeys in vehicles which are not as full as those used for main route transportation.

When comparing the material inputs per tonne kilometre of the two case consignments sent to Germany, it was observed that in regard to the consumption of abiotic natural resources, water, and air, transportation by land is much more eco-efficient than air transport (factor 5.5, 58, and 25, respectively). In addition, on the Kotka-Bremen route almost 90% of the consignment's abiotic natural resource consumption was due to transportation from Kotka to Vantaa. By making the Kotka-Vantaa route section more efficient the consignment's eco-efficiency could, however, be considerably increased, the difference between air and land transportation then even increasing.

### **3 Reflection concerning factor X improvements in transport**

#### **3.1 Comparison of the MIPS values for transport**

When comparing MIPS values for domestic passenger traffic in Finland it can be seen that from the standpoint of the consumption of abiotic natural resources the bus, bicycle and metro are the most eco-efficient modes of transport (Table 1). From the water consumption standpoint travelling by bus/coach is clearly the most eco-efficient option. In regard to air consumption cycling is the best alternative. Maximum differences between the different modes of travel are factor 5, 17, and 14 for abiotic resource, water, and air consumption, respectively. When travelling to areas close to Finland the ship is more eco-efficient than the aeroplane (Table 2). On longer haul flights, the MIPS values decrease.

In goods traffic the most eco-efficient form of transport per tonne kilometre from the abiotic resource and water consumption perspective is the full trailer truck (Table 3). In regard to air consumption the best alternative is the train. The differences between the different modes of transports are greater than in the case of passenger travel, varying by a factor of 47, 157, and 140 for abiotic resource, water, and air consumption, respectively. Calculated per tonne kilometre the van is the least eco-efficient mode owing to its average load being so small. In international goods traffic the ship is a markedly more eco-efficient form of transport than the aircraft because of its low fuel consumption (Table 4). Maximum differences range between factor 9 in abiotic resource consumption over European distances and factor 34 in air consumption over short distances.

The modes of transport shown in Tables 1 – 4 are not totally comparable with each other. For instance, bicycles and aircrafts cannot be considered as modes of travel competing with each other but they can both compete with cars in certain circumstances. Despite this, obvious errors in the MIPS values for different modes of transport can be pointed out. Thus, in principle there is considerable potential for increasing the resource efficiency of transport.

There is a difference in the potential reduction of resource consumption in the different categories for material input. The contribution of infrastructure to the MIPS values for abiotic resources and water consumption was significant. Thus, improvements in these areas require new approaches in the planning and use of infrastructure. Regarding the material input for air consumption (mainly combusted oxygen), a reduction in the fuel consumption is most relevant.

## 3.2 Options for decreasing MIPS values

Within the constraints of this study, it was not possible to comprehensively estimate the relationships with material intensity of measures commonly proposed for reducing the environmental loading due to traffic. However, a few methods which have emerged in the public discussion are reflected below from the natural resource consumption perspective.

### 3.2.1 *The material input of infrastructure*

The share of the infrastructure in abiotic natural resource consumption by different modes of transport is appreciable (see Figure 1). The use of material from quarrying or excavating at the construction site reduces the need for importing soil and stone materials. Another way of enhancing the eco-efficiency of infrastructure construction is to replace new building materials by waste raw materials or by surplus materials imported from elsewhere. Also imported recycled materials or by-products, for example stones from the mining industry, coal and peat ash, metallurgical crushed slag, blast furnace sand and crushed concrete, can decrease the material input. So far, there has been little utilisation of waste for making road foundations (Hänninen et al., 2005).

Straight road and rail lines demanded by fast transport connections do not leave much chance of avoiding terrain that is unfavourable from the construction standpoint. This increases the demand for cuttings and soil stabilisation, so that abiotic resource consumption per route kilometre rises. Infrastructure planning can appreciably influence the material intensity of the infrastructure built.

Most of the natural resource consumption by roads and railways is due to their construction, with just a small contribution coming from their maintenance (e.g. Hänninen et al. 2005: 55-56; Vihermaa et al. 2005: 29). On this basis the construction of new infrastructure increases the overall consumption of natural resources far more than does the maintenance of existing roads and railways. New roads also tend to increase, rather than decrease, the amount of traffic (e.g. Tapio 2002), which again raises the total use of natural resources. Rather than building new roads, the capacity of existing ones should be uprated by, for example, ways of improvement having lower materials intensity. These ways could include, for instance, developing traffic arrangements at road junctions, constructing or designating overtaking lanes, diverting traffic to a parallel road, or by investing in traffic control systems.

The need for including infrastructure already built into MIPS calculations can also be reflected on a general level. If someone walks a distance of one kilometre along a private road to a bus stop instead of being taken there, how much natural resources in actual fact are spared? At least the fuel

consumption of the passenger car; but what about the infrastructure? It is easy to maintain that the road is in any case there, having once been built, so that the natural resource consumption due to the road does not need to be calculated in addition to the car's consumption. However, there is no such thing as free infrastructure, as resources have been used for it at least at some point in the past. In addition, this kind of thinking could also be applied to public transport: since the bus is going to pass that way anyway, then a single passenger will not increase the consumption by travelling on it. However, from a holistic point of view thinking along these lines is unsustainable as in the long term the bus will not run at all, if the single passengers do not make use of it. Consequently, the material input of infrastructure should be allocated to all types of users and cannot be omitted.

### 3.2.2 *The material input of the means of transport*

The contributions of car manufacturing and car fuel consumption to vehicle abiotic natural resource consumption are both around five percent, while fuel consumption is the governing factor in terms of air consumption (Figure 1). Shortening the service life of vehicles, e.g. by a shift in taxation from vehicle purchase to vehicle use, would thus enlarge the relative and absolute contribution of vehicle manufacturing and reduce the proportion of the natural resource consumption due to the use of the vehicles. Reducing fuel consumption would decrease air consumption directly. On the other hand, shortening the lifespan of individual vehicles by e.g. 20% would call for a fuel consumption reduction in the equivalent size class to prevent the consumption of abiotic natural resources from increasing.

According to a study by the Wuppertal Institute for Climate, Energy and Environment, replacing a passenger car with a steel chassis by a car with an aluminium (alloy) chassis and consequently lower fuel consumption would require the vehicle to be driven over 500,000 km, for the increased manufacturing materials' abiotic natural resource consumption to compensate for the lowered fuel consumption (Schmidt-Bleek 1998). The service life of a bus or coach is appreciably longer than 500,000 km, so that in this instance the increased use of aluminium can more easily be defended.

Various development trends are apparent in existing cars and on the car markets. A Smart-type small 2-person car in terms of its capacity answers an appreciable proportion of peoples' travel needs (the average ridership in Finland is 1.4 persons; see Table 8). Thanks to its compact size, this type of car requires a somewhat smaller infrastructure and less parking space, at least in urban areas.

However, the trend appears to be precisely the opposite: an increase in large vehicles (space wagons or people carriers, city 4X4s) is raising natural resource consumption in the form of higher fuel consumption. Moreover, the space requirement of this kind of vehicle, both in traffic and when parked, is higher than average, thereby increasing the infrastructure requirement.

The hybrid car (a combination of internal combustion engine and electric motor) saves fuel but requires fitting with an electric motor containing a lot of copper (which has a high abiotic material intensity). While it is fair to assume a decline in air consumption by this kind of engine, owing to the increased use of copper the overall abiotic natural resource consumption is unlikely to decrease.

The contribution of fuel consumption to abiotic natural resource consumption of vehicle transport as a whole is of the order of five percent (see Figure 1). By using biofuels, this proportion could be lowered. However, if the biomass for biofuels had to be cultivated for fuel use, it would also become necessary to examine this form of biotic natural resource use (which is beyond the range of this study). The abiotic material inputs in biomass cultivation would also have to be considered. Using biogas generated from wastes as a fuel would not have to include natural resource consumption due to cultivation. With the use of biofuel, however, air consumption would remain at the same level, since oxygen is also used up when biofuel is burned. In the MIPS concept, air consumption does not change based on the use of renewable resources. Thus, this method is not equivalent to the general practice of carbon dioxide emission calculation, in which the carbon dioxide bound up in growth is taken into account (carbon cycle).

### 3.2.3 *Service unit: capacity use and service life*

By making the use of a means of transport more effective, eco-efficiency can be improved. Even in long haul goods transportation, a significant proportion of natural resources are consumed at the start and end of journeys in conjunction with goods collection and delivery (cf. Table 12). Therefore, special attention should be devoted to improving the efficiency of goods collection and delivery journeys.

If two people travel to work in the same car instead of both using their own, in principle the consumption of natural resources by the journey is halved. If travelling together leads to extra driving, the savings are reduced, although they will most likely not entirely disappear altogether (see Table 11).

The running of public transport vehicles is not eco-efficient if they are empty because the MIPS values rise as the ridership falls. However, when public transport is examined in the network, maintaining schedules on some little-used runs, e.g. through state funding, can promote the use of the entire network. If public transport support reduces private car use, it promotes dematerialisation, because passenger car transport is the most highly consumptive form of passenger traffic (see Table 1).

Shared trips reduce the consumption of natural resources in direct proportion to the number of people sharing. They can lessen the amount of both fuel and vehicles, as well as the infrastructure requirement and thus provide one means of lowering the MIPS values in all the sub-areas. Car sharing not only reduces use of the infrastructure but also the number of cars and private car performances (Meijkamp 1998).

In addition to an increase in the capacity use of infrastructure, an increase in the service life of the infrastructure could be seen as a major contributor to decreasing the material input per unit service in transport. Especially with abiotic resource use, an increase in the service life of the infrastructure would be necessary for cutting down the high share of the infrastructure in the MIPS values for transport.

### 3.3 Relevance of the consumer's choice

As shown in section 3.1, a potential for a factor X increase in the resource efficiency of transport can be found when comparing and analysing average MIPS values for transport. Despite general recommendations concerning the material intensity of different transport modes, the consumer of transport services can make decisions about how to travel or how to transport in a certain case. As section 2.3.5 shows, the results for distinct cases are not necessarily equal to the average figures. Thus, reflection on a case basis can be useful.

Case studies also show that the consumer's choice is relevant, but limited. Through his or her daily choices everybody can promote a reduction in natural resource consumption by opting for the most eco-efficient alternative among the available means of travel and by keeping the travel performance as small as possible. However, the consumer cannot choose a non-existent service. Again, with existing services, there are usually factors other than material intensity influencing the consumers' choice, e.g. prices, speed and service availability. Thus, the responsibility for the dematerialisation of transport cannot be laid solely on the consumer, but one has to consider the circumstances and structures shaping and influencing the transport system, within which the consumer has to make choices.

#### 3.3.1 *Passenger transport*

The natural resource consumption per person on the Helsinki to St. Petersburg route was calculated for five modes of transport (Table 9). The train uses the least amount of air, but has high values for abiotic resources and water consumption. Abiotic natural resources and water on this journey are consumed least when using the passenger car ferry. The coach consumes almost as little, but in terms of air consumption the coach is an appreciably better option than the passenger car ferry. However, at present the consumer cannot choose the car ferry, as this service is not offered. The coach is a resource-efficient, but time-consuming option so that the consumer might make a choice based on other criteria.

The resource consumption of one work trip may appear small (Table 10), but since the trip is made twice a day, 220 days a year, the values and their differences have to be taken seriously. Work trips made by the passenger car in the example consume 11.2 tonnes of abiotic natural resources a year. Travelling by bus uses up 1,400 kg of abiotic natural resources a year, which is a factor of 8 less. According to Mäenpää et al. (2005) the overall consumption of natural resources by households in 1995 came to well over 15 tonnes per capita (without the infrastructure contribution). Thus, a work trip of sufficient length, especially one made by passenger car, may well double a citizen's total natural resource consumption.

As with the journey to work, so also with the journey to school: the values may look small but when the trip is made twice a day, 180 days a year, the values and their differences begin to acquire more significance. For instance, transporting one child to school, as in this example, by passenger car in a rural area consumes 13.3 tonnes of abiotic natural resources a year. By contrast, the coach consumes 470 kg of such resources over the same period of time (factor 28 less). The distance of services such as schools is one important factor influencing the possibilities and the need for the choice

of transport mode. If e.g. schools in rural areas are closed down, the distances grow even and this may affect additional transportation if walking or cycling becomes impossible.

### 3.3.2 *Goods transport*

The distance of the service available is also relevant in terms of goods transport. The case calculation indicated that sending a letter in Finland is equivalent from the standpoint of its abiotic natural resource consumption to a journey of well over 100 m by passenger car. Transporting a letter to a letterbox by passenger car multiplies the consumption of natural resources severalfold. Thus, the consumption of natural resources by the sending of letters remains the smaller, the fewer the letters taken for posting use different forms of motorised transport. Thus, the decision of the consumer not to use the car for delivering his or her letter is relevant. However, the consumer cannot directly influence the letterbox network. Keeping the collection network for letters sufficiently dense conserves natural resources. Equivalent phenomena have also been observed in the energy consumption of infrastructure changes in the retail trade (Kasanen & Savolainen, 1992): drivers' journeys by passenger car are a more significant factor than trade logistics lorries, so that the increased passenger car journeys by consumers when a shop closes down clearly exceed the energy savings made by the cooperative business by closing the shop. Consequently, ways of shopping and distribution (e.g. e-commerce and home delivery) that reduce the customers' need to drive elsewhere promote dematerialisation.

The use of products produced locally in principle lowers the product transportation intensity and in that respect also the materials intensity. However, there are various kinds of preconditions associated with this. The transport chain's eco-efficiency is radically affected by the collection and delivery journeys at the start and end of each transportation (Table 12). If, for example, procuring or consuming locally grown food increases the passenger car or van journeys, with their high materials intensity (see Table 1), the extra performances may increase the material intensity of the products.

When comparing the material inputs per tonne kilometre of the two case consignments (Table 12), it was observed that in regard to the consumption of abiotic natural resources, transportation by land is over 5 times more eco-efficient than air transport (factor 5). In terms of water consumption the difference between the two examples is factor 58 and in the case of air consumption almost factor 17. Thus, speed also costs in terms of natural resources, and resource use can be reduced by avoiding air transport and preferring slower delivery.

### 3.3.3 *Choosing the least consuming means of transport*

Replacing road and air transport by rail and water transport has been put forward as a means of, for example, reducing greenhouse gas emissions. The effect of replacing modes of transport is here considered from the natural resource consumption angle.

In passenger transport the vehicle consumes more abiotic natural resources and air than rail transport (Tables 1, 9, 10), even though exceptions do turn up when specific road categories and routes are examined. In

Finland, rail transport uses more water than vehicular traffic because regulated hydropower plays an important part in the Finnish electricity mix. A change in the method of generating electricity may radically affect the MIPS values for rail traffic, especially in terms of water consumption.

Travelling by bus uses up natural resources and water to a far less extent than rail traffic. Air consumption is, however, higher (Tables 1 and 9). When there are several passengers in a car, the latter's eco-efficiency improves. If increasing rail traffic calls for additional construction of rail infrastructure, the abiotic natural resource consumption may not necessarily decrease, because modern two-track lines are material intensive. If, however, road investments of equivalent capacity are avoided, lower amounts of natural resources will be consumed by the rail investment.

A domestic flight consumes on average less abiotic natural resources and more air than a train journey (Table 1). The differences between travelling by train and by passenger car are less pronounced. When travelling to nearby areas (from Finland to Stockholm, St. Petersburg and Estonia) the ship is slightly more eco-efficient than the aeroplane (Table 2). On the Helsinki-Tallinn route the aeroplane consumes, however, less abiotic natural resources and air than the express boat.

The relationships between the MIPS values of different modes of transport are different in goods traffic. Lorry transport consumes on average slightly less abiotic natural resources and appreciably less water than goods train transport, but goods train deliveries consume less air (Table 3). In goods traffic air transport is generally a less eco-efficient option (Tables 3 and 4).

Domestic maritime cargo deliveries were not studied in the FIN-MIPS Traffic project due to their low level of significance (Lindqvist et al., 2005). If Finland's coastal traffic is compared to cargo ship traffic going to areas close to Finland, the MIPS values for its abiotic natural resource and air consumption are higher than in road and rail transport, while the value for water is of the same order of magnitude as in road transport, but lower than in rail transport. Hence, transferring domestic goods transport to the sea within the current system framework would not conserve much natural resources.

The aforementioned comparisons indicate that there are differences between modes of transport and it is thus possible to achieve savings in natural resource consumption by choosing the best means available. However, there are no fundamental bases from the natural resource consumption standpoint for replacing vehicle and air transport by rail and maritime transport in any case.

#### 3.3.4 *The paradox of speed*

Increasing speed is usually considered desirable and useful. However, numerous results of the FIN-MIPS Transport research indicate that speeding up traffic increases natural resource consumption in the form of energy consumption and/or infrastructure material inputs. Thus, decisions by consumers and planners to prefer lower speed transport modes would save resources.

For example, the straight road and rail lines demanded by fast transport connections, with their cuttings, do not leave any chance of avoiding terrain

that is unfavourable from the construction standpoint, so that natural resource consumption per route kilometre rises. Additionally, speed easily increases travelling and/or the length of journeys and thus the traffic and its natural resource consumption as a whole.

In Finland, for instance, it is not possible to leave for weekend shopping visits to Central Europe by car, but it is possible by air and this is becoming increasingly popular. Air transport increases natural resource consumption in the form of increasing performances, despite being relatively eco-efficient per person kilometre in mode of transport comparisons (see Tables 1 and 2).

In maritime transport the express boat consumes considerably more natural resources than the slower passenger car ferry, this being a result of the higher fuel consumption due to the increase in speed, among other factors (Lindqvist et al., 2005).

In goods transport fast transportation by air is much more consumptive than other modes of transport (Tables 3, 4, 12).

### 3.4 Transport system level

A significant percentage of abiotic natural resource consumption by the traffic system comes from infrastructure provision. The abiotic natural resource consumption primarily reveals the amount of earthworks and construction undertaken on behalf of the traffic. The abiotic natural resource consumption is equivalent to around 25% of Finland's Total Material Requirement (TMR). In the study by Maenpää (2005) the calculated contribution of traffic to the total consumption of natural resources is appreciably smaller. This is influenced by the fact that the previously constructed infrastructure is evenly applied across all the years of use, while the amount of traffic infrastructure construction nowadays is less than one might think from the average values calculated in this study.

The maintenance of old roads consumes appreciably lower amounts of natural resources than the construction of whole new roads, so that the amount of further construction is fundamental to natural resource consumption by the transport system. A substantial decrease in abiotic resources used by transport can only be achieved if the growing need for infrastructure is re-thought and turned into a more efficient use and an extension of the service life of the existing infrastructure.

The most important factors regarding water consumption are rainwater transferred from its normal route, and electricity consumption. With air consumption approximately 90% was due (with the exception of bicycle traffic) to energy consumption. Air consumption by traffic reflects carbon dioxide emissions quite well.

From the relatively low MIPS values for busy routes, one may gain the impression that by increasing the amount of traffic, i.e. the service unit, on existing routes we could decrease the MIPS values and increase eco-efficiency. This does not, however, mean a reduction in natural resource consumption as a whole. From the environmental aspect, it is the total consumption and not the size of the relative MIPS values that is of relevance. Higher eco-efficiency, in other words a lower MIPS value, is not the same as less consumption of natural resources. This reinforces the viewpoint that in addition to eco-efficiency we must also aim for sufficiency.



Eco-efficiency is increased by e.g. the choice of vehicle based on the MIPS values, and an increase in the use of the vehicle or the infrastructure. In both cases, the natural resource consumption in relation to the performance falls. Sufficiency is promoted by endeavours to reduce the transport performance, when the consequence is a reduction in the overall consumption as well.

Travelling by public transport in general consumes smaller amounts of natural resources per person kilometre than travelling by private car (Tables 1, 9, 10, 11). Hence, the eco-efficiency of traffic improves when the public transport contribution to the overall traffic performance grows. In public transport as well, the ridership of vehicles is important, because the MIPS values rise as the ridership falls.

The contribution of roads to the consumption of abiotic natural resources and water by the transport system is considerable (Tables 5 - 7). Most of the natural resource consumption by roads is due to their construction, with just a small contribution coming from their maintenance. On this basis the construction of new roads increases the overall consumption of natural resources far more than does the maintenance of existing roads. Rather than building new roads, the capacity of existing ones should be updated.

It is generally assumed that by concentrating the human community traffic can be reduced compared to a situation where an equivalent amount of construction takes place outside the existing community structure. If concentrating the community structure increases the use of the existing traffic routes without the need for constructing new ones, it reduces the MIPS values for transport. Concentrating the community structure can also reduce the overall natural resource consumption if it can be used to decrease traffic performances, and if it promotes the use and profitability of more eco-efficient modes of transport. If, however, the community structure is intensified by constructing on weak foundations, the materials intensity of the infrastructure increases. In particular the consumption of abiotic natural resources may rise compared to a situation where construction takes place on sturdy, but more distantly located, ground. The "profitability" limit, especially from the abiotic natural resource consumption perspective, needs to be calculated in each case.

A carfree quarter can reduce infrastructure materials input in two ways. The number of streets is less than normal, since the number of roads leading to properties decreases. Roads leading directly to residential properties are lighter in construction and materials intensity, but they are numerically greater thus consuming big amount of resources (Talja et al., 2006). Secondly, devehicularisation makes the construction of narrower and lighter traffic routes than normal possible, for example within residential areas based on apartment buildings. In addition, devehicularisation may promote the use of other forms of transport to the passenger car, which consumes the most natural resources. For example, in Austria the arrangement of parking outside apartment block areas has been found to improve the profitability of public transport and to reduce traffic performance, i.e. journey length and quantity (Knoflacher 2004).

One purpose of telecommuting is the reduction of journeys between home and work place. Cutting down the number of journeys directly reduces natural resource consumption. Lessening the amount of journeys during the rush hour also reduces the pressure for bolstering up the infrastructure.

However, if telecommuting increases the readiness to move to places a long way away and/or requiring the use of a passenger car, then the increased travel cancels out at least part of the savings in natural resource consumption achieved by the telecommuting.

#### **4 Overall conclusions – how to achieve factor X?**

Applying the MIPS methodology to the traffic system brings a new perspective to the discussion on the environmental impact and eco-efficiency of traffic. The most important new aspect concerns taking abiotic natural resource consumption into account. Another strongpoint of the MIPS method is its simplicity: products and services differing from each other can be made comparable on the basis of kilograms of resources.

Reducing the total consumption of natural resources by transport is only possible if the growth in traffic performances ceases. Predictions on traffic performance growth increase the pressure to construct new roads, which increases abiotic natural resource and water consumption, as well as the traffic performance when new and better roads are introduced. According to Tapio (2002), there is a self-perpetuating connection between traffic predictions and performances, which is difficult to break without effective intervention measures.

Within the framework of the FIN-MIPS Transport research, the traffic system and different modes of transport have been studied in an exhaustive fashion. Natural resource consumption by transport can be considered high from the standpoint of both the national economy and, for instance, the overall consumption of natural resources by households. If comprehensive materials flow data from other sectors of consumption were available, a wider view on the role of transport in dematerialising consumption and the intervention measures required for dematerialisation would become possible.

In the light of the results of the study, natural resource consumption by traffic is appreciable, for example in relation to Finland's Total Material Requirement. Reducing the overall consumption would require a reduction in the amount of traffic performance. This can, despite the potentials observed in this study, in the present situation be regarded as a challenge, since the number of transport performances have almost constantly risen over the last few decades (Finnish Road Administration, 2006).

A material intensive traffic system can be considered one cause of a way of life and a society headed in an unsustainable direction, or at least as an underlying factor. On the other hand, material intensive traffic can also be considered a consequence of an unsustainable way of life and society, since traffic is not a purpose in itself, rather it is one kind of community "support activity".

Even if a material intensive traffic system is regarded as merely the result of a way of life and society, the situation can be considered disturbing. Since the abiotic natural resource consumption of the community's "support activity" is responsible for one quarter of the total consumption of natural resources, it may be that our society is on the way towards "The tower of Babel" (Van Dieren 2005), at which the society will suffocate and collapse in the constantly escalating need for resources called for by growth maintenance.

Still, if a large dematerialisation of society (factor 10) is a prerequisite for achieving a sustainable society and way of life, the traffic system must also be vastly dematerialised from its present level. According to Gudmundsson and Nielsen (1999), the consumption of solid (equivalent to abiotic) materials during the life cycle of passenger car transport in Denmark could at best be reduced by 71% (factor 3.6) by 2050 and the carbon dioxide emissions (equivalent in principle to air consumption) by 88% (factor 8.3).

The FIN-MIPS Transport study shows that similar reductions in resource use are in principle possible also in Finland although requiring remarkable efforts. Efforts have to be done on different levels and by different actors viz. consumers, infrastructure and municipal planners, infrastructure administration, producers of equipment, providers of services, and last but not least local and national political decision-makers.

## References

- Finnish Road Administration (2006). *Finnish Road Statistics 2005*. Edita, Helsinki, Finland
- Gudmundsson, H. and Nielsen, T. (1999). Extended Summary of Reduction of Environmental Pressure From Car Transport – Case Study of Eco-efficiency in the Danish Transport Sector. In *Factor 4 and Factor 10 in the Nordic Countries – The Transport Sector – The Forest Sector – The Building and Real Estate Sector – The Food Supply Chain*. TemaNord 1999:528. Nordic Council of Ministers, Copenhagen, Denmark.
- Hakkarainen, E., Lettenmeier, M. & Saari, A. (2005): *Polkupyöräliikenteen aiheuttama luonnonvarojen kulutus Suomessa (PyöräMIPS)*. [Bicycle MIPS – Natural Resource Consumption in Finnish Bicycle Traffic.] Liikenne- ja viestintäministeriön julkaisu 55/2005. Ministry of Transport and Communications, Helsinki, Finland. Available from: <<http://www.mintc.fi/julkaisut>>
- Hänninen, S., Hellén, S., Lettenmeier, M. & Autio, S. (2005). *MateriaEuro – Luonnonvarojen käyttö Helsingin katujen rakentamisessa ja ylläpidossa*. [MateriaEuro – Natural Resource Use in Street Construction and Maintenance in Helsinki]. Helsingin kaupungin rakennusviraston julkaisu 1/2005. Public Works Department, City of Helsinki, Finland. Available from: <<http://www.hkr.hel.fi/julkaisut/julkaisut2005.html>>
- Kasanen, P. & Savolainen, M. (1992). *Jakelujärjestelmän ja kuluttajan roolin muutosten vaikutus energian kulutukseen*. [Influence on the energy consumption of changes in the distribution system and in the role of consumers.] Helsingin yliopiston sosiaalipsykologian laitoksen energiajulkaisu 7/1992. University of Helsinki, Finland.
- Knoflacher, H. (2004). *Roles of Measures in Changing Transport and Other Behaviour*. In “Communicating Environmentally Sustainable Transport. The Role of Soft Measures”. OECD Publishing, Paris, France.
- Lindqvist, A., Lettenmeier, M., Saari, A. (2005). *Meriliikenteen aiheuttama luonnonvarojen kulutus (MeriMIPS)*. [Natural Resource Consumption in Maritime Transport (MaritimeMIPS)]. Liikenne- ja viestintäministeriön julkaisu 58/2005. Ministry of Transport and Communications, Helsinki, Finland. Available from: <<http://www.mintc.fi/julkaisut>>
- Meadows, D., Randers, J. & Meadows, D. (2004). *Limits to Growth. The 30 Years Update*. Chelsea Green Publishing Company, White River Junction, US
- Meijkamp, R. (1998). *Changing consumer behaviour through eco-efficient services: an empirical study of car sharing in the Netherlands*. Business Strategy and the Environment 7: 234-244
- Mäenpää, I. (2005). *Kansantalouden ainevirtatilinpito. Laskentamenetelmät ja käsitteet. Suomen ainetaseet 1999*. [Material Flow Balance Account of the National Economy. Accounting methods and terms. Finnish Material Balance 1999] Statistics Finland and Thule-institute, Helsinki.

- Nieminen, A., Lettenmeier, M. & Saari, A. (2005). *Luonnonvarojen kulutus Suomen lentoliikenteessä (LentoMIPS)*. [Natural Resource Consumption in Finnish Air Transport (Flying MIPS)]. Liikenne- ja viestintäministeriön julkaisu 57/2005. Ministry of Transport and Communications, Helsinki, Finland. Available from: <<http://www.mintc.fi/julkaisut>>
- Saari, A., Lettenmeier, M., Pusenius, K. & Hakkarainen, E. (2006). *Influence of vehicle type and road category on the natural resource consumption in road transport*. Transportation Research Part D. In press.
- Schmidt-Bleek, F. (1993). *Wieviel Umwelt braucht der Mensch? MIPS - Das Maß für ökologisches Wirtschaften*. Birkhäuser, Berlin, Basel, Boston. In English: Schmidt-Bleek, F. (1993). *The Fossil Makers – Factor 10 and more*. Available from: <[www.factor10-institute.org/seitenges/Pdf-Files.htm](http://www.factor10-institute.org/seitenges/Pdf-Files.htm)>
- Schmidt-Bleek, F. (1998). *Das MIPS-Konzept: weniger Naturverbrauch – mehr Lebensqualität durch Faktor 10*. [The MIPS Concept: Less Nature Consumption – More Quality of Life.] Droemersche Verlagsanstalt, München, Germany
- Rithoff, M., Rohn, H., Liedtke, C. & Merten, T. (2002). *Calculating MIPS. Resource productivity of products and services*. Wuppertal Special 27e. Available from: <[www.mips-online.info](http://www.mips-online.info)>
- Talja, S., Lettenmeier, M. & Saari, A. (2006). *Luonnonvarojen kulutus paikallisessa liikenteessä – Menetelmänä MIPS* [Natural Resource Consumption of Local Transport According to the MIPS Concept]. Liikenne- ja viestintäministeriön julkaisu 14/2006. . Ministry of Transport and Communications, Helsinki, Finland. Available from: <<http://www.mintc.fi/julkaisut>>
- Tapio, Petri (2002). *The Limits to Traffic Volume Growth. The Content and Procedure of Administrative Futures Studies on Finnish Transport CO<sub>2</sub> Policy*. Acta future fennica no 8. Tulevaisuuden tutkimuksen seura, Turku, Finland
- Vihermaa, L., Lettenmeier, M. & Saari, A. (2005). *Luonnonvarojen kulutus Suomen rautatieliikenteessä (RautatieMIPS)*. (Natural resource consumption in Finnish railway transport [Railway MIPS].) Liikenne- ja viestintäministeriön julkaisu 56/2005. Ministry of Transport and Communications, Helsinki, Finland. Available from: <<http://www.mintc.fi/julkaisut>>
- Vihermaa, L., Lettenmeier, M. & Saari, A. (2006). *Natural resource consumption in rail transport: A note analysing two Finnish railway lines*. Transportation Research Part D 11: 227-232.
- Van Dieren, W. (2005). *The Limits to Growth and the Tower of Babel or How arts can tell a scientific story better*. Presentation. Factor 10 –Symposion 25.11.2005. House of Design, Hällefors, Sweden.
- Von Weizsäcker, E. U.; Lovins, A. B. & Lovins, L. H. (1998). *Factor 4. Doubling Welfare, Halving Resource Use. A Report to the Club of Rome*. Earthscan, London, UK

# POSTER Teaching and Implementation Models for Sustainable PSS Development

*Motivations, Activities and Experiences*

T. C. McAloone

*Technical University of Denmark, tm@mek.dtu.dk*

## 1 Introduction

The past two decades have seen increasing efforts to consider the potential negative effects of products' manufacture, use and disposal on the local and global environment (Ehrenfeld, 2001). Over this time efforts have been made to relate the goals and ideals of sustainability to the domain of product development, thus adding new dimensions, such as social and moral values, to the original agenda of environmental improvement. The redefinition of the role of the product developer, from environmentally conscious product developer to sustainably aware product developer has led to new insights into the way in which products are developed and used – and to where environmental effects occur in the lifetime of a product.

The product developer has thus a more complex role in relation to sustainability, as the focus for improvement of a product may not (and very often does not) lie in the physical artefactual ingredients of the product or the processes used to create it. Rather, the focus for improvement of a product's environmental performance most often lies in the manner in which the product is *used* and *consumed*. A product's *use* phase is often environmentally significant, as this is the largest source of environmental impact. A product's *consumption*, or rather, a given user's *consumption behaviour* is even more important, as this dictates exactly how many use-phases, how many products and how much *product redundancy* is created, due to the user's lack of awareness, motivation or ability to consume a product in an environmentally respectful manner (McAloone, 2005).

The problem with both *use* and *consumption* is that the product developer traditionally has very little power over these two elements; they occur after the product has left the factory and entered into the hands of the user (the consumer).

Until the real environmentally harmful phases of a product's life can be harnessed by the producing company, it is often impossible to make the radical (Factor X) environmental improvements to the product itself that are necessary to maintain an environmental equilibrium (e.g. Reijnders, 1998).

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

## 2 Introduction to PSS

An increasing amount of companies are currently taking control over (and accepting responsibility for) a larger portion of their products' life-cycles. Many of these are doing this for reasons other than environmental, but there are also examples where environmentally-based product-life 'takeovers' have been with environmentally-founded goals in mind (McAloone & Andreasen, 2002). In general it can be said that western society is gradually realising the need for optimised resource consumption, leading to a search for solutions and business models, promising not only local optimisation but sustainable consumption from an overall perspective. In parallel, a general shift in focus from the exchange and consumption of goods to the exchange of competences and the consumption of services emerges (Matzen & McAloone, 2006). This activity is now commonly referred to as Product/Service-System (PSS) development.

PSS development gives a number of possibilities to the company, ranging from the re-invention of core-business, through gaining customer loyalty, expanding the customer base, and importantly, to the possibility of removing some of the traditional environmental problems connected to the consumption behaviour of users – although this should certainly not be considered as being a purely inevitable situation.

PSS stimulates the opportunity to adopt a more sustainable approach to business creation, as the physical products can be managed as valuable inventory that remains within the system and not just consumables that disappear from the system. For example, the greatest environmental impact of energy using products (EuP's) is in their use phase, where the use is totally at the consumer's discretion. Environmentally, this most often gives a detrimental situation, as the user has little knowledge of proper usage, or has different usage patterns that were not intended for the given product.

The underlying principle of PSS strategy is to shift from business based on the value of *exchange of product ownership and responsibility*, to business based on the value of *utility of the product and services*. The idea being that the customer pays only for the use of the product when needed and does not have to worry about operation, maintenance or disposal. In this way companies have the opportunity to dematerialise their business by decoupling their value creation with resource consumption (Tan et al, 2006). Value is instead created by supporting the customer's activities related to the use of products and not necessarily through material consumption. This is done through intangible services and knowledge intensification that ensures optimal operation and performance of products in relation to the individual customer's activities. It is believed that PSS approaches will enable and motivate companies to reuse, rationalise and enhance their products and services more efficiently throughout their life phases. This strategy also allows companies to enhance their competitiveness by expanding features, value and benefits not apparent with traditional product-oriented offerings.

### 2.1 How does PSS differ from product development?

In traditional manufacturing companies the physical product is considered to be at the core of the offering with services being complementary and supplemented in aftermarket activities. With PSS approaches this view changes. Here the customer's interaction with the

product and its related activity is at the centre of attention. Value is created during the activity and based on the performance and outcome of the activity. This shift in view challenges our current understanding of development and the models we use to represent the development task.

With physical products the task is to determine the product's structural characteristics so that the desired properties may be attained, and the product in use then delivers utility and value to the customer. In the area of services we do not have the equivalent insight into the relations between what structures a service and which properties contribute to the customer's perception of utility and value.

We observe two life/cycle systems that must be considered in PSS development: 1) the life cycle of the physical artefact and 2) the activity life-cycle relationship between the providing company and customer, representing a product-oriented and a service-oriented view, respectively (Figure 1). Companies must gain insights into both views in order to achieve the potentials of PSS and to reap the potential environmental benefits of optimising these two life-cycle systems.

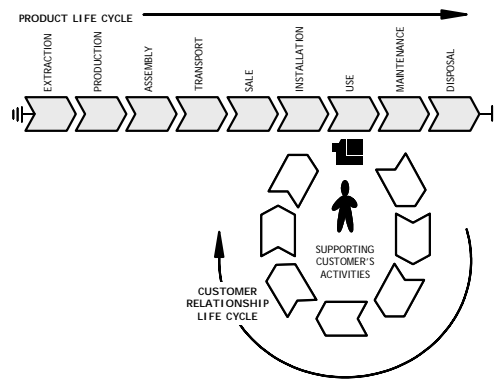


Figure 1 – Two life-cycles must be observed and optimised (Tan et al, 2006)

### 3 Our research motivations

PSS is relatively new as a research discipline and we still lack overview in order to be able to understand how to design a PSS. For example, who should sit in the project team for the creation of PSS concepts, and with which tools? No longer merely a team of engineers with a set of linear development models..? A PSS requires an orchestration of a complex network of stakeholders, both in- and outside of the company, in order to deliver an *augmented product* to the customer in a satisfactory manner – and to be able to sustain this satisfaction throughout the whole company-customer relationship.

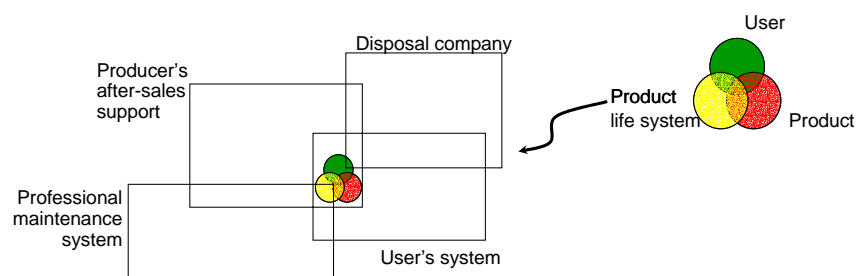


Figure 2 – A PSS is composed as an augmented product (McAloon & Andreasen, 2002)

We therefore see that the area of PSS has a number of important research dimensions, including:

1. A theoretical understanding of the operations-related opportunities inherent in PSS approaches to business, exploring and explaining opportunity parameters pointing towards e.g. the dematerialisation of offerings, optimising of performance or consumption etc. This dimension could also be referred to as PSS as a potential of benefit.
2. A theoretical understanding of the phenomenon of combined product and service offerings, exploring and explaining the inherent virtues and inferiorities of physical products throughout their life cycles and how these can be supported and relieved by service offerings. This dimension could also be referred to as PSS as a theory.
3. A prescription of the structures and management technologies necessary to enable companies and company networks to develop, deliver and operate PSS solutions. This dimension could also be referred to as PSS as a strategy.
4. A prescription of the processes which will enable development teams to identify and take advantage of the potentials referred to in paragraph 1 of this listing. Furthermore a prescription of working tasks and documentation models aiding the development team in the concretisation, communication and realisation of PSS solutions. This dimension could also be referred to as PSS as development methods. (Matzen & McAloone, 2006).

We can prepare ourselves for a significant change in the way that traditional product manufacturing companies deliver their products to their customers – especially in the western world, where companies no longer can expect to compete on a global market with respect to cost, quality or time. It is our hypothesis, that if carried out correctly (aided by professional methods and approaches) the shift from the development, sales and provision of discrete, physical products, to the practice of *functional sales*, provided as a product of PSS-development, will give radical environmental improvements.

For this to be possible, we believe that we need to expand both our *mindset*, in order to be able to understand the proper nature of a PSS and our *design degree of freedom*, in order to be able to carry out professional PSS design. We need to be able to understand how to design the life-cycle first, then the product (Kimura & Suzuki, 1996), to ensure an efficient product, durable company-customer relationship and reduced environmental effect.

#### **4 Activities**

In recognition of the need to bring a closer relationship between the theories and practices of LCA, ecodesign, innovation and product development, the Sustainable Innovations Group was established at The Technical University of Denmark, DTU, in 2005. Our group comprises teachers, researchers and consultants in the field of sustainable innovation and it is our goal to reap the advantages of both the analytical and synthesis approaches to environmental improvement, and to set our work in the context of providing models and methods for the development of



ecologically and economically sustainable solutions to students and to organisations.

At the core of our current project activities within our group are a series of PhD students, researching in design methodological aspects for product/service-system solutions and in aspects and constraints of implementing PSS in industry. Industrial partners comprise both manufacturers of electro-mechanical devices, public institutions and branch organisations – all interested in exploring options of PSS in their field of activity.

In the following we will briefly introduce our activities in the industrial implementation and then dedicate a little more time to describe our undergraduate teaching of PSS.

#### 4.1 Industrial implementation

For a number of years we have worked with companies, developing and implementing ecodesign strategies and methods/tools. These activities with industry have been an integral part of our theory- and method development research, where a number of descriptive and normative results have been produced (e.g. Olesen et al, 1996). In the late 90'ies it seemed that an ecodesign saturation point was reached, where companies had reached a limit to the viability of the environmental improvements striven for or claimed to be achievable. The low-hanging fruits had been plucked and the only opportunities left for making significant environmental improvements lay in the product life phases that lay beyond the producing company's reach and responsibility.

The emergence and development of PSS as a strategy has therefore meant that some of the earlier 'unreachable' phases of the product's life-cycle (and the customer's/user's activity cycle) can now be planned for and designed into the PSS. As a result of this, our collaborative activities with industry focus on the advancement of supporting models for the development of sustainable PSS solutions, based on an understanding of product- and service life-cycles, and on the transition from a product-oriented strategy to a service-oriented strategy. Our research is empirical in nature and our models so far have been largely descriptive.

#### 4.2 Teaching PSS

We see our teaching activities in the area of PSS as giving the opportunity to test and develop our descriptive models of industrial activities into more normative tools and techniques for the students.

At DTU we have had an increasing focus on sustainable PSS development teaching for the past five years. Currently we have two courses amounting to 15 ECTS points, where we educate fifth semester bachelor students in sustainable PSS development. In the following we describe our approach.

##### 4.2.1 *The Design & Innovation programme at DTU*

The product developers we are educating today will hold large responsibilities in the industry of the future. From our dialogue with Danish companies we have derived an important set of criteria for professional

product developers, including: the ability to synthesise (creative ability); to visualise and communicate; to stage the design process (Andreasen et al, 2000); to utilise knowledge and skills in related subjects and areas; to utilise and lead specialists in related subjects and areas; to function well in, or lead, a design team; and to be aware of the social, environmental and sustainability ramifications of their involvement in industry.

The above criteria have formed the basis for a new five-year bachelor-master programme at DTU, entitled *Design & Innovation* ([www.design-ing.dk](http://www.design-ing.dk)). We educate our students with a focus on three core competence areas:

- Technical engineering competencies  
*Reflective, technological engineering competences, which refer to the reform of teaching and integration of the core engineering curriculum.*
- Socio-technical competencies  
*Competencies to be utilised in the creation and renewal of systems and situations and where complex, political decisions confront the engineering field's way of modelling and optimisation.*
- Creative/synthesis competencies  
*Aimed at integrating technical and social components during the development of products, systems, processes and services. The education emphasises the development of the students' personal, creative potential, engagement and enthusiasm, professional insight and the mastery of methods.*

The students acquire these competencies via a series of themed semesters in the bachelor programme, and by specialising in the master programme. In the fifth semester of the bachelor programme, the semester theme is "Innovation for sustainability", which is where the students are educated in sustainable PSS design.

#### 4.2.2 Description of PSS course

The Design & Innovation education programme is project-based and integrates disciplinary teaching models throughout the syllabus. On the fifth semester of the bachelor programme, we have two courses:

- Product life and environmental issues (5 ECTS points)  
*A theoretical course in product life thinking, Design for X, environmental regulation and ecodesign.*
- 'Product/Service-Systems' (10 ECTS points)  
*A project-oriented course, placing the focus on learning and practising techniques for the consideration of whole product-lives, stakeholder galleries, customer activities, and product/service offerings.*

Through their project work the students are trained in identifying and analysing environmental issues in a holistic perspective; synthesising environmentally improved solutions to consumption needs; and developing strategies towards the realisation of these solutions. At the time of writing this paper we are on our third year of running these two courses, which have approximately 55 students attending each year.

#### 4.2.3 *A normative approach to PSS*

As previously mentioned, we pair our industrial research activities and descriptive results with our teaching activities, which are often normatively designed and delivered to the students. The main reasons for doing this are that this activity strengthens our understanding of the industrial situations observed; delivers a clear and concrete set of steps to the students; and allows us as researchers and model-builders to reflect on our theoretical framework and model synthesis.

In our course on sustainable PSS development the students are presented with an object (washing machine, barbecue, transport system, etc.) as point of departure for their project and then required to follow the steps listed below, throughout their 13-week engagement in the course:

1. Create a product life gallery
  - *graphical representation of the product's life, focusing on encounters with various life-cycle systems and the related environmental effects.*
2. Identify the functional unit provided by the product
  - *based on existing theories for Life Cycle Assessment (LCA).*
3. Carry out an 'Analysis, Diagnosis, Focusing and Goal-Setting' exercise
  - *to take stock of and plan changes to the environmental effects.*
4. Sketch the actor-network (the system), describing its nodes (the stakeholders) and the connections (value-chains, information chains etc.)
  - *to fully understand the stakeholders involved in the emerging PSS.*
5. Identify and sketch the customer activity cycle
  - *a mapping of the customer's experience with respect to their needs satisfaction.*
6. Describe the physical artefact(s) that are necessary to deliver the service-system
  - *the 'packaging' for the PSS, developed in the previous steps.*

We find it useful and interesting to exemplify the above six steps in the following, in order to show the level of depth and description the students are required to go into.

##### **Stage 1 - Product life gallery**

A product life gallery is the physical result of a largely qualitative mapping of the product's lifecycle, detailing the functional unit, stakeholders, environmental effects, DFX impacts, environmental trade-offs and dispositions/delegations (Olesen, 1992). The gallery is prepared by a group of 7-8 students within the first three weeks of the project course, and forces the students to carry out a great deal of detective work regarding the product. The result is one large graphical overview of the product's environmental profile (see Figure 3).

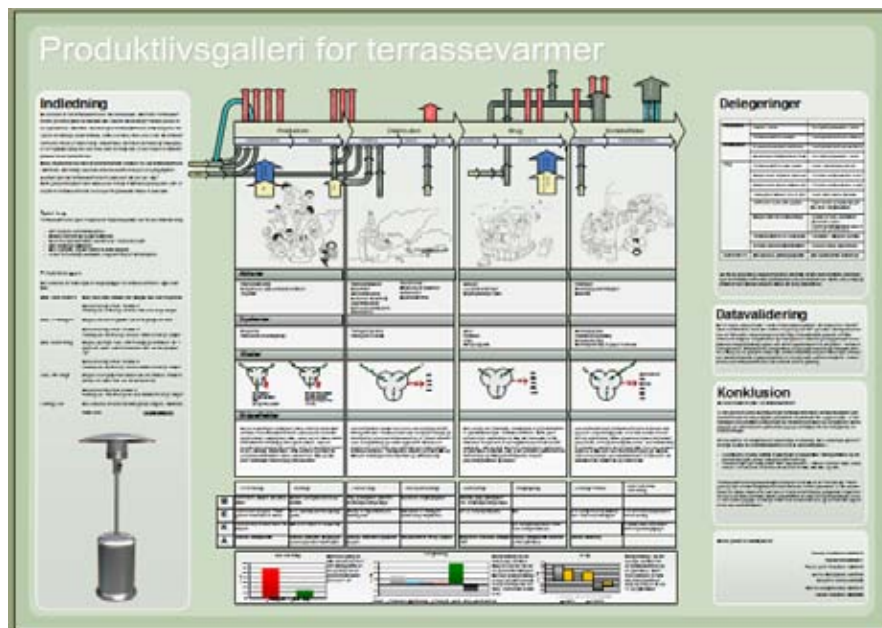


Figure 3 – Product life gallery for terrace warmer (Student project submission, 2005)

### Stage 2 – Functional unit

The functional unit is identified at this stage of the project, in order to begin the definition of the ‘service’ that the product under analysis should provide to the user. The functional unit is described here as a quantified performance expectation of the product, over a given usage period and frequency. In the case of the terrace warmer in Figure 3 above, four different functional units were chosen, to display four contrasting use/ownership scenarios.

### Stage 3 – Analysis, Diagnosis, Focusing & Goal-setting

This stage of the project is intended to firstly create a consolidation of a historical study of the product’s life cycle effects in order to identify what environmental effects occur (*analysis*), and a *diagnosis* of who, where and when the identified environmental effects were disposed for or actually caused. After these facts have been established, a *focusing* exercise is carried out in order to pinpoint areas of environmental improvement, before moving onto a *goal-setting* exercise, which elicits how and where to realise the environmental improvements related to the delivery of the functional unit identified in stage 2 (maybe by a quite different product than the one originally assessed).

### Stage 4 – Actor-network

Based upon Actor-network theory (Latour, 1991) the students are required to map all of the stakeholders they can identify for their case product and to map the flows of value, communication, service, information, transport and materials (where appropriate).



### Stage 5 – Customer Activity Cycle

The practice of modelling the Customer Activity Cycle (CAC) is adopted from a research model by Vandermerwe (Vandermerwe, 2000) and used by our research group to model the customer’s needs and activities, as opposed to the product’s life cycle. The CAC’s main virtue is the way in which it prompts the designer into a consideration of the sequence of activities of his customer, hereby contributing to the knowledge of the designed offerings use phase. The CAC modelling technique has been actively developed throughout the period where we have used it in our teaching, to provide a series of synthesis-oriented aspects that the original model did not include.

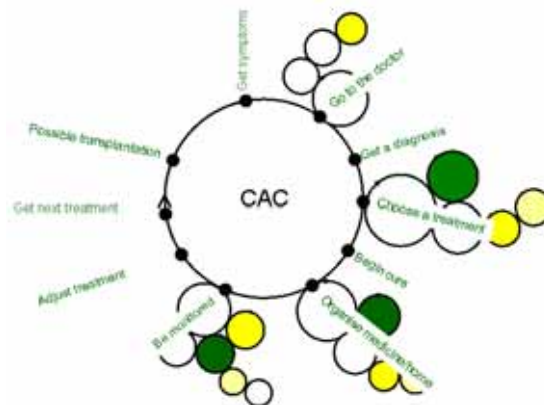


Figure 6 – CAC model for a sick patient; example taken from (Vandermerwe, 2000)

### Stage 6 - Describe the physical artefact(s) and the PSS

The final assignment in the course is a description of a concept for a new PSS, with radically improved environmental performance. Here the students are asked to model the stakeholder network and their relations, explain the life-cycle activities associated with the PSS and argue for the benefits for stakeholders as well as the environment.

In the example in Figure 7, a service to provide clean clothes in the home could replace washing machines. Dirty clothes would be picked up at the home at regular intervals and returned back clean and folded. The clothes would be tracked by a microchip tag, sewn in, that would contain washing instructions and user information. A virtual wardrobe would allow the user to see what clean clothes were available, suggest what to wear or offer deals on new clothes to buy online.

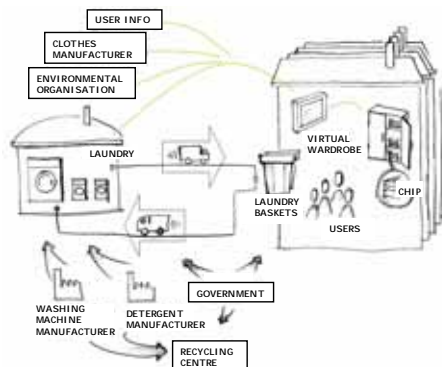


Figure 7 – An example of a PSS concept description (Student project submission, 2004)

## **5 Experiences**

We have chosen the point of departure for our industrial research and teaching activities where PSS is a strategy that is focused on the provision of usage value of products through integrated solutions of products and services over an extended (for the company) product life period. An underlying principle behind a PSS strategy is to shift focus from business based on the value of the transfer of product ownership and responsibility, to business based on the value of utility of the product and services.

Through our efforts to teach PSS to large groups of students, we have learned many important and enlightening lessons regarding the development of methods and tools for sustainable PSS design. In fact, the focus of the products delivered as start-points to the students for their projects in 2004, 2005 and 2006 respectively, has purposely been altered each year, in order to test different aspects of the models under development (this work is detailed in a separate paper (Tan & McAloone, 2006)).

We are experiencing that companies are beginning to approach the topic of PSS development in a more consolidated fashion. For the first years of PSS implementation, it has been uncertain as to who inside a company should be allowed to orchestrate and design a PSS. We are experiencing from our approach described in this paper, that the orchestration of a PSS requires an equal amount of orchestration within the company itself. Therefore our model development for use in teaching is also beginning to make a full loop integration back into industry, where we are currently modelling actor-networks, customer activity cycles and product life galleries with and for companies who wish to adopt PSS strategies.

We are aware that there are many areas where our methods have weaknesses, holes and maybe even contradictions. But we believe that our empirical-methodical balance is an efficient and trustworthy way of gaining deep insight into complex relationships. And we are busily building the frameworks for a PSS methodology through the various PhD- and other research projects in our group.

## **References**

- Andreasen M.M., McAloone T.C., Hansen C.T. (2000) "On the teaching of product development and innovation", in E. Eder (edit.): Proceedings of International Workshop on Education for Engineering Design (EED), Pilsen, November 23-24.
- Ehrenfeld, J.R. (2001) "Designing 'sustainable' product service systems", Proceedings of EcoDesign 2001: 2nd International Symposium On Environmentally Conscious Design And Inverse Manufacturing, Tokyo International Exhibition Center, Tokyo, Japan.
- Kimura F. and Suzuki, H. (1996) "Design of right quality products for total life cycle support", Proceedings of 3rd International Seminar on Life Cycle Engineering, 'Eco-Performance '96', Zürich, Switzerland, pp. 127-133.
- Latour, B. (1991) "Technology is society made durable", in *A Sociology of Monsters*, Routledge, pp. 103-131.
- Matzen D. & McAloone, T. C. (2006) "A tool for conceptualising in PSS development", Meerkamm (editor): Design for X, Beiträge zum 17. Symposium, Neukirchen, 12-13. oktober 2006; Lehrstuhl für Konstruktionstechnik, TU Erlangen.
- McAloone, T. C. (2005) "Industrial Integration Of Environmental Issues Into The Organisation: Past, Present & Future Challenges", in Proceedings of The 15th

- International Conference on Engineering Design (ICED '05), Design Society, 15-18 August 2005, Melbourne, Australia.
- McAloone, T. C. and Andreasen, M. M. (2002) "Defining product service systems", Meerkamm (editor): Design for X, Beiträge zum 13. Symposium, Neukirchen, 10-11. October 2002; Lehrstuhl für Konstruktionstechnik, TU Erlangen, pp. 51-60.
- Olesen J. (1992) "Concurrent development in manufacturing - based on dispositional mechanisms", PhD thesis (Integrated Production Systems programme), Technical University of Denmark, Lyngby.
- Olesen J., Wenzel H., Hein L., Andreasen M.M., 1996, Environmental Design (in Danish; orig. title: Miljørigtig Konstruktion), Danish EPA, Copenhagen, Denmark
- Reijnders, L. (1998) "The factor X debate - setting targets for eco-efficiency," Journal of Industrial Ecology, vol. 2, pp. 13-21.
- Tan, A. & McAloone, T. C. (2006) "Characteristics Of Strategies In Product/Service-System Development", D. Marjanovic (editor): Proceedings of the DESIGN 2006 9th International Conference on Design, Dubrovnik, 15-18 May 2006, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, pp. 1435-1442.
- Tan, A., McAloone, T.C. & Andreasen, M.M. (2006) "What happens to integrated product development models with product/service-system approaches?", 6th Integrated Product Development Workshop, IPD 2006, Schönebeck/Bad Salzelmen, B. Magdeburg, October 18-20, 2006.
- Vandermerwe, S. (2000) "How increasing value to customers improves business results". Sloan Management Review, Vol. 4.



# POSTER Environmental Impacts and Household Characteristics

*An econometric analysis of Norway 1999-2001*

Glen P. Peters<sup>a</sup>, Jørgen Aasness<sup>b</sup>, Nina Holck-Steen<sup>a</sup>, Edgar G. Hertwich<sup>a</sup>

<sup>a</sup>*Industrial Ecology Programme, Norwegian University of Science and Technology, Trondheim, Norway, glen.peters@ntnu.no*

<sup>b</sup>*Unit for Taxation, Inequality and Consumer Behaviour, Statistics Norway, Oslo, Norway.*

## 1 Introduction

There has been a long interest in the relationship between household expenditure and various household characteristics; such as income, household members, education, urbanity, and so on (Prais and Houthakker 1955). These studies have been applied in numerous applications, particularly to the distribution effects of government policies (e.g., Aasness, Bye et al. 1996). More recently some authors have investigated the relationship between household characteristics and direct household environmental impacts<sup>1</sup> (HEI). As an example, econometrics has been used to evaluate the drivers for household energy consumption, such as electricity, and these studies have application in areas such as urban planning and energy infrastructure (Poulsen and Forrest 1988). Since the early work of Herendeen there has been increased interest in evaluating the relationship between total, direct plus indirect, HEI and household characteristics (Herendeen 1978). Generally these studies have not incorporated the large theoretical and empirical literature from econometrics. Our aim in this paper is to provide a better linkage between previous consumer econometrics and HEI studies.

Consumption theory is largely based on a maximization of utility given a budget constraint,

$$\begin{aligned} \max U(\mathbf{x}) \\ \sum_i p_i x_i = I \end{aligned} \tag{1.1}$$

where  $U$  is the utility function which represents the consumers preferences for a combination of goods,  $x$  is a vector representing the quantity of each good purchased,  $p$  is the price of each good, and  $I$  is the income of the

<sup>1</sup> For simplicity we use HEI to describe both environmental impacts and energy consumption. *Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

consumer. From this it is possible to derive Engel functions for the expenditure on particular products and services,

$$x_i = x_i(I, \alpha) \quad (1.2)$$

where  $\alpha$  represents various household characteristics. Various types of Engel curves have been employed ranging from linear, log-linear, log-log, and various non-linear specifications (Prais and Houthakker 1955; Tran-nam and Podder 1992). Most emphasis has been placed on constructing functions based on household income or expenditure. The Engel curves and the resulting elasticity have been of most interest. The elasticity,

$$\varepsilon_i = \frac{I}{x_i} \frac{\partial x_i}{\partial I} \quad (1.3)$$

measures how the expenditure on one product changes with the given explanatory variable, income in this case. If the elasticity is less than zero the product is called *inferior*, between zero and one it is called a *necessity*, and greater than one it is called a *luxury*.

Most environmental studies have determined both the direct and indirect HEI for different household characteristics (Herendeen 1978). The direct HEI result from fuel combustion by households, such as, petrol in a car or wood in a fireplace. The indirect HEI result from the production of consumable items for household consumption and are usually calculated using environmental input-output analysis (Leontief 1970). Overall, the household environmental impacts are

$$f_h^{total} = f_h^{direct} + f_h^{indirect} = \sum_i Fuels_i * EF_i + F(I - A)^{-1} \mathbf{x} \quad (1.4)$$

where  $Fuels_i$  are the fuels directly combusted in the household,  $EF_i$  are the fuel specific emission factors,  $F$  is the emission intensity,  $I$  is the identify matrix,  $A$  is the inter-industry requirements matrix, and  $\mathbf{x}$  is the vector of household demand.

Despite similarities, the environmental and consumer expenditure studies have subtle differences. In particular, the consumer studies consider expenditure on individual products and services, while the environmental studies consider the weighted aggregated of all household expenditure (the emission factors providing the weights). Summarising the main HEI studies, one finds that the main focus is on income and expenditure and generally a log-log functional form has been used to describe relationships. While the elasticity is one of the main quantities of interest, little attention has been given to the significance and meaning of the elasticity. Several studies have considered other household characteristics---the number of household members, urbanity, education, age, and so on---but there has not been a rigorous treatment of multi-collinearity. Table 1 gives an overview of the previous studies in relation to income and expenditure.

Table 1: The elasticities from various studies (adapted from Wier, Lenzen et al. 2001; Lenzen, Wier et al. 2006).

Country	Year	Income elasticity of energy	Income elasticity of CO <sub>2</sub>	Expenditure elasticity of energy	Expenditure elasticity of CO <sub>2</sub>	Change in energy with household size
Australia	1993-94	0.59	0.55	0.74	0.70	-0.16
Australia	1998-99			0.78		-0.02
Brazil	1995			1.00		-0.07
Denmark	1995	0.51	0.51	0.90	0.90	-0.20
Denmark	1995			0.86		-0.22
India	1993-94			0.86		-0.01
Japan	1999			0.64		0.06
Netherlands	1990	0.63		0.83		-0.33
New Zealand	1980			0.40		
Norway	1973			0.72		-0.27
USA	1960-81			0.85		
USA	1972-73			0.78		-0.33

Table 1 shows a large variation in expenditure elasticities between different countries. Except for Brazil, the elasticities are less than one, which would imply that HEI are a necessity. There does not seem to be any trend in the elasticities which relates to country specific characteristics. However care needs to be taken when interpreting these elasticities. The elasticity is based on aggregated expenditure with each product weighted by country specific emission factors. Thus, the elasticity may reflect different production technologies and assumptions rather than different consumer behaviour.

The main aim of this paper is to provide a better linkage between consumer theory and the analysis of HEI. In particular, we place more emphasis on the statistical procedures used. Initially we describe the data and methods used to construct individual HEI based on the Survey of Consumer Expenditure (SCE). Second, we discuss the rationale for the Engel functions applied in this study. Third, we perform various statistical tests to establish an appropriate Engel function for Norwegian HEI. Based on this we present results for Norway based on different production technology assumptions. Finally we discuss the implications of our work and conclude.

## 2 Data preparation and emission estimates

We use the Norwegian Survey of Consumer Expenditure (SCE) for the years 1999-2001 as the basis for calculations. These data are converted into 2000 values using the Consumer Price Index (CPI). The SCE estimates household consumption based on a 2-week expenditure diary and interviews. The households are selected at random. In our study we have 3361 households equally distributed between the three years. The raw data covers 507 products and services in a Norwegian specific classification system.

This is then mapped to the COICOP<sup>2</sup> system. Minimal manipulations are performed on the raw data. The COICOP data is then converted into the NACE<sup>3</sup> industry classification to calculate the indirect emissions using a multi-region input-output model (Peters and Hertwich 2006). The direct emissions are calculated from the household fuel consumption and an emission factor. For some fuels, the fuel consumption is estimated based on monetary data.

### 3 Engel functions for Norwegian HEI

Based on previous Norwegian research, we take a reference model that is linear in expenditure and household size (Aasness, Biørn et al. 1993),

$$x_j = a_j + b_j y + c_j n_1 + d_j n_2 + v_j \quad (1.5)$$

where  $x_j$  is the household expenditure on product  $j$ ,  $y$  is the total household expenditure,  $n_1$  is the number of kids in the household,  $n_2$  is the number of adults in the household,  $a$ ,  $b$ ,  $c$ ,  $d$  are constants, and  $v$  is the error term. At the micro-level  $c$  and  $d$  are important as different age groups have different consumption behaviour for many items, such as alcohol and toys.

It is important to note that (1.5) describes the expenditure on an *individual* product or service for the given household characteristics. To determine the indirect HEI each product or service is weighted by a product specific emission factor and then aggregated,

$$f_h^{indirect} = F(I - A)^{-1} \mathbf{x} = \mathbf{F}^t (\mathbf{a} + \mathbf{b}y + \mathbf{c}n_1 + \mathbf{d}n_2 + \mathbf{v}) \quad (1.6)$$

where the coefficients are now vectors constructed from (1.5) and  $\mathbf{F}^t = F(I - A)^{-1}$ . Based on the linear Engel function it becomes apparent to describe the indirect HEI using a linear function,

$$f_h^{indirect} = A + By + Cn_1 + Dn_2 + V \quad (1.7)$$

where  $A = \mathbf{F}^t \mathbf{a}$  (a dot-product), and similarly for the other scalars. The direct emissions are calculated in a similar fashion.

Since we chose linear Engel functions, (1.5), the functional form of the HEI is also linear, (1.7). This relationship may not hold if non-additive Engel functions are applied. One key advantage of using additive Engel functions is the ability to scale from the micro- to macro-level. By multiplying (1.7) by the number of households it is possible to link the individual household data to national statistics of household consumption,

$$f_h^{National} = AH + BY + CN_1 + DN_2 + VH \quad (1.8)$$

<sup>2</sup> Classification Of Individual Consumption according to Purpose.

<sup>3</sup> Statistical Classification of Economic Activities in the European Community, Revision 1.1.

where  $H$  is the number of households in the country,  $Y$  is the total household expenditure in the country, and  $N$  is the total number of adults and kids in the country. This allows one to link changes in household characteristics to national environmental impacts. One good example is the effect of decreasing household size on total HEI (c.f., MacKellar, Lutz et al. 1995).

## **4 Econometric analysis of the Engel functions**

In this section we test the different possible functional forms. We begin with our base linear model. For the hypothesis testing we use CO<sub>2</sub> emissions, although the dataset covers SO<sub>2</sub>, NO<sub>x</sub> and energy.

### **4.1 Dealing with uncertainty**

An important consideration when using the SCE is that the expenditure data can be biased. For instance, in the two week survey period a household member in one household may have an expensive tooth extraction, while households with similar income and expenditure may not have this unusually large dentistry expenditure. This is particularly relevant for HEI as the biased expenditure may be amplified by a relatively large emission factor,  $F^i$ . Some authors have addressed this issue by using the more certain income data<sup>4</sup> to determine the expenditure (Aasness, Biørn et al. 1993).

In this study we adjust for biases and uncertainty in the expenditure data using the more reliable data on household size and income. First, we group households of the same size together (i.e., households with the same  $n$  variables, Table 2). Second, the grouped households are sorted by income and then placed sequentially into groups of ten<sup>5</sup>. This puts households of the same size and similar income together. The groups of ten then have their expenditure averaged. This grouping and averaging technique is similar to performing a two-stage least squares approximation with income as the instrument variable (Malinvaud 1980, Chapter 10, §9). The grouping and averaging serves two purposes. First, it allows a comparison of households of the same size which gives a clearer indication of the relationship between other variables. Second, it reduces uncertainty and bias in the expenditure data.

Figure 1 shows the data before grouping and averaging and Figure 2 shows after grouping and averaging. Clearly, averaging the data reduces the spread and removes some of the outliers. Performing a regression on both these figures using (1.7) produces similar coefficients but the unaveraged data set only explains 75% of the variation, while the grouped and averaged data explains 92% of the variation (more details below). If using the data before averaging then one may seek alternative explanatory variables to describe more than 75% of the variation. It then may be questionable if the correlations are realistic.

<sup>4</sup> Income data is often obtained from tax records and does not suffer from the same uncertainty as the expenditure data.

<sup>5</sup> If the number of households is not divisible by ten, then the last group has the remainder.

Table 2: The grouping of households by household size. Groups 7 and 8 include some non-typical households, for instance, one with 8 kids and 5 adults. Group 7 is mainly adults and Group 8 is mainly kids. Group 8 also includes the households with 3 children and 3 adults because we assume that the third adult is a child above the age of 16.

Group Number	Number of Kids	Number of Adults	Frequency	Percentage	Colour
1	0	1	452	13 %	Blue
2	0	2	818	24 %	green
3	1	2	333	10 %	red
4	2	2	579	17 %	turquoise
5	3	2	271	8 %	purple
6	<= 3 persons		362	11 %	yellow
7	>= 4 persons, >= 3 adults		444	13 %	black
8	>= 4 persons, >= 3 kids		102	3 %	blue star/dashed line
			3361	100 %	

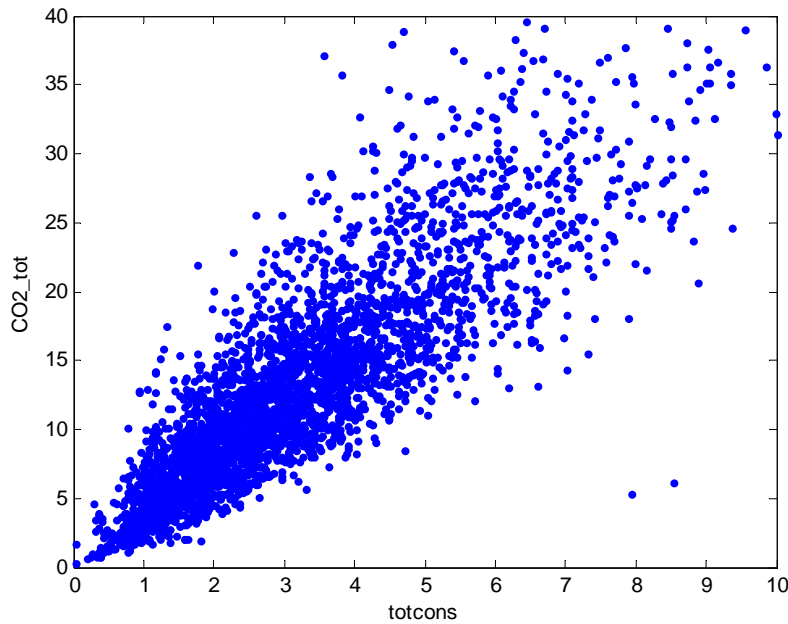


Figure 1: The ungrouped and unaveraged data. Some of the data points lie outside the axes. The CO<sub>2</sub> emissions are measured in tonnes and the total consumption (totcons) is measured in 100,000 Norwegian Kroner (NOK).

It is also possible to plot the data in their respective groups. This removes one of the variables from the calculation, household size, and hence reduces some of the uncertainty. We only show the data after averaging, Figure 3. Again, the grouping and averaging process removes the outliers and the spread in the data. We base most of our analysis on the grouped and averaged data, Figure 2 and Figure 3.

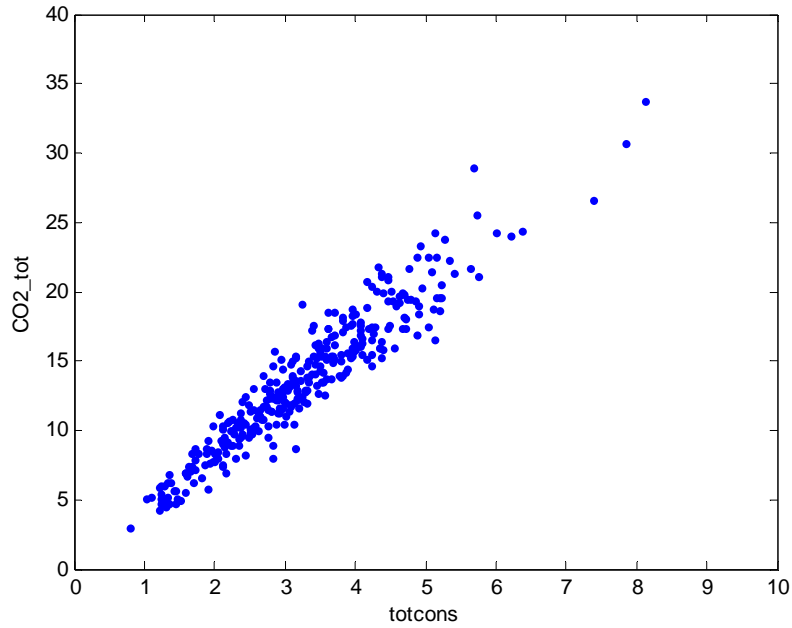


Figure 2: The grouped, then averaged data.

## 4.2 Robustness of the Reference Model

### 4.2.1 Reference Model

The reference model is given by (1.7) and is applied to the grouped and averaged data, Figure 2. The results of the regression are shown in Table 3. The columns represent the coefficients, StdDev is the standard deviation, CI are the confidence intervals, t value is the t-statistic, and the last three columns relate to the elasticity,

$$\varepsilon = \frac{\bar{y}}{f'} \frac{\partial f'}{\partial y} \tag{1.9}$$

where the bars represent average values in the linear regression model.

Table 3: The coefficients from the Reference Model.

Explanatory variable	Coefficient	StdDev	CI		t value	Elasticity	CI	
			low	high			low	high
Intercept, <i>A</i>	-0.447	0.267	-0.970	0.076	-1.67			
Totcons, <i>B</i>	3.682	0.085	3.515	3.849	43.20	0.879	0.839	0.919
Kids, <i>C</i>	-0.078	0.080	-0.236	0.079	-0.98	-0.018	-0.053	0.018
Adults, <i>D</i>	1.042	0.133	0.781	1.304	7.82	0.235	0.176	0.294
R <sup>2</sup>	0.921							

The most notable result from the reference model is the size of the expenditure elasticity of around 0.88. This is higher than found in many other studies, Table 1. Our confidence intervals are relatively small due to

the reduction in variation due to the averaging process. Our model describes 92% of the variation.

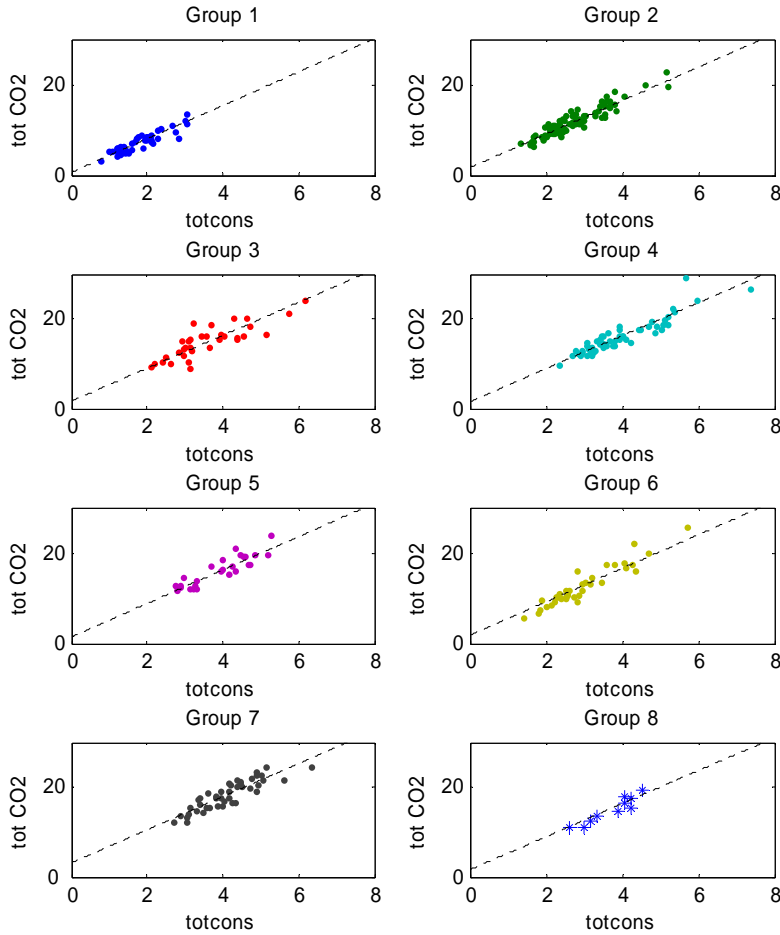


Figure 3: The grouped data after averaging across income.

We will now test the robustness of the reference model to various modifications.

#### 4.2.2 Hypothesis 1

The  $B$  coefficient from (1.7) for each different household group in Figure 3 overlaps with the  $B$  coefficient for the Reference Model.

*Result:* Figure 4 shows the  $B$  coefficient for each group and the vertical line is the coefficient for the Reference Model. The hypothesis is confirmed, the regression line for the whole sample of grouped data fits well to each of the groups.



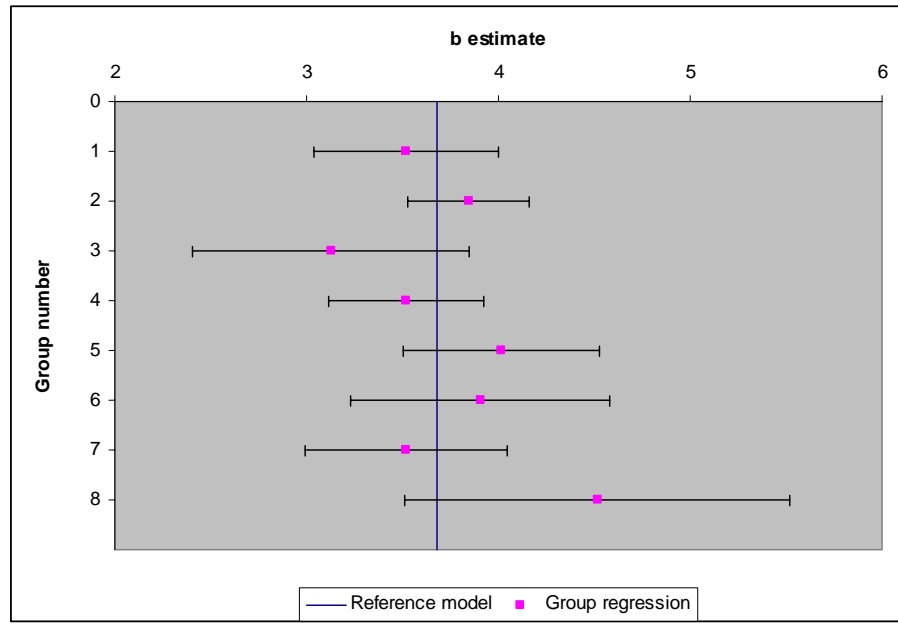


Figure 4: The  $B$  coefficient for the Reference Model (vertical line) and the grouped data with confidence intervals.

#### 4.2.3 Hypothesis 2

The  $A$  coefficient for the whole group matches the  $A$  coefficient plus the household size components for the grouped data,  $A^* = A + Cn_1 + Dn_2$ .

*Result:* This hypothesis was confirmed except for Group 8 (results not shown to conserve space).

Hypothesis one and two show that each household size exhibits similar expenditure behaviour to the entire data set. The linear model holds for different subsets of the data in addition to the entire dataset. This suggests that it is worth investigating a regression with only household expenditure.

#### 4.2.4 Hypothesis 3

The reference model can be reduced to

$$f_h^{total} = A + By + V \quad (1.10)$$

*Result:* We conducted a series of F-tests for this hypothesis in addition to a series of hypotheses that dropped one term at a time from (1.7). We found that the model in Hypothesis 3 described 91% of the variation with an elasticity of 0.947. However, the F-test suggested that the best model was to include the expenditure and number of adults,

$$f_h^{total} = A + By + Dn_2 + V \quad (1.11)$$

It is surprising that such a simple model, (1.10), can describe a complex data set. There may be several reasons for this, one is that the relationship used in (1.6) is essentially linear (this is discussed later). Also, the averaging technique reduces the variance in comparison to other studies.

Since many other studies have used non-linear specifications instead of the simple relationship it is worth investigating different functional forms with our dataset.

4.2.5 Hypothesis 4

A log-linear model,

$$\log(f_h^{total}) = A + B \log(y) + Cn_1 + Dn_2 + V \tag{1.12}$$

describes more variation than the Reference Model.

*Result:* The coefficients for this model are shown in Table 4. This model describes 93% of the variation which is slightly higher than the linear model. Since the relationship is log-log in expenditure, the coefficient is the same as the elasticity. The measured elasticity, 0.906, is in the same range as the measured elasticity in the linear case. Even though the log-linear model describes 1% more of the variation, we feel that this does not justify the use of the non-linear model as it is not additive.

Table 4: The model variables for the log-linear model.

Explanatory variable	Coefficient and Elasticity	StdDev	CI low	CI high	t value
intercept	1.384	0.020	1.345	1.423	69.07
log(totcons)	0.906	0.021	0.866	0.947	43.90
kids	-0.004	0.006	-0.017	0.008	-0.72
adults	0.075	0.010	0.054	0.095	7.11
R <sup>2</sup>	0.931				

4.2.6 Hypothesis 5

A polynomial model,

$$f_h^{total} = A + B_1y + B_2y^2 + B_3y^3 + Cn_1 + Dn_2 + V \tag{1.13}$$

describes more variation than the Reference Model.

*Results:* The coefficients for the polynomial model are shown in Table 5. The model describes 92% of the variation, but the higher order coefficients of expenditure are zero. Thus, the model has essentially reverted back to the Reference Model. Thus we see no reason to pursue a polynomial model.

One of the reasons to pursue the model in Hypothesis 5 is its linkages to the Environmental Kuznets Curve hypothesis (EKC). The EKC claims that

environmental degradation initially increases with income, but once a certain threshold is reached environmental degradation will decrease with income (thus, the Engel function would be an inverted U shape). For the inverted U shape the coefficient on the quadratic term must be significant. Some also claim the EKC would form an N shape requiring the cubic term to be significant. Clearly, our dataset shows no indication of an EKC.

Table 5: The coefficients for the polynomial model.

Explanatory variable	Coefficient	StdDev	CI low	CI high	t value
intercept	-1.180	0.898	-2.941	0.581	-1.31
totcons	4.339	0.802	2.768	5.910	5.41
totcons^2	-0.151	0.205	-0.552	0.250	-0.74
totcons^3	0.010	0.016	-0.022	0.042	0.63
kids	-0.095	0.083	-0.258	0.069	-1.14
adults	1.004	0.142	0.727	1.282	7.09
R <sup>2</sup>	0.921				

#### 4.2.7 Hypothesis 6

Another important consideration is the significance of other household characteristics in the correlations. When performing multi-variant correlations it is important to consider multi-collinearity (Poulsen and Forrest 1988). Multi-collinearity may underestimate parameters such as elasticities since some contributions to variance may be distributed between two correlated variables. Since our reference model already describes more than 90% of the variation, we feel that the impact of other demographic variables will not be significant. We are yet to perform a rigorous analysis of other household characteristics.

### 4.3 Statistical analysis of technology assumptions

The emissions in the Reference Model are calculated using a MRIO model. This means that the emissions embodied in imports are calculated using regional specific technology. Not all HEI studies have used a MRIO model, but rather assumed that imports are produced with domestic technology. For the case of Norway, which has a clean energy mix, the MRIO model would produce emissions greater than in a single region IO model (SRIO) that assumes the imports are produced with Norwegian technology.

We compared the elasticities using the MRIO, SRIO, and a model that only determine the domestic emissions (and ignores the emissions embodied in imports). The elasticity using a SRIO was 0.894 ( $\pm 0.042$ ) which is very similar to the Reference Model. The small change may be since we assume that all households have the same import behaviour. However, the elasticity for the domestic emissions only was 0.721 ( $\pm 0.041$ ) which is lower than in the SRIO and MRIO models. This would suggest that wealthy households import more than poor households which seems to contradict the previous

result. Further investigation is required to determine how different households change their expenditure on imported items<sup>6</sup>.

An extension of the technology analysis would be to calculate the emissions using a SRIO of an average country (or countries), for instance, calculate the emissions using German technology. This extension would allow a more consistent comparison of elasticities between countries. We are yet to investigate this extension.

## 5 Discussion

We have performed various statistical tests to support our use of a linear model describing the relationship between HEI and household expenditure and size. The Reference Model describes 92% of the variation and this only improves marginally if we take more complex non-linear Engel functions. We find a CO<sub>2</sub>-expenditure elasticity of 0.88 for Norway in 1999-2001. Comparisons with other countries are difficult since most previous studies have considered energy-expenditure, Table 1. Further, it is difficult to determine how different methods and assumptions between studies may affect the results. The energy-expenditure elasticity for Norway 1973 was 0.72 (Herendeen 1978) which is considerably smaller than the value we obtain for CO<sub>2</sub>. Most countries have an energy-expenditure elasticity of less than 0.88, but our value is similar to that of Denmark---a country that shares many similarities with Norway.

Within a given country, it is worth investigating what factors determine the elasticity. Starting from (1.6) it is possible to decompose the consumption into a structural component and a volume component,

$$f_h^{indirect} = \mathbf{F}^t \frac{\mathbf{x}}{y} y = \left( \sum_i F_i^t \frac{x_i}{y} \right) y \quad (1.14)$$

where the fraction is the structure of consumption (vector with coefficients summing to one) and  $y$  is the total expenditure (volume of consumption). This expression shows that if the consumption structure is the same in each household, then the elasticity would be unity (further,  $A$ ,  $C$ ,  $D$ , in (1.7) would be zero). Therefore changing consumption structure across households drives the elasticity away from unity, but whether it tends above or below unity depends on  $\mathbf{F}^t$ . If, for example, households with high expenditure spend a greater share on pollution intensive products (relatively high  $\mathbf{F}^t$ ) then the elasticity would be expected to tend greater than one, conversely if the households with high expenditure spend a greater share on services (relatively low  $\mathbf{F}^t$ ) then the elasticity would tend less than one. This would suggest that the elasticity depends on correlations between the components of  $\mathbf{F}^t$  and  $\mathbf{x}$ . Most HEI studies have found the elasticity to be less than one

<sup>6</sup> Unfortunately it is not possible to determine how imports vary with household characteristics through the SCE. By using the IO data we can determine the import behaviour of aggregated household consumption. Thus, in effect, we can only investigate how household expenditure on items that are imported into Norway changes with household characteristics. This assumes that households have no preference over domestic or imported products.

indicating that wealthy households spend a greater share of income on products and services with lower  $F^t$ . The one exception is Brazil, with an elasticity of one, which is attributed to high inequality in access to private transportation (Cohen, Lenzen et al. 2005). This later point, suggests that the elasticity may relate to inequality in general, and not necessarily environmental factors or consumption behaviour.

A comparison of elasticities between countries raises the issue of how comparable the data are. Both physical and statistical characteristics of a country may affect the elasticity. From a physical perspective each country has different production technology, energy mix, climate, state of development, in addition to household characteristics including culture. These factors will undoubtedly blur any comparison between countries. From a statistical perspective, each analysis may make different assumptions calculating the emissions, constructing the data, selecting industry and product classifications, treatment of capital acquisitions, and so on. This again will greatly affect comparison between countries. These factors may make country comparisons of the relationship between HEI and household characteristics futile.

To make a comparison of HEI between countries it may be more appropriate to use the same  $F^t$  in all calculations---for instance, a global averaged emission intensity. Even though this would not represent the *real* elasticity for a given country it would allow a consistent comparison between HEI and household consumption.

## **6 Conclusion**

We used a linear reference model to describe the relationship between HEI and household expenditure and size in Norway for 1999-2001. The linear Reference Model describes 92% of the variation and this only improves marginally if we take more complex non-linear functions. We found a CO<sub>2</sub>-expenditure elasticity of 0.88. In our data set we allowed for uncertainty and bias in the expenditure data by grouping households of similar size and averaging small subsets of households based on the more reliable income data. We used various statistical methods to test the robustness of our Reference Model.

We then discussed drivers behind the elasticity and what may affect comparisons of elasticities between countries. Within a country the elasticity depends on weighted correlations between product specific emission intensities and the share of expenditure on products. The elasticities may also reflect general inequality within a country rather than environmental factors or consumption patterns. Between countries, both physical and statistical variations between countries are likely to affect regional emission intensities and hence country comparisons. These issues may be circumvented by using a global average for the emission intensity when comparing elasticities between countries.

## References

- Aasness, J., E. Biørn, et al. (1993). "Engel functions, panel data, and latent variables." Econometrica **61**(6): 1395-1422.
- Aasness, J., T. Bye, et al. (1996). "Welfare effects of emission taxes in Norway." Energy Economics **18**: 335-346.
- Cohen, C., M. Lenzen, et al. (2005). "Energy requirements of households in Brazil." Energy Policy **33**: 555--562.
- Herendeen, R. (1978). "Total energy cost of household consumption in Norway, 1973." Energy **3**: 625-630.
- Lenzen, M., M. Wier, et al. (2006). "A comparative multivariate analysis of household energy requirements in Australia, Brazil, Denmark, India and Japan." Energy **31**(2-3): 181-207.
- Leontief, W. (1970). "Environmental repercussions and the economic structure: An input-output approach." The Review of Economics and Statistics **52**(3): 262--271.
- MacKellar, F. L., W. Lutz, et al. (1995). "Population, Households, and CO<sub>2</sub> Emissions." Population and Development Review **21**(4): 849--865.
- Malinvaud, E. (1980). Statistical Methods of Econometrics, Amsterdam: North-Holland.
- Peters, G. P. and E. G. Hertwich (2006). "The importance of imports for household environmental impacts." Journal of Industrial Ecology **10**(3): 89--109.
- Poulsen, M. F. and J. Forrest (1988). "Correlates of energy use: domestic electricity consumption in Sydney." Environment and Planning A **20**: 327-338.
- Prais, S. J. and H. S. Houthakker (1955). The Analysis of Family Budgets, Cambridge University Press.
- Tran-nam, B. and N. Podder (1992). "On the Estimation of Total Expenditure Elasticities from Derived Engel Functions with Applications to Australian Micro-Data." The Economic Record **68**: 142.
- Wier, M., M. Lenzen, et al. (2001). "Effects of Household Consumption Patterns on CO<sub>2</sub> Requirements." Economic Systems Research **13**(3): 259--274.

# POSTER Analysis of Models for Solutions in Service/Product Engineering

Tomohiko Sakao<sup>a</sup>, Nicolas Maussang<sup>b</sup>, Daniel Brissaud<sup>b</sup>, and  
Peggy Zwolinski<sup>b</sup>

<sup>a</sup>*pmd, Darmstadt University of Technology, Darmstadt, Germany, sakao@pmd.tu-darmstadt.de*

<sup>b</sup>*3S Laboratory, University of Grenoble, Grenoble, France,  
{nicolas.maussang, daniel.brissaud, peggy.zwolinski}@hmg.inpg.fr*

## 1 Introduction

It is being recognized that service activities today are an important issue in manufacturing industries as well (see e.g. (Oliva *et al.*, 2003)). Their service activities are often intended to provide various types of services along the life cycles of their products. In those business cases as well as their mind sets, service activity is beginning to be increasingly incorporated into the design space, an area which has been traditionally dominated by physical products in manufacturing industries (Alonso-Rasgado *et al.*, 2004; Mont, 2004; Tukker *et al.*, 2006). The trend that the solution type offers are becoming more and more appreciated can be a factor for this change.

As a result, a distinguished border between the secondary and tertiary industries is fading out from the view point of service providing. This has an impact on the service industries, because enterprises providing services to meet customers' desires nowadays have to combat much more competitors than in the old days. At the same time, this is an opportunity as well for service firms to widen their design space to include physical products.

For both manufacturing firms and service firms to be competitive in such a business environment, a new model is required to support effectively and efficiently those who engineer integrated solutions of products and service activities. To develop optimized solutions according to quality, cost, time to market, it is important to develop simultaneously both products and services (Maussang *et al.*, 2005). This paper analyzes two potential models to represent objects to be designed for such offers in business. One is what is named Agent-based model (AM) in Service/Product Engineering (SPE), formerly called Service Engineering (Sakao *et al.*, 2007). SPE has been developed as a discipline to increase the value of artefacts by focusing on service. Another is Function-based model (FM) that is based on Functional Analysis (Afnor, 1991; Afnor, 1996; Afnor, 1996). Engineering designers to develop product, service or organisation use this model. They can also

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

represent objects in order to design them again with this model to decrease cost and increase performances. It is included in the Value Analysis and Engineering method (Miles, 1971). The models are analyzed through application to a business case operated in industries. The example is a rental bicycle service in Lyon, France, named “Vélo’v”. It should be noted that designing services addressed in this paper include designing physical products.

The remainder of the paper consists of the following sections. Section 2 explains why a new object model to represent a solution is needed. Section 3 introduces the two models. Section 4 presents the application of the models to an industrial business case. After some discussions in Section 5, Section 6 concludes the paper.

## 2 Need of new object model

### 2.1 Requirements of the object model

First, a service in this paper is defined as “an activity that a provider causes a receiver, usually with consideration, to change from an existing state to a new state that the receiver desires, where both contents and a channel are means to realize the service” (Tomiyama, 2001) according to the scheme of Service/Product Engineering (SPE) (see Figure 1). Service contents are provided by a service provider and delivered through a service channel. Physical products are either the service contents or the service channel. Service activities support service contents to be transferred or activate service channels. Hence, a service receiver is satisfied with just contents, which are any type of material, energy, and information. A service channel is used to transfer, amplify, and control the service contents. Thus, a service in this paper refers to integration of service activities and physical products.

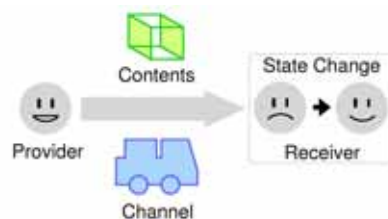


Figure 1: The elements of service (Sakao *et al.*, 2007)

Now, let us identify the requirements for a model representing the object to be offered in such era as introduced in Section 1. First, for designers of physical products, it is necessary to address a notion so abstract to represent what is achieved by physical products. Value is one of such abstract concepts, because customers always intend to obtain value in their buying action. In addition, the value must be represented with connection to functions, which they begin with in engineering design (Pahl *et al.*, 1988; Suh, 1990). For designers or managers of the whole solution, it is required to represent service activities as well. Service activities must also be grounded to what is provided with customers, and value can be such a concept. Including function between products or service activities, and value in the model allows designers to generate more options, because function in general can be fulfilled by multiple products and service activities. For



instance, a function, transmit information, can be achieved by a number of products and service activities such as software’s automatic sending email, employees’ calling by telephone, etc.

Furthermore, service activities and physical products do not exist independently. They have interrelation with each other. Thus, the needed concepts of the model for a solution are described in Figure 2.

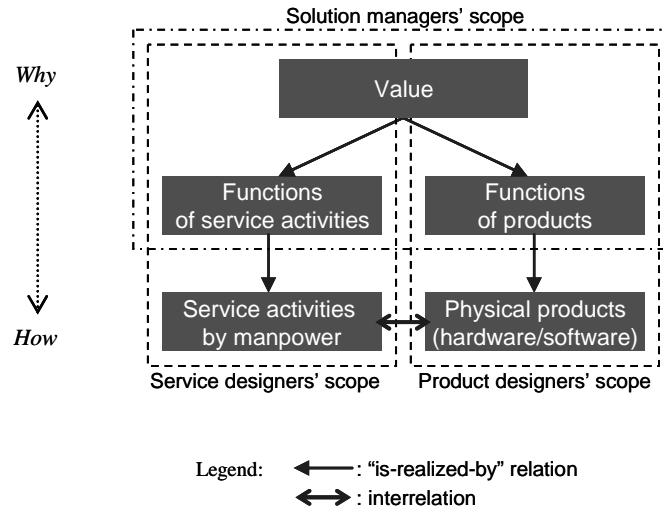


Figure 2: The needed concepts of the model and scopes of the solution-developing team

## 2.2 Existing models

Shostack has proposed an object model of services that are applicable to design in general (Shostack, 1981). The model contains “service element” and “product element”, which are provided and utilized, respectively, by the processes represented by “blueprint”. However, this model does not provide sufficient information for designers. Congram *et al.* developed a methodology called the structured analysis and design technique (SADT) for service managers and providers to have a model describing service processes but not physical products (Congram *et al.*, 1995). Dausch *et al.* developed a reference model of service agreement engineering to help mass-customise and evaluate service agreements (Dausch *et al.*, 2006). While this is helpful both for providers and customers, it does not support product designers. In the field of service innovation, Gallouj *et al.* proposed foundations of a theory for innovation in services including a conceptual object model (Gallouj *et al.*, 1997), which does not address product characteristics.

On the other hand, there are two models with potential for such representation as explained in Paragraph 2.1 by their integration. One is Agent-based model (AM) in Service/Product Engineering (SPE) (Sakao *et al.*, 2007), while the other is Function-based model (FM). These two are explained in more detail in Section 3.

As reviewed briefly above, models to meet requirements explained in Paragraph 2.1 are unavailable at present. This is critical because anyone needs an object model in order to design efficiently.

### 3 Potential models

#### 3.1 Agent-based model

##### 3.1.1 Overview

To meet the requirements for the model described in Section 2 partially, a service model has been developed consisting of four sub-models: “Flow Model”, “Scope Model”, “Scenario Model”, and “View Model”. The remainder of Paragraph 3.2 explains the four sub-models with more focus on the View Model, after describing an important concept in those sub-models called “receiver state parameter”. Then, it explains the innovation seeds embedded in the model.

##### 3.1.2 RSP

Receiver state parameters (RSPs) (Sakao *et al.*, 2007) are classified into value and cost, depending on whether the customers like them or not. The term “value” here is different from that in Value Engineering (Miles, 1971), where it is defined as function over economic cost. In SPE, value is defined as the change of a receiver’s state that he/she prefers, so that function is just a realization method to provide the value in SPE.

Change of a receiver is represented by a set of receiver state parameters (RSPs). Since an RSP consists of quantitative value, including Boolean logic and multi-value logic, any comparison between two RSPs can be computed. In addition, a new assumption is introduced that all RSPs are observable and controllable. This assumption has been unproven with human receivers because there is no such a reliable method to measure the consumer behaviour.

RSPs change by received contents. Hence, it is assumed that contents consist of various functions, whose name is Function Name (FN), whose operating objects are Function Parameters (FPs) and whose effect is represented by Function Influences (FIs).

As the receiver’s states may change with respect to supply of contents, RSPs can be written as functions of contents. Parameters expressing contents are called content parameters (CoPs). In the same way, the parameters of channel, which make the flow of CoPs change and thus influence RSPs indirectly, are called channel parameters (ChPs). Hence, it is assumed that both contents and channels consist of various functions, and both CoPs and ChPs belong to FPs.

It should be pointed out that the selection of contents and channels is subjective – and this seems to be among the greatest reason that services have not been sufficiently dealt with as an engineering issue.

For instance, in a service by a cafe, one can recognize positive RSPs such as a taste of coffee, sound of music, and even workspace available. On the other hand, negative RSPs in the service may include a monetary cost, transportation to the cafe, and noise.

##### 3.1.3 Flow model

When the relationship between a receiver and a provider is focused on, many intermediate agents exist among them. The sequential chain of agents is called a “Flow Model” of a service (see the upper half of Figure 3, which takes an example from a cafe service: agents such as a cafe runner, a

customer, and a coffee machine maker participate in this service). This model is needed because in SPE designers are supposed to consider how organizations participating in a concerned service can be successful in their business.

One of the traditional and typical services is a travel bureau, which arranges and purchases various tickets on behalf of customers. Contents are different from a ticket to another, even if all the tickets are delivered to the customers. In this way, services can be delivered through complex multiple structures consisting of various go-betweens, which are represented by a Flow Model. The intermediate agents have double characteristics of a receiver and a provider, which is represented by a symbol of a smiling circle “intermediate agent”.

3.1.4 Introduction of new concept; outsider

A new concept called outsider is introduced in this paper. An outsider is an agent who does not participate in the service but has influence on the service. A type is a competitor against a concerned provider, an agent who is not a receiver of the service but a receiver from a concerned provider in a different service, or an agent who makes a certain RSP necessary to be provided in the service. For instance, in a cafe service, an agent who sells cans of coffee is an outsider unless the cafe runner buys cans of coffee, because they are a competitor against the cafe runner.

This is beneficial for designers because they can understand more the reasons of the measures of a service; e.g. why a concerned service employs a specific agent, a receiver desires a specific RSP, etc.

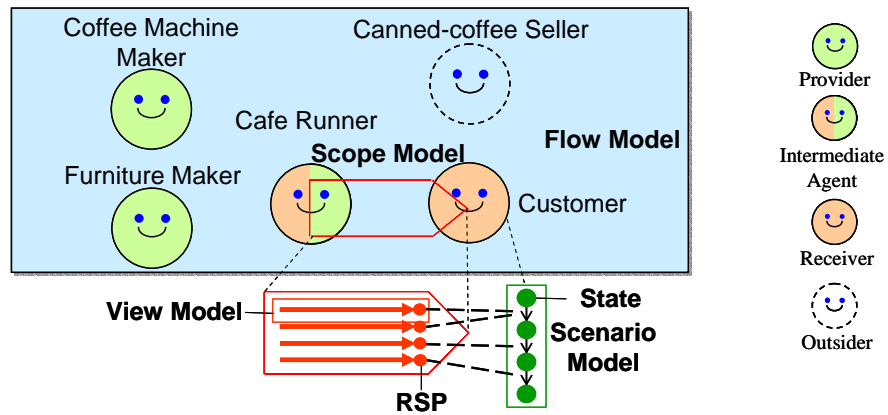


Figure 3: The relation among three sub models; Flow Model, Scope Model, Scenario Model, and View Model

3.1.5 Scope model

Practical services have complicated structures of intermediate agents, connected to one another on an almost infinite chain. Therefore, it is necessary to specify the effective range of the service from an initial provider to a final receiver. In comparison to the View Model in which a single RSP is expressed, the Scope Model deals with all the RSPs within the provider and the receiver (see the lower half of Figure 3). In other words, a Scope Model handles multiple View Models, namely multiple RSPs. Thus, it

helps designers to understand the activities between the provider and the receiver.

### 3.1.6 Scenario model

A Scenario Model represents two kinds of information; one is behaviour of a receiver in receiving the service while the other is a property of the receiver. This is necessary because the grounds behind RSPs of service receivers should be understood. The former is described as a transition graph whose node represents a state of a receiver and whose arc refers to a transition between two states (either temporal or causal) as shown in Figure 3. A state is described as a set of parameters with their values. Furthermore, those parameters have a hierarchical relation among themselves from end to means. By using this transition graph, the receiver's final goals, and their activities can be described. RSPs are a partial set of parameters of a state selected by designers. The latter is represented by an application of the concept called Persona (Cooper, 1999). Persona is an imaginary target user and is frequently used in practical design of software interfaces. The information to identify Persona is classified into two types; one is demographic data, such as age, gender, and professional carrier, while the other is psychological data, such as personality and life style.

### 3.1.7 View model

A View Model expresses the relationships among the elements of the service; i.e., the mutual relationships among the RSPs and FPs (CoPs and ChPs). It should be noted that not only product functions but also those of service activities are represented here by CoPs and ChPs. Furthermore, physical structures are represented using function parameters. It should be emphasized here that a View Model could work as a bridge between value represented in the form of RSP and physical structures. In addition, the View Model, like Flow Model, represents a current concerned service or a service idea to be developed more concretely.

RSPs change according to how the receiver evaluates subjectively the received contents. The subjectivity is crucial and this is why the sub model is called View Model: this represents how the service receiver views the service. An RSP is linked to several CoPs because the receiver evaluates the contents. The CoPs may be supported by several ChPs existing in the chain of several agents in the Flow Model. The View Model illustrates visually the relationships among the parameters (RSP, ChP, and CoP) in the graph of connected nodes.

Figure 4 depicts a simple example taken from a cafe service for the customers eating a preferred cake. The value in this case is the cake that is preferred by the service receiver and delivered by the cafe. The top function, "Deliver a preferred cake" is deployed into two functions, "Take an order" and "Transport a cake". FPs for the first function include "Time for customers to select" and "Time for customers to wait", since these are concerned characteristics for customers in a cafe. In addition, another FP, "Possibility of mistakes" may be important, because something wrong is in some cases transported. An entity contributing to achieve these two functions is in this case modeled as "Server", which is normal in a cafe. This means these two functions are realized by service activities. It is taken for granted that different functions can be sub-functions of "Deliver a preferred cake". In addition, there are other options for the adopted entity to fulfill the

function. For instance, the function, “Take an order” can be achieved by a device sensing the touch on the surface on a table for customers like an ATM (automatic teller machine) for banking service. The second function may be carried out by a conveyer as seen in some sushi restaurants transporting sushi on a conveyor in front of the customers. These are the cases where physical products realize the functions.

Importance of FPs can be also calculated using the scores of RSPs showing the importance and correlation between RSPs and FPs by use of the QFD (Quality Function Deployment) (Akao, 1990) manner (Arai *et al.*, 2005).

## 3.2 Function-based model

### 3.2.1 Overview

The Value analysis developed by Miles was used to decrease costs during product development or redesign by focusing on the fulfilment of required customers’ functions (Miles, 1971). The value analysis has led to the development of an engineering design methodology to develop either product or service through the Functional Analysis. However, when service is developed with Functional Analysis, it often leads to detail organisational frame. The Functional Analysis is composed of various methods and tools (Afnor, 1991; Afnor, 1996; Afnor, 1996). This global method enables engineering designers to start from the external functions required by customer in order to detail the internal functions that will fulfil the customers’ requirements. The tools used in this methodology are the External Functional Analysis and Internal Functional Analysis.

### 3.2.2 External Functional Analysis

External Functional Analysis is used to list the service functions (external functions) provided to the customer by the “product”<sup>1</sup>, irrespective of the means available to provide them. It can be carried out on the different situations in the product life cycle (use, manufacture, maintenance, recycling, etc...). The “product” is, at this point, considered as a black box, which can satisfy customer needs and those of the professionals involved in making it (Prudhomme *et al.*, 2003). The graph of interactors is used to express these needs. It described service functions and constraints (figure 4):

- The interaction functions (IF), which correspond to the services provided by the product during the product life cycle;
- The adaptation functions (AF) that reflect reactions, resistances or adaptations to elements found in the outside environment (E1, E2, E3);
- The constraints are defined as a design characteristic, effect or provision for design, which is made compulsory or forbidden for whatever reason.

These functions are obtained from systematic analysis of the possible relations between:

- The different elements of the outer environment via the product for IF;
- The elements of the outer environment and the product being designed for AF.

<sup>1</sup> The “product” can be either a physical product, a service or an organisation

Different tools are put forward (e.g.: graph of interactors, figure 4) to express external functions.

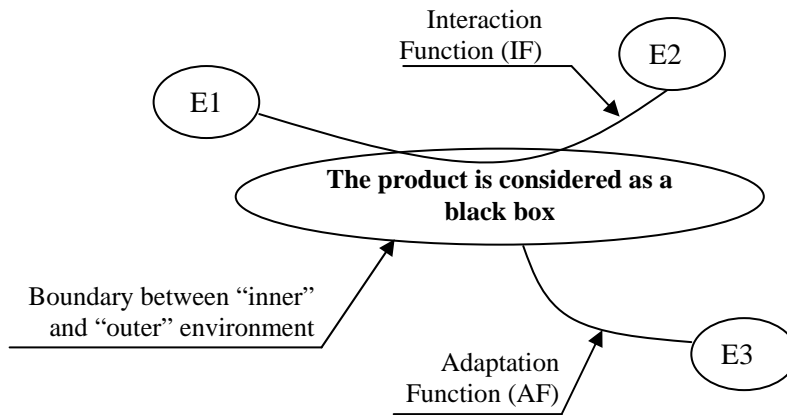


Figure 4: External functional analysis and graph of interactors

### 3.2.3 Internal Functional Analysis

Once the external functions have been described, it is necessary to ‘translate’ those functions into technical functions because only technical functions can be detailed with solutions and components. In order to lead to these solutions, two tools will be used: the FAST (Functional Analysis System Technique) diagram and the Functional Bloc Diagram (FBD).

The FAST diagram is employed to detail service functions. Each function is described with technical functions that will be fulfilled by solutions. In the case of PSS, these solutions can be physical products or technical services (Aurich *et al.*, 2006) The construction of this diagram is based on wondering how we can detail a function and conversely why a function is required (see figure 5).

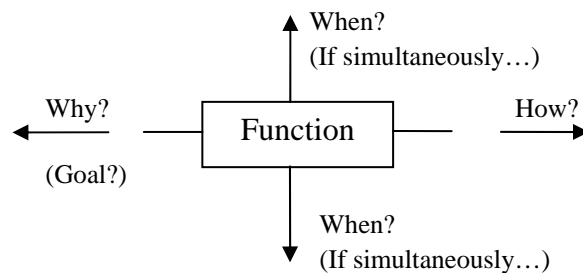


Figure 5: Method to construct FAST diagram

The FBD will map the components of the ‘product’ used to fulfill the service functions and the links between them will be described. It can be physical links, visual links, informative links, etc... In this representation, the outer environment will appear and it is possible to draw by which component the interaction functions will go through. The components influenced by the adaptation functions will be asterisked. With the FBD we can have some information about:

- The different components of the product and particularly, those necessary to the function realization;
- The contacts between the components;
- The design choices (Design Buckle (DB)) that are for example technical solutions used to assemble components or to put them in position. In the case of PSS solution, the design buckle can represent organisational choice including products and services.

### 3.3 Comparison

Table 1 compares the two models by showing how each of the models represents important elements of a service. On the other hand, Table 2 addresses important processes and which part of the models support them.

Table 1: Important elements of service and their representation by the two models

<i>Elements</i>	<i>Agent-based model</i>		<i>Function-based model</i>	
Agents in service	xx	Agents (in Flow model)	x	Outer environment (in graph of interactors)
Agents' activities	xx	Scenario model		
Agents' value/sacrifice	xx	RSP (of Agent)	x	Interaction functions Adaptation functions
External functions	x	Functions	x	Interaction functions Adaptation functions
Technical functions	x	Functions	xx	Technical functions
Products	x	Entities	xx	Physical objects
Employees for service activities	x	Entities	xx	Service units
Constraints among entities			xx	Design Buckle

Notes; "xx" means "fully represented" and "x" means "partially represented".

The AM is originated of describing *who* participates in the service, while the FM is of *what* is the offer. As a result, the former describes the information about the agents in detail but differentiates neither the types of functions nor those of entities. It further describes the agents' activities, which correspond to *why*. On the other hand, the latter does not represent all the agents, but connote three types of functions and differentiates physical products and service units. This means the focus is relatively put on the information of *how*.

Since the FM does not represent all the participants of the service as mentioned above, it is in principle impossible to fulfil the holistic optimization of the benefits over costs of all the agents. On the other hand, it has strength for function deployment due to its richer concepts.

Table 2: Processes in service design and their support by the two models

<i>Processes</i>	<i>Agent-based model</i>		<i>Function-based model</i>	
Holistic optimization of agents	xx	Flow model		
Focus a relation between two agents	xx	Scope model	x	FBD
Agent analysis	xx	Scenario model	x	Graph of interactors
Function deployment	x	View model	xx	FAST diagram
Constraint analysis			xx	FBD

Notes; “xx” means “fully supported” and “x” means “partially supported”.

## 4 Application to industrial case

### 4.1 The case

The case study of this paper is the example of the renting system installed in Lyon, France, called Vélo’v. This system enables customers to rent bikes in order to move in the city and only pay for the use-time. Customers can rent a bike from a place (for example the central station) and take back this bike to another place (for example the city hall). Stations are spread in the city every 300 meters. The customer must buy a card (short or long lasting card) and then register in a station (identification through the card), choose a bike, use it and bring back to a station. Depending on the card he would have, the customer will pay when he will bring back the bike for a short lasting card, or will be charged on a long lasting card. This system is installed since May 2005 and will operate with 250 stations and 3,000 bikes at the end of 2006.

### 4.2 Representation with the Agent-based model

#### 4.2.1 Agents and their relations in the service

Figure 6 shows the agents and the relations between agents in the scheme of Flow and Scope models of the service case explained in Paragraph 4.1. The “operating company” provides the service with the end user named “Bicycler”, while it has suppliers (the manufacturers of bicycles and parking systems, and the city hall leasing the parking areas). It should be noted that those who transport bicycles from stations to others in order to equalize the availability of stations are inside the operating company thus do not appear as an agent. The city hall provides the bicyclers with discount for public transport (bus and metro) fee, while it does not give such perks to the “Automobilers”. The reason is the city hall of Lyon wants to decrease the traffic in the city by promoting the use of public transport and bicycles. It is also important for designers to have an outsider named “people with vandalism” in mind to make this service work, since this kind of service often becomes a target of such vandalism.

In the scope model between “Operating company” and “Bicycler” (labelled D), for instance, the RSP of the bicycler shown in Table 3 are included. It should be noticed that the costs such as the risk of bicycle being stolen and the effort for maintenance are not included as opposed to the case of buying bicycles.



Table 3: RSP of the bicycler

Value	Cost
<ul style="list-style-type: none"> <li>• Use right of bicycle</li> <li>• Quality of bicycle</li> <li>• Condition of bicycle</li> <li>• Availability in station</li> <li>• Parking space of bicycle</li> </ul>	<ul style="list-style-type: none"> <li>• Economic cost for use right</li> <li>• Moving to station</li> <li>• Effort for receiving bicycle</li> <li>• Transporting bicycle back to station</li> <li>• Effort for returning bicycle</li> </ul>

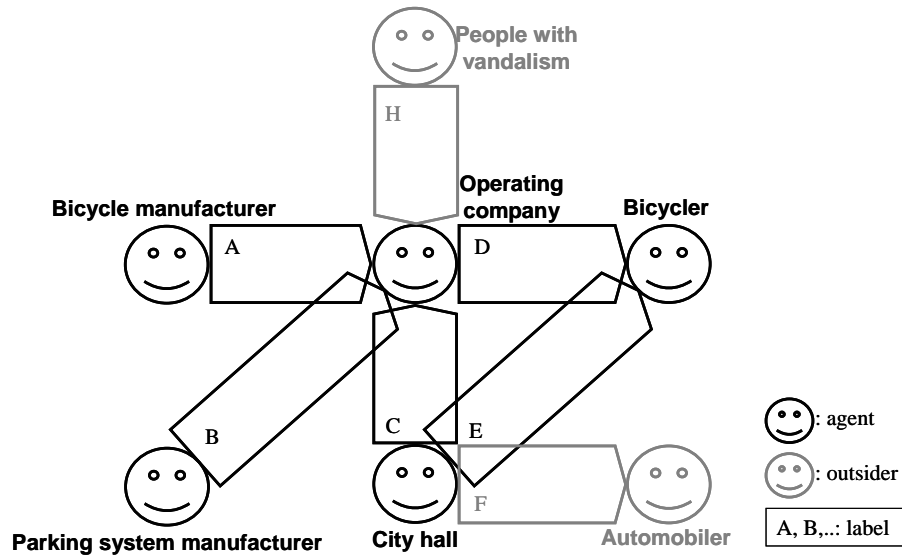


Figure 6: Flow and scope models

#### 4.2.2 Agents' activities

Figure 7, as an example, shows the activities of the customers of the operating company, namely the bicyclers, using Scenario model. This model is represented in the form of a state transition as shown in the middle. Each transition means an activity within receiving this service. It is associated with RSP that the agent perceives during the activity. For instance, when receiving the bicycle, he/she recognize a positive RSP named "Availability in station" and a negative RSP, "Effort for receiving bicycle". It should be mentioned that this depends on the agents' characteristics, which are represented by Persona model. Thus, the scenario model contributes to grounding the RSP.

#### 4.2.3 Functions of providers

Figure 8 shows the results of function deployment of one of the RSP belonging to the bicyclers, namely "Quality of bicycle" using View model. This model represents how this RSP is influenced by the functions of the operating company. They are deployed down and finally connected with entities.



the “link” between those elements and the PSS to develop. The link will be the service functions (or external functions) required by the customer.

Before highlighting functions, it is important to characterise the outer environments. This characterisation will help the emergence of supplementary functions expected by the customer. In our case, the functions can be detailed as:

- IF1: the PSS enables the customer to move in the city. Two others adaptation functions which are “the PSS must be adapted to the customer” and “the PSS must be adapted to the city plan” are implicit;
- AF1: the PSS must be adapted to the environment (climate and road-user)
- AF2: the PSS must resist to vandals.

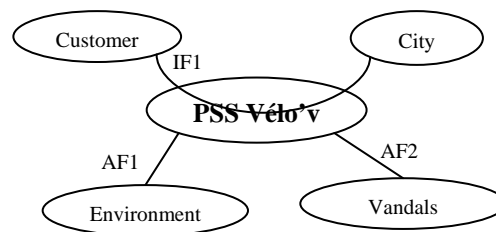


Figure 9: Graph of interactors for Vélo'v.

Instead of indicating outer environment that influences the PSS, it is also possible to indicate constraints that must be respected during the whole design process. In the case of Vélo'v, it could be possible to indicate two constraints:

- C1: the product must be manufactured by the current manufacturer; and
- C2: the costs.

Each service function and constraint must be characterized to help designer to find the right compromise about the product or service unit performance. This characterisation takes into account several elements of the outer environments and considers the characteristics of the action between the PSS and the outer environments. For example, Table 4 is a partial description of the interaction function 1 “the PSS enables the customer to move in the city”. In this table we have criteria about the customer and the city involved in the function, and criteria for the action, in this case “move”.

The characterisation of service functions permits to engineering designers to have external criteria and will be necessary to justify the technical solutions that will be used afterwards in the internal representation. For each criterion, allowance must be indicated.

Once all service functions are described, engineering designers will define the technical functions that will achieve the external functions.

#### 4.3.2 *FAST: from technical functions to solutions*

The emergence of service functions has highlighted the customers' needs but those functions will be realized by technical functions and consequently technical solutions. In the case of PSS, there are not only physical components that will fulfil this function, but also service units, service activities will ensure the functions and consequently the service proposed to customers.

Table 4: Characterisation of IF1

Criteria	Level	Allowance
<b>Customer</b>		
Man or woman	> 14 years old	...
Health	No handicap	...
Language	French or not	...
Etc.	Etc.	Etc.
<b>City</b>		
Average temperature	X °C	+/- 2 °C
Number of rainy day	X day	+/- 5 days
Kind of surface	Road, cobblestone, other	...
Etc.	Etc.	Etc.
<b>To move</b>		
Life span	X years	+/- M months
Average distance between places	X km	...
Average time between places	X mn	...
Etc.	Etc.	Etc.

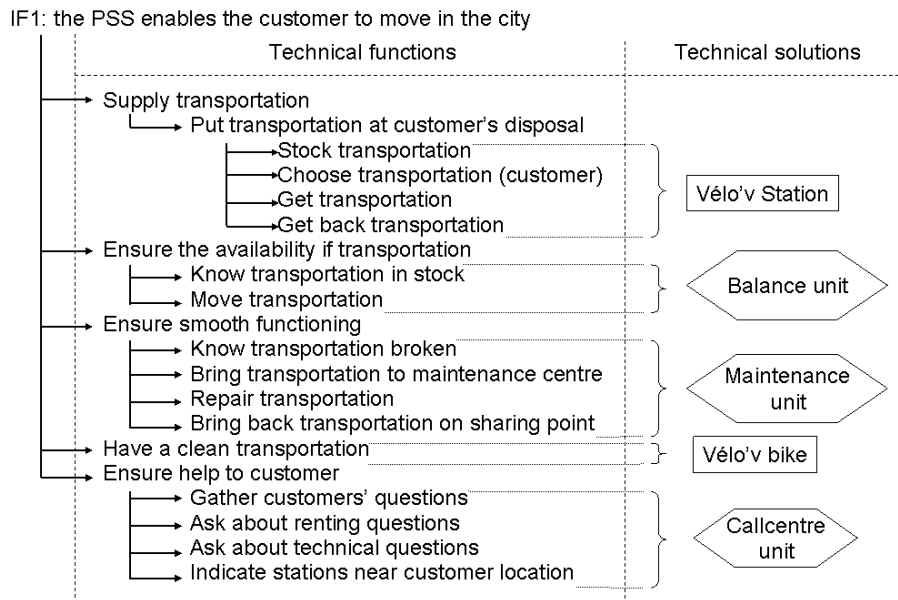


Figure 10: FAST diagram of interaction function 1.

In Figure 10, the interaction function 1 is decomposed. In this representation, both physical objects (physical products) and service units appear. Physical objects are symbolized with rectangle, while services units are represented with hexagon. The contribution of this tool is to map in a same model physical objects and immaterial units. Until now, designers only represent physical products, or services units within an organisation, but there was still a gap to represent both.

Once the choices are realised concerning products and service units necessary to realise technical functions (right side of FAST diagram), the Functional Bloc Diagram is used to represent the links between these service activities and physical products.

4.3.3 Functional Bloc Diagram of Vélo’v

The Functional Bloc Diagram (FBD) gives a schematic formalism of the product with the different components, the links between them, the functional flow and the flow concerning design choices. In the case of PSS development, those components can be either physical objects or service units (service activities).

In the FBD (see Figure 11), links between objects and service activities are detailed. For example, the maintenance unit that repairs bikes will be linked to the station to take and bring back bikes. Moreover, bike and station are also linked due to the physical link between the storage area and bicycle. Consequently, in this particular representation we can have either links between physical objects, or between object and service units. It would be also possible to have link between two services if for example the hotline gives information to the maintenance unit about the broken bikes. These links reflect the overall organisation of the system. By representing IF1, this function will go from the customer to the city by going by the bike. However, in order to fulfil this function, technical functions and solutions are necessary. The components realise only the “primary” technical functions. This is an overall organisation that will ensure the service provided to the customer.

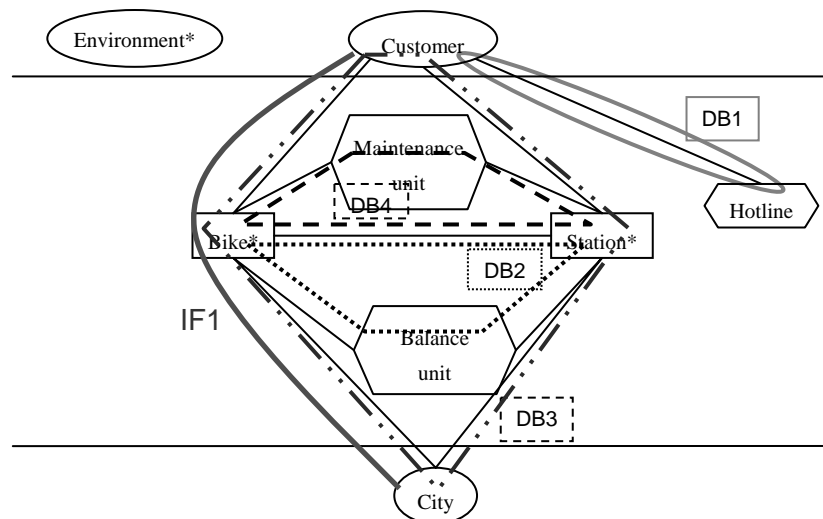


Figure 11: FBD of Vélo’v example

The FBD details 4 design buckles:

- DB1: ensure help to customer
- DB2: ensure the availability of transportation
- DB3: supply transportation
- DB4: ensure smooth functioning of transportation

In a design buckle, both products and services are linked. It will be necessary to detail each link because the components will influence themselves. In order to do that, designers have to implement criteria about this link. The criteria for relations will be a mean for designers to integrate constraints during the development of elements and consequently to optimized the overall set of product and services.

#### 4.3.4 *Outlooks*

By using Functional Analysis representation, it is possible for engineering designers to have both products and technical services as technical solutions. In the FBD, products and technical services are equivalent to modules. Afterwards, it is important to detail these modules and the links between them. However, by mapping a global interrelation between modules, engineering designers will be more aware about the necessity for integrate during the representation of product and/or service units the influence of the others modules.

## 5 **Discussions**

The application of the two models to an industrial service in Section 4 verified especially the comparison in Paragraph 3.3. First, all the agents in the AM were not modelled in the FM; e.g. the city hall. It should be noted that the city where the bicyclers drive was in the FM, but not the city hall. Second, all the value/sacrifice of agents in the AM were not modelled in the FM; for instance, the time for maintenance. This originates from the little focus of dynamics in the FM. The bicyclers' time for moving did not appear in the FM, either, since this becomes apparent by describing the agents' activities. The economic cost paid by an agent to another is modelled as cost in a Scope model in the AM, while it is not fully modelled in the FM. Although the costs are modelled as constraints in the FM, it is not grounded who pays them to whom. Lastly, the discount of public transport modelled as value of the bicycler in the AM was not in the FM since the city hall was absent.

On the other hand, the FM represented functions and their media by richer notations than the AM. Although they can be represented by both the FM and the AM, the FM specifies the types of functions and their media. In addition, the constraints among the adopted entities are represented only in the FM.

Following the discussions above, combining the two models has potential to describe solutions in SPE better than only one of them.

## 6 **Conclusion**

This paper analyzed two object models, namely AM and FM that have potential for representing solutions in order to design simultaneously products and services activities in order to fulfil customers' needs. From the analysis, the strength and weakness of each model have been identified.

In the future research, integration of the models taking advantage of each one's strength will be achieved. This is expected to support designers who engineer a combination of service activities and products efficiently. Such a model is effective for management, design, and innovation, because they support designers to describe solutions in a consistent model for both physical products and immaterial service activities. Engineering designers tend to be more focused on physical products, whilst management people are more conscious about immaterial service activities. However, in order to provide an optimized solution, having such a model for engineers and managers would be appreciated to discuss, exchange view points, integrate constraints in order to innovate solutions.

## 7 Acknowledgements

This research was partially supported by a Research Fellowship Program by Alexander von Humboldt Foundation in Germany.

## References

- Afnor (1991). *Afnor standards, Normes NF X50-151 : Expression fonctionnelle du besoin et du cahier des charges fonctionnel.*
- Afnor (1996). *Afnor Standards, NF X50-100 : Analyse fonctionnelle - Caractéristiques fondamentales.*
- Afnor (1996). *Afnor Standards, Normes NF EN 1325-1 : Vocabulaire du management de la valeur - Analyse de la valeur, Analyse fonctionnelle.*
- Akao, Y. (1990). *Quality Function Deployment*, Productivity Press, Portland, OR.
- Alonso-Rasgado, T., Thompson, G., and Elfstrom, B. (2004). *The design of functional (total care) products.* Journal of Engineering Design 15, 6: 515-540.
- Arai, T. and Shimomura, Y. (2005). *Service CAD System - Evaluation and Quantification.* Annals of the CIRP 54, 1: 463-466.
- Aurich, J. C., Fuchs, C., and Wagenknecht, C. (2006). *Modular design of technical Product-Service Systems.* in Innovation in Life Cycle Engineering and Sustainable Development Brissaud, D., Tichkiewitch, S., and Zwolinski, P., Editors. 2006, Springer. 303-320.
- Congram, C. and Epelman, M. (1995). *How to describe your service - An invitation to the structured analysis and design technique.* International Journal of Service Industry Management 6, 2: 6-23.
- Cooper, A. (1999). *The Inmates Are Running the Asylum*, Sams.
- Dausch, M. and Hsu, C. (2006). *Engineering service products: the case of mass-customising service agreements for heavy equipment industry.* International Journal of Services Technology and Management 7, 1: 32 - 51
- Gallouj, F. and Weinstein, O. (1997). *Innovation in services.* Research Policy 26, 4-5: 537-556.
- Maussang, N., Zwolinski, P., and Brissaud, D. (2005). *Design of Product-Service systems.* in 10th European Roundtable on Sustainable Consumption and Production, Antwerp.
- Miles, L. (1971). *Techniques of Value Analysis and Engineering*, McGraw-Hill, USA.
- Mont, O. (2004). *Product-service systems: Panacea or myth?* , in *International Institute for Industrial Environmental Economics.* 2004, Lund University: Lund
- Oliva, R. and Kallenberg, R. (2003). *Managing the transition from products to services.* International Journal of Service Industry Management 14, 2: 160-172.
- Pahl, G. and Beitz, W. (1988). *Engineering Design: A Systematic Approach*, Springer-Verlag.

- Prudhomme, G., Zwolinski, P., and Brissaud, D. (2003). *Integrating into the design process the needs of those involved in the product life cycle*. Journal of Engineering Design 14, 3: 333-353.
- Sakao, T. and Shimomura, Y. (2007). *Service Engineering: A Novel Engineering Discipline for Producers to Increase Value Combining Service and Product*. Journal of Cleaner Production, in print.
- Shostack, G. L. (1981). *How to Design a Service*. in Marketing of Services, Donnelly, J. H. and George, W. R., Editors. 1981, American Marketing Association. 221-229.
- Suh, P. (1990). *The Principles of Design*, Oxford University Press.
- Tomiyama, T. (2001). *Service Engineering to Intensify Service Contents in Product Life Cycles*. in Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Tokyo: IEEE Computer Society, 613-618, CD-ROM.
- Tukker, A. and Tischner, U. (2006). *New Business for Old Europe*, Greenleaf Publishing.



## POSTER Credible sustainability reports

*An empirical investigation on the interaction between sender and communication style: the case study of tegut*

Nina Stockebrand and Achim Spiller

*Department of Agricultural Economics and Rural Development,  
University Goettingen, Germany*

### 1 Introduction

Since the 1990s sustainability reports have become more and more common in some branches of trade in Germany. In food retail not many approaches can be found. Currently Metro is the only company in Germany, which has presented a sustainability report so far (Loew, 2005) even though especially the food retail industry as a global and highly concentrated business stands in the focus of the sustainability discussion (Homann, 2006, Schneidewind, 1998, Spiller, 2005). The companies operate in the full spotlight of public scandals and the lacking transparency of the trade contributes to alienate the public.

The question of credibility of information is therefore of extreme importance in food retailing (Huck, 2006). This means, that sustainability reports are judged much more under aspects of credibility than in other branches. Even though the topic credibility of sustainability reports has been investigated in various works (GRI, 2002, KPMG, 2002, IÖW and IMUG 2001, ECC Kohtes Klewes, 2003), some questions still remain unanswered. Especially the significance of the sender of a message (the company) as well as the communication style used have not yet been taken into consideration in the studies on the credibility of sustainability reports. At the same time, general studies on communication styles state an influence of these factors on the credibility of a message.

Therefore, the main focus of this study lies on the analysis of the credibility of two different communication styles and their interdependencies with the sender (the company). The study provides an overview of the works on credibility of sustainability reports and uses this as a framework for a detailed case study with one leading German retailer. The case study deals with the analysis of the credibility of different communication styles and possible interdependencies between communication style and sender respectively. The company tegut, which is characterized by a strong focus on ecological products, provides for an interesting field of investigation.

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

## **2 Credibility, communication style and sender-effect**

### **2.1 Status quo in the research of credibility**

Credibility is a central problem of sustainability reports (Frings, 2003). This problem did not just appear with the emergence of the issue of sustainability but has been discussed in reports of social, environmental and financial nature. Thus, national and international standards for reports of accounting have been developed that are now adapted to the sustainability discussion, e.g., the GRI-standard. A reference to these standards is often used to aid the credibility of sustainability reports (Quick and Knocinski, 2006). This topic has been investigated in numerous studies. Table 1 provides an overview of the works and their focus of investigation.

Table 1: Status quo of credibility in sustainability reporting (own representation)

Author	Methodological Approach	Variables influencing credibility in sustainability reporting
ACCA 2005	rating of sustainability reports	<ul style="list-style-type: none"> <li>● content/communication</li> <li>● external judgment</li> <li>● process of creation reports</li> </ul>
Adams and Evans 2004	theoretical consideration	<ul style="list-style-type: none"> <li>● company</li> <li>● external judgment</li> </ul>
Clausen, Loew 2005	stakeholder inquiry and company inquiry	<ul style="list-style-type: none"> <li>● company</li> <li>● external judgment</li> </ul>
ECC Kohtes Klewes 2003	stakeholder inquiry	<ul style="list-style-type: none"> <li>● content/communication</li> <li>● external judgment</li> </ul>
Frings 2003	guideline	<ul style="list-style-type: none"> <li>● content/communication</li> <li>● external judgment</li> <li>● process of creation reports</li> </ul>
GRI Global Reporting Initiative 2002	guideline	<ul style="list-style-type: none"> <li>● content/communication</li> <li>● external judgment</li> <li>● process of creation reports</li> <li>● adress to target group</li> </ul>
Hauth und Raupach 2001	theoretical consideration	<ul style="list-style-type: none"> <li>● content/communication</li> </ul>
Herzig und Schaltegger 2003	theoretical consideration	<ul style="list-style-type: none"> <li>● content/ communication</li> </ul>
IÖW und imug 2001	guideline	<ul style="list-style-type: none"> <li>● content/communication</li> <li>● external judgment</li> <li>● process of creation reports</li> </ul>
Kim 2005	theoretical consideration	<ul style="list-style-type: none"> <li>● content</li> <li>● company</li> <li>● external judgment</li> <li>● process of creation reports</li> <li>● adress to target group</li> </ul>
KPMG 2002	company inquiry	<ul style="list-style-type: none"> <li>● external judgment</li> </ul>
Loew et al. 2005	rating of sustainability reports	<ul style="list-style-type: none"> <li>● content/communication</li> <li>● external judgment</li> </ul>
Pleon Kohtes Klewes GmbH 2005	stakeholder inquiry	<ul style="list-style-type: none"> <li>● content/communication</li> <li>● external judgment</li> <li>● company</li> </ul>
Stratos 2005	benchmarking	<ul style="list-style-type: none"> <li>● content</li> <li>● external judgment</li> </ul>

Especially surveys among stakeholders show a number of hints how to increase credibility in sustainability reporting. It is exposed that in particular the orientation of the content towards the target group contributes to the credibility of the reports. In addition, a positive external judgement can

cause an increase in credibility (ECC Kohtes Klewes, 2003). In comparison to an empirical research in 2003, the study of Pleon (Kohtes Klewes) in 2005 showed an increase in the importance of verification for the credibility of sustainability reports (60 % 2005 vs. 48 % 2003). However, the majority of reports have not yet used external verification as a way of increasing credibility (Pleon, 2005). Loew and Clausen (2005 in Pleon) complete their statements regarding credibility with the general image of a company and its evaluation in the public (*ibid.*).

As another research stream, some authors (IÖW and imug, 2002) tried to provide solutions for the problem of credibility through the development of guidelines. Rating agencies (Loew et al., 2005, ACCA, 2005) standardized specific criteria for credibility on the basis of different fundamental approaches (GRI, 2002, WBCSD, 2001). In a recent ranking that depicts credibility (Loew et al., 2005), companies in general score relatively low.

The communication style is another often mentioned but rarely evaluated issue. Critical communication, although advised by many studies, is not yet commonly used. Furthermore, there is a lack of empirical studies that investigate whether a critical style of writing can contribute to the credibility of a sustainability report. Loew et al. (2005) reveal that out of 150 companies only 5 mention unsolved problems in their sustainability report. The remaining 145 do not address any problems that come with sustainable management. From a theoretical point of view, sustainability management deals with difficult trade-offs between economic, environmental and social issues which includes critical decisions in many cases.

Up to now, no empirical analysis has confirmed the assumption that a company itself has an influence on the credibility of a sustainability report. Academic research in communication investigated attributes for credibility with the help of theoretical approaches (e.g. Adams and Evans, 2004, Kim, 2005) and mentioned the relevance of the company itself. Thus, the objective of the following study is to combine the questions of communication style and the sender-effect in an empirical survey in the food retailing.

## 2.2 Sustainability problems of food retailing

The circulation of sustainability reports in food business varies. Whereas reports are very common for large brand manufacturers (Selbach and Löhr, 2004), food retail is partly an exception (Loew et al., 2005). European companies such as Kesko, Ahold and Tesco focus more and more on sustainable topics (SustainAbility and UNEP, 2002). In Switzerland companies like Migros and Coop have long been dealing with sustainable management and have integrated these concepts into their politics (Spiller, 2005). In Germany, these tendencies are just at the beginning, a fact that is reflected in the low number of published sustainability reports.

Within the German food retail market only Metro can present a sustainability report. Whereas the Tengelmann Group includes some short information on sustainability into the annual business report, all other leading companies such as Edeka, Aldi and Rewe still are without effort in the sector of sustainability (Loew et al., 2005). “Apparently, the trading of goods is not seen as responsible as the producing of goods” (*ibid.*). In contrast to this, the public debate about sustainable food retailing is growing.

Similar to the chemical industry, food companies became more and more the focus of public attention. (Selbach and Löhr, 2004) However, the food retail industry is still only little involved in the discussion about sustainability.

The public responsibility of the food retail industry becomes clear in the negotiations with its suppliers. Through its position of power, the retail branch is significantly involved in the choice of the assortment and is able to foster or to repress sustainable products (Stippel, 1997). It takes on the role of a 'gatekeeper' and is thus able to preselect the choice of the customer (Spiller, 2005). Socially, the retail sector assumes responsibility in so far as it secures business for its suppliers while at the same time providing jobs and financial security for their employees. This can only be guaranteed if the company operates economically and secures a long term presence on the market. The 'Three-Column-Principle' of sustainability can thus be transferred to the food retail sector. However, the idea of sustainability that is based on an equilibrium of the three columns ecology, social aspects and economy has not yet been fully implemented into the food retail business of which the low number of published sustainability reports is an indication. Therefore, stakeholders remain sceptical towards the retail branch and assume a strategy of maximum profit (ibid.).

### 2.3 Case study tegut

Tegut is a company that has dealt with sustainable topics since the 1980s (Will, 2006, Spiller, 2001). The Hessian family enterprise based in Fulda is a larger regional chain with 301 stores (in 2005) in Hesse, Thuringia, Bavaria, and South-Lower Saxony (LZ |NET, 2006a; tegut.com). Since the mid 1980s and until nowadays, tegut has consequently dealt with organic food. With a total volume of sales of 1 billion Euros and an increase by 4% in 2004, tegut implemented its concept successfully. Today, organic products account for 10% of the whole assortment; measured by the volume of sales this amounts to even 15%. Frequently, the promotion of organic products is linked to regionality, as, for example, it is supported in projects from the Rhön-area (LZ |NET, 2006a, LZ |NET, 2006b). At the same time, social aspects such as the association with other people and the promotion of their abilities belong to the company's policy and philosophy, which affected 5,412 employees in 2005 (tegut.com). The award „Ausbilder des Jahres 2005“ (trainee teacher of 2005) confirms the company's successful social commitment (LZ |NET, 2005). All in all, tegut is seen as benchmark of sustainability management in the conventional food retailing. However, the company has not published a sustainability report yet.

### 2.4 Structure of the case study

In cooperation with tegut, an empirical survey was conducted in the summer of 2006. The comprehensive personal interviews include 113 respondents, 81 customers and 32 employees of tegut. Main focus was measuring the effect of a self-critical communication style, sender effect and their possible interaction.

The analysis of the communication style was carried out on the basis of two different text extracts on the purchase of bananas in the Dominican Republic. The texts differed in their communication style. While one text describes the problems of the purchase of Bananas and hence addresses the

topic in a critical way, the second rather reminds of a naive report suppressing any problem. On the one hand the authenticity of a communication style is examined by a choice experiment between the two texts and on the other hand by the inquiry of criteria of authenticity acquired in former projects. By combining these cards the extent of the effect of the communication style in one company can be determined. For these purposes both communication styles were combined with two companies, tegut and Edeka (tab.2). Edeka is the market leader in the German food retailing (32 billion Euros turnover in 2005) and works with a similar marketing concept.

Table 2: Composition of cards (own representation)

	Composition	
	Company	Communication style
Card 1	tegut	uncritical
Card 2	Edeka	critical
Card 3	tegut	critical
Card 4	Edeka	uncritical

The respective cards had to be ranked according to the perceived level of authenticity. This ranking allows a measurement of the interactive effects between communication style and the company involved. Furthermore, additional seven-point rating scales and image questions were used to evaluate the reputation and the perceived awareness of sustainability reporting.

## 2.5 Empirical results

The publishing of a sustainability report by tegut is conceived as “rather important”, “important” or “very important” by 93% of the respondents. In the first appraisal of the communication style, 68% of all respondents evaluate the critical communication style as more credible. For the employees, this type of report is even more credible (84%). Such evaluation can basically be explained by the way the critical text appeared to the subjects; more honest (\*\*\*) and more competent (\*\*) (tab.3). In order to determine the factors which have an influence on the credibility of the texts the acquired criteria of credibility of the status quo examination were tested as independent variables in a binary logistic regression. The decision of choice between text 1 and text 2 serves as dependent variable.

Table 3: Strength of effect of written criteria on credibility (Logit regression) (own representation)

determinate of effect	regression-coefficient	Wald	Significance
more honest	0,958	11,129	0,001***
more competent	0,875	8,290	0,004**

Beside the differences between the target groups education, age and income lead to differences in the perception of the text. The critical text is more positively evaluated by younger respondents with a higher educational background and higher income. A comparable result could be determined in the study by Hoveland (1965).

## 2.6 Interaction effects

In order to determine the interaction effect between the communication style and the company the card inquiry was used. The comparison of the rank averages (tab. 4) points out the differences that can be interpreted by means of the following rule:

The differences between the factor-degrees of the one factor become irregular in regard of the degrees of the other factor (Jaccard and Turrisi, 2003)

This means that the difference between both columns, tegut and Edeka, as well as the difference between both rows, critical communication style and uncritical communication style, must be unequal when showing an interdependency (interaction).

Table 4: rank average of card inquiry (own representation)

		company				difference
		tegut		Edeka		
Communication-style	critical	<b>Card 3</b>		<b>Card 2</b>		1,31***
		$\mu$	$\sigma$	$\mu$	$\sigma$	
		<b>1,68</b>	0,898	<b>2,99</b>	0,898	
	uncritical	<b>Card 1</b>		<b>Card 4</b>		0,92***
		$\mu$	$\sigma$	$\mu$	$\sigma$	
		<b>2,19</b>	1,125	<b>3,11</b>	0,868	
difference		0,51**		0,12 n. s.		

Table 4 shows that the average rating of the company not only differs from column to column but also from line to line. Except for the difference between card 2 and card 4, the deviance is significant<sup>1</sup>, thus showing an interaction effect between the two variables.

<sup>1</sup> The comparison of average values of paired random samples gives information, in how far the differences are significant (Bühl, Zöfel. 2000: 279). In so doing, the average rating values of the cards 3 and 2, the cards 1 and 4, the cards 3 and 1 as well as the cards 2 and 4 were compared.

As a result, it can be revealed that:

- Tegut is preferred compared to Edeka, i. e. its image is better with consumers as well as with employees.
- The critical communication style is more credible than the uncritical.
- The influence of the company itself affects the critical text to a larger degree (difference 1.31) than the uncritical one (difference 0,92).
- The effects of communication have a larger influence in the case of tegut (difference: 0.51) than in the case of Edeka (difference: 0.12)
- The communication style does not affect the credibility of Edeka and is therefore of less importance for the company

On the one hand, the results of earlier studies regarding the communication style are validated. On the other hand, conclusions can be drawn about the difference in effectiveness of the two variables. The stronger influence of the critical text in the evaluation of credibility on card 2 and card 3 shows that a critical style of writing is more credible in connection with the more sustainability oriented company tegut than it is with the competitor Edeka. In comparison, the use of an uncritical style of writing has less influence on the evaluation of credibility on the cards of tegut and Edeka.

Due to the reputation of tegut as a sustainability oriented firm, a more critical style of writing is expected by the customer. If a critical style of writing is not used, the evaluation of credibility shows noticeable lower results than for the same text read in connection with Edeka. In this case, Edeka cannot enhance its credibility significantly through a critical communication style. Compared to tegut, the company is much less involved in ecological and social issues and it is expected, that its statements about sustainability are seen as much less credible. Neither a critical description nor an uncritical one can convey information in a credible manner compared to tegut.

When looking at the evaluation of customers and employees separately, the following can be stated: Customers rate the tegut cards as significantly more credible than the Edeka cards and thus judge the credibility of sustainability reports with respect to the sender or the company respectively. Employees rate only card 3 as noticeably more credible compared to all other cards, that is they evaluate according to the compatibility between company and communication style. The communication style has to match the company in order to appear credible.

As a conclusion, three forms of answering behaviour can be differentiated when looking at ranking 1 and ranking 2:

1. Preference of company: 40 respondents (46% of customers and 26% of employees) evaluate the credibility of the cards based on the company.
2. Preference of text: the same number of respondents evaluate according to the communication style. Out of 40 respondents 18 (40% of employees, 20% of customers) preferred the critical text and 22 (20% of customers) the uncritical one



3. Interaction: 19 respondents (33% of employees, 13% of customers) evaluated on the basis of coherence between text and company.

### 3 Overall conclusion

As a conclusion, a sustainability report should include critical aspects (communication style effect), however, particularities of the target group have to be taken into consideration. Whereas employees demand a critical discussion within the company and evaluate a critical communication style as more credible, the communication style loses significance when looking at customers. Their evaluation relies more on the company itself (company effect). When customers trust a company and are convinced of its credibility, they trust the contents of the sustainability reports. A critical communication style in some cases shows too much in depth information.

The interaction effect has to be taken into consideration especially when addressing employees. They expect an authentic representation of the company in the context of a sustainability report. If the expectations of the employees do not match the communication style in the sustainability report, it is seen as not authentic. Employees are involved in the daily routine of the company and expect an honest and critical communication as they are able to evaluate reports with regard to their validity. Stakeholders that are closely involved with the company, employees in this case, possibly suppliers as well, will challenge statements more critically and evaluate credibility according to an interactive effect.

The credibility of sustainability reports in the food retail branch can be enhanced through the use of a critical communication style but the most important aspect for consumers is the image of the company itself. If the company acts convincingly with regard to sustainability in public, its sustainability report will be perceived as credible, mainly independent of the communication style. On the contrary, companies that seek to use a sustainability report *pro forma* as a means of enhancing their image will face problems with their credibility if they have not yet convincingly implemented sustainable forms of management. In such cases, other criteria for credibility such as external evaluations can become of more importance.

Generally, this study confirms the relevance of sustainability reporting for the food retail branch. In addition to the present criteria for credibility, it also emphasizes the relevance of a suitable communication style as well as the company image itself for the credibility of sustainability reporting.

## References

- ACCA (2005). *Towards transparency: progress on global sustainability reporting 2004*. London
- Adams, Evan, (2004). *Accountability, Completeness, Credibility and the Audit Expectations Gap*. *Journal of Corporate Citizenship* 14: 97-115
- Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

- Bühl, A. and Zöfel, P. (2000). *SPSS Version 10 Einführung in die moderne Datenanalyse unter Windows*. München
- ECC Kohtes Klewes (2003). *Global Stakeholder Report 2003: Shared Value: The first world-wide stakeholder survey on non financial reporting*. Bonn, London
- Frings, E. (2003). *Glaubwürdigkeit in der Marketingkommunikation: Konzeption, Einflussfaktoren und Wirkungspotenzial*. Wiesbaden
- GRI Global Reporting Initiative (2002). *Sustainability Reporting guidelines*. Boston
- Homann, K. (2006). *Gesellschaftliche Verantwortung der Unternehmen. Philosophische, gesellschaftstheoretische und ökonomische Überlegungen*.  
<http://www.wcge.org/downloads/DD-04-6.pdf>,
- Hovland, C. (1965). *The influence of source credibility on communication effectiveness*. Advertising management: 339-352
- Huck, S. (2006). *Glaubwürdigkeit: Erfolgsfaktor in der Unternehmenskommunikation - Ergebnisse einer qualitativen Befragung von Kommunikationsverantwortlichen*. Stuttgart
- IÖW and imug (2001). *Der Nachhaltigkeitsbericht: Ein Leitfaden zur Praxis glaubwürdiger Kommunikation für zukunftsfähige Unternehmen*. Berlin
- IÖW and imug (2002). *Nachhaltigkeitsberichterstattung: Praxis glaubwürdiger Kommunikation für zukunftsfähige Unternehmen*. Berlin
- Jaccard, J., Turrisi, R. (2003). *Interaction effects in multiple regression*. London
- Kim, K. (2005). *Interaktive Nachhaltigkeitsberichterstattung von Unternehmen: Konzeption und Analyse der Internetnutzung von GF- 500- Unternehmen hinsichtlich der Nachhaltigkeitsberichterstattung*. Frankfurt am Main
- KPMG (2002). *International Survey of Corporate Sustainability Reporting 2002*. De Meen
- Loew et al. (2005). *Nachhaltigkeitsberichterstattung in Deutschland: Ergebnisse und Trends im Ranking 2005*, Berlin
- LZ | NET (2005). *tegut hat die Nase vorn*. Lebensmittel Zeitung vom 07.10.05. [www.lz-net.de](http://www.lz-net.de)
- LZ | NET (2006a). *Handel: tegut Gutberlet-Stiftung & Co*. Lebensmittel Zeitung vom 01.09.2006. [www.lz-net.de](http://www.lz-net.de)
- LZ | NET (2006b). *tegut bleibt im Rhein-Main-Gebiet weiter am Ball*. Lebensmittel Zeitung vom 28.09.06, unter: [www.lz-net.de](http://www.lz-net.de)
- Pleon (2005). *Accounting for Good: the Global Stakeholder Report 2005 The second world-wide Survey on Stakeholder Attitudes to CRS Reporting*  
[http://www.pleon.de/fileadmin/downloads/Pleon\\_GSR05\\_dt.pdf](http://www.pleon.de/fileadmin/downloads/Pleon_GSR05_dt.pdf)
- Quick, R., Knocinski, M. (2006). *Nachhaltigkeitsberichterstattung - Empirische Befunde zur Berichterstattungspraxis von HDAX-Unternehmen*. Zeitschrift für Betriebswirtschaft 76: 615-650
- Schneidewind, U. (1998). *Die Unternehmung als strukturpolitischer Akteur: Kooperatives Schnittmengenmanagement im ökologischen Kontext*. Marburg
- Selbach, D., Löhr, S. (2004). *Nachhaltigkeitsbericht*. PR-Magazin 35: 32-35
- Spiller, A. (2001). *Preispolitik für ökologische Lebensmittel: Eine neo-institutionalistische Analys*. Agrarwirtschaft 50: 451-461
- Spiller, A. (2005). *Nachhaltigkeit in Distribution und Handel*. Brunner, K.-M. and Schönberger, G. (Hrsg.) (2005). *Nachhaltigkeit und Ernährung: Produktion - Handel - Konsum*, Frankfurt, New York
- Stippel, P. (1997). *Brauchen wir die Preisbindung ?*. Absatzwirtschaft: Zeitschrift für Marketing 40: 18-19
- SustainAbility and UNEP (2002). *Trust Us The Global Reporters 2002 Survey of Corporate Sustainability Reportin*. London, Paris
- WBCSD (2001). *Sustainable development reporting: Striking the balance*.
- Will, B. (2006). *Bio-Produkte: Mehrwert für den Mainstream*. Lebensmittel Zeitung vom 01.09.2006. [www.lz-net.de](http://www.lz-net.de)

# POSTER Coffee Provider System

*Development and analysis of a product service system*

Raffaella Leane Zenni Tanure<sup>a</sup>, Michaelle Bosse<sup>a</sup>,

Aguinaldo dos Santos<sup>a</sup>

<sup>a</sup> *Federal University of Paraná, Design and Sustainability Research Center,  
design.pss@gmail.com*

## 1 Introduction

### 1.1 Coffee's Consume

In Brazil, coffee is largely consumed, the ABIC (Brazilian Coffee Industry Association) considers that the per capita consume can still be raised continually, since the Brazilian market has plenty capability to assimilate product's built ups and innovations, through the continuous quality's improvement. Taking a survey as start point, the conclusion was that brazilians are already consuming 15,54 millions of packs a year, a raise of 3,96% comparing to 12 months closed in October' 2004, while the world's balace is stablished around 1,5% a year. The per capita consume evoluted in 2,5%, hitting 4,11kg of toasted/mowed coffee per habitant/year, against 4,01 kg/hab.year in the year before, which approaches even more the brazilian's consume to european and american standards (ABIC, 2005).

This data bring the evidence of an urge in project's development related to coffee's consume, like this proposed project, that aims in changing the way of dealing with a coffee machine.

### 1.2 Sustainable Development

The concept of sustainable development has appeared in the early 1970's, in a controversial context about the relations between economical growth and environment, emphasized specially by publishing of the Rome's Club briefing, that preached the zero development as a way of avoiding ambient catastrophes. It emerges from this context as a counseling proposition, in which the technical progress is recognized as an effective way of reducing relatively the ambient boundaries, but not as a way of eliminating those boundaries (May et al, 2003). Sustainability is defined as the choices and opportunities improvement of the present generation, not discarding those of the future generations. The equity between generations is in the core of the human sustainable development (PNUD, 1998). For this to happen, every productive action must be realized in a conscious way, respecting the *Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

environment, preserving its resources; providing this way the ambient, economic and social balance recovery. Recent studies, based in demographical advances, have concluded that sustainable product and consume would occur only when the use of natural sources is equal to 10% of the systems found in societies developed nowadays. This evaluation is approximate. Anyway it indicates the hugeness of the changes that will occur in the next fifty years (Friends of the earth, 1995).

In fact, there is a need of acting over the processes, products, services and other ways of consuming to achieve preventive solutions. According to Papanek (1995), the designer plays the role of the guide the industrial development to the ambient sustainability, once he has the function of defining the interactions between the product, the human being and the environment, reminding that every decision related to process and product modifications do not depend exclusively on the designer, but on different kinds of knowledge acting together.

When sustainability related to product's development is discussed, it refers to the product's cycle of life, the "Life Cycle Design". The designer must pay attention to all project's phases, since the extraction of the natural source to the product's discard. The phases are described below, along with the fundamental moments that characterize each of them (Manzini & Vezzoli, 2002):

1. *Pre-production*: acquisition, resource logistics, and transformation processes to the production that follows;
2. *Production*:: there are three fundamental moments in product's production: material transformation, montage, final touches;
3. *Distribution*: logistics, wrapping (its life cycle must be considered too) and stocking;
4. *Product's use*: phase in which all necessary consume to its working is considered, e.g. maintenance, fixing or substitution of damages parts.
5. *Discard*: brings up some possibilities, like incineration, splitting in parts, recycling or re-fabrication and reuse (partial or total).

Nowadays, new studies related to "eco-sustainable" projects go beyond the product's development, but involve the whole system in which the product is inserted. Besides the product, possible services that might contribute in offering results with less ambient impacts and larger user's satisfaction by bringing additional value are considered.

## **2 Product Service System (PSS)**

A Product-Service System can be defined as the result of a strategic innovation, moving the focus from the act of projecting and selling concrete products only to sell a system of products and services that together are capable in supporting specific client's demands, yet, there's the "satisfaction" as a value, instead of concrete individual product's property (UNEP, 2002).

The change from products to PSS makes possible for the company to move progressively in direction to a new way of dealing with the clients. The company that sells the service – assuming that the user doesn't acquires the product but the result/service – extends its relation with the consumer after the product's selling, with a continuous interaction in the phase of use,

by supply's acquisition and delivering, maintenance and quality service. Added to it, the company's potential in playing the role in the ending of product's life cycle aiming to reuse its materials or recycling them, making it possible to use less sources (UNEP, 2002).

PSS solutions make possible advantages to producers/providers, users and environment by three ways, according to UNEP (2002):

1. *Services offering additional value to the product's life cycle:* the company gives additional services in order to guarantee functionality and durability, extension of product's life, which is sold to the consumer. A typical service contract would include maintenance, fixing damages, updating and substitutions in a pre-determined period. As the contract expires, the PSS provider would take the product back, deciding about possible selling or discard;
2. *Services giving the clients final results:* offers a group of customized services, like substitute to the buy and use of products, to attend the consumer's needs. The group of services doesn't require that the client takes total responsibility over the product. Doing this, the producer keeps the property over the products and is paid by the consumer only for the established results. The user is set free from the problems and charges involved by acquisition, use and maintenance of the equipment and product.
3. *Services that make possible plateaus to the consumers:* the company offers access to products, tools, opportunities that make it possible to the consumer to reach the intended results. The client pays only the time that really used the equipment.

Two examples of companies that use PSS are shown below (UNEP, 2002):

1. *Allegrini:* since the beginning, Allegrini always invested attention to ambient respect. The description of Product-Service System is understood as a service that gives additional value to the product's life cycle, based in a distribution of detergent rest-giveaway. The "quick products" are analyzed in mobile pick-up-trucks, which moves from one house to another in a regular route. Each family extracts the needed detergents from the mobile pick-up-truck, whatever quality or quantity is desired, using special recipients and paying only for the recharge amount. The ambient benefits are obtained by the distribution process's optimization, in terms of packing and transporting. In a period of an year, it has been observed that no recipient was replaced.
2. *COVIAL:* is a cooperative located in the Vinícola Aurora Ltda, the biggest wine company in Brazil. The description of the Product Service system is simple; the COVIAL cooperative has ten members: the manager, three agronomists, two technicians, a secretary and two social assistants. The associates are part of the process taking decisions for COVIAL through thirteen dealers elected that assist cooperative's meetings regularly. The COVIAL gives plateaus and a final service "of the result" to its associates. Gives the technical equipment to the work in the wine fields (offered to be registered by associates) and buys seeds from Italy, France and South Africa to guarantee the Vinícola Aurora harvest's quality. The result was that different wine producers established a network and a

structured service centre, created its own system supporting the product's service.

### 3 Research Method

In the project development discussed here, some research methods were used:

1. *Bibliography Review* : refers to the search of data in literature and in some digital media, in order to consolidate a conceptual and methodological structure to support the project process.
2. *Case Study*: analysis of a product, a coffee machine, existing in the product market in Curitiba-PR, using the SDO system - Sustainability Design Orienting Toolkit, available in the internet;
3. *Action-research*: development of a product service system.

#### 3.1 SDO – Sustainability Design Orienting Toolkit

The aim of this tool is to guide the project process to sustainable solutions, determining the priorities of sustainability (using the check-list), by using sustainable design directions (idea's list) and checking and visualizing (through proper graphics) the improvements related to the existing system used as reference and its priorities. This program was developed to be a bridge between language, data and tools of the sustainability universe and its evaluations and the designer's world, when dealing with complex systems (SDO).

During its methodology phases, the ideas created and its associated scenarios will be orientated using the directions (and the list of related ideas), an effective support in the process orientation of decision by showing objectives (sustainable solutions). They inspire and indicate the solutions that have more possibilities considering sustainability (SDO).

The key concept of this tool is integrating the generating design concept process by building it up with sustainable ideas to be developed in brainstorming sessions. So, guidelines are created with priorities connected to the existing referential system to be redesigned (SDO).

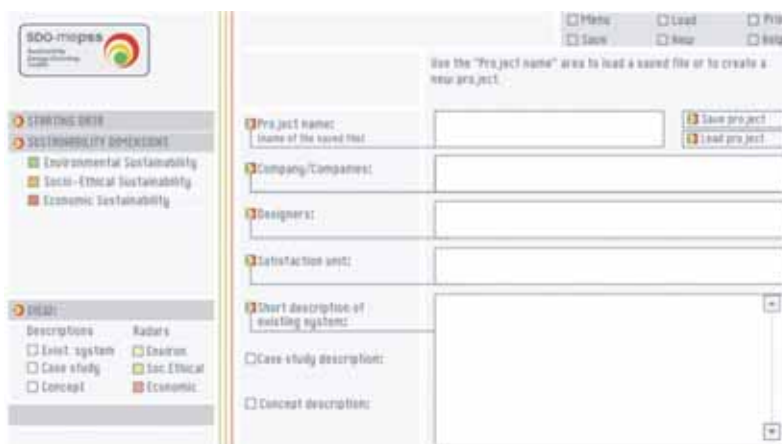





Figure 2: initial page of the system SDO

#### 4 Result: Coffee Provider System

A national produced coffee machine has been analyzed using the SDO tool, in which some problems could be noticed if related to sustainability. This analysis can be used as base to the next step, the development of a service product to provide coffee.

As follows, there is a comparative graphic, with some characteristics of each product. Still, there is a diagram given by the SDO tool, where the advances in the service product developed can be noticed relating to the current coffee machine.

Table 1: Comparative

 <p style="text-align: center;">Current Coffee Machine</p>	<ul style="list-style-type: none"> <li>• Individual use;</li> <li>• Water reservoir, heating board and filter support make an unique body, it can't be split in parts;</li> <li>• Dischargeable paper filter use;</li> <li>• It was designed only to make coffee;</li> <li>• Hard maintenance, in that case, the preventive;</li> </ul>
 <p style="text-align: center;">Product + service</p>	<ul style="list-style-type: none"> <li>• Allows shared use;</li> <li>• Every part is separable, upper and lower compartments and filter;</li> <li>• Permanent filter use;</li> <li>• Allows preparing other beverages and the use of the heated base to other uses;</li> <li>• Makes it easy to maintenance and splitting in parts.</li> </ul>
 <p style="text-align: center;">Comparative Diagram</p>	<p style="text-align: center;">Ambient Sustainability Graphic, considering the following topics:</p> <ul style="list-style-type: none"> <li>• Optimization of the system's life;</li> <li>• Reduction on logistics and distribution;</li> <li>• Reduction of used sources ;</li> <li>• Minimization of residual elements/ evaluation</li> <li>• Conservation / biocompatibility</li> <li>• Toxic reduction.</li> </ul> <p> <span style="display: inline-block; width: 15px; height: 15px; background-color: gray; border-radius: 50%;"></span> Current Coffee Machine  <span style="display: inline-block; width: 15px; height: 15px; background-color: #90EE90; border-radius: 50%;"></span> PSS         </p>

For the displayed one the argued knowledge is used to establish a PSS.  
Thus:

#### 4.1 Concept

A coffee providing system in which all services are included, like the supply of mineral water, coffee powder, cups, sweeteners and still, the preventive maintenance, all available through a monthly fee.

#### 4.2 Key-points

- The user is no longer owner of the product, he takes benefits of the service. The provider holds the property, to guarantee the perfect function of the product-service (see boards 04 and 06 of the storyboard).
- Partnership between many companies, the coffee machine industry, the coffee producer, etc.

#### 4.3 The Provider's Role

- Supervising the whole product's life cycle (see board 07 of the storyboard);
- Compromise of leaving the product in perfect use, meaning, correctly installed by capable employers, as well as providing all the necessary supplies to the service accomplishment (coffee). This way, the supplies will be replaced as soon as they're over, there's a recipient exchange (all rechargeable), the user changes the empty recipient by a loaded one (see board 4 of the storyboard. As soon as the supplies are rejected, e.g. the coffee powder already consumed, the provider takes the material and distributes among local agriculture workers (see board 05 of the storyboard). A periodic maintenance of the product is also offered to the user, as well as the replacement of the product parts. In the end, in the product disuse, contract breakdown or unbearable use, the provider takes the product for adequate uses, already set up by the industry (recycling of the pieces, etc.)

#### 4.4 Benefits of this Service to the Provider

- Trust and loyalty (provider – producer): the provider has more and longer contact with the consumer, which brings the possibility of a continuous relationship.
- The partnership between many companies, providers of the supplies, guarantee that each one is benefited from the constant relationship with the consumer (see board 02 of the storyboard).
- Product's end of life (see board 07 of the storyboard): the producer holds the power of determining the product's destination in its discard phase to separating parts, recycling or re-fabrication and reuse (partial or total).



#### 4.5 Benefits of this Service to the Consumer

- The product is now a service and no longer an ambient object (offices and houses)
- Security of use: the product gets preventive and fixing maintenance.
- Commodity: supplies provided to the service product accomplishment, residual materials collected and properly discarded.

#### 4.6 Benefits of this Service to Environment

The optimization of product's use reduces the need of many coffee machines, in case of a group of offices, for example, by the shared use. In consequence, the natural source extraction and the amount of discarded is reduced also by the periodic maintenance.

#### 4.7 Storyboard

To explain the product service, there's a storyboard to be followed:

Table 2: Coffee Provider System









	<p>1. The product's delivery is made in commercial place to the service provider company by the telephone or internet request.</p>
	<p>2. The service of providing coffee is paid; meaning the maintenance and product replacement are included.</p>
	<p>3. The same coffee machine offers possibilities of shared use, using many jars and preparing other beverages, like tea and cappuccino.</p>
	<p>4. Since the heating base is independent, it can be used for other uses, like food heating.</p>

Table 3: Coffee Provider System – second part

	<p>5. All recipients are rechargeable to later supply replacement. In the case of cups, the user separates them and the company collects them.</p>
	<p>6. The residual coffee is collected by the service provider company, which takes it to agriculture workers to use as organic fertilizer.</p>
	<p>7. There are regular visits from the technician for preventive maintenance. Right-on-time response to eventual fixing or replacements of pieces/parts.</p>
	<p>8. In the end of its life or contract end, the company takes the product back and finds another use for it, like recycling or reuse and proper discard.</p>

## 5 Conclusion

The implementation of a product-service system offers benefits to the users as well as companies and yet to the environment, when it comes to sustainable development, subject that everyone should be conscious about, so the natural resources don't end.

To the designers the big change about a PSS project is that the possibilities of the service should be considered already in the product conception, besides, the project must be done to facilitate the maintenance, updating; every phase of the product life cycle should be closely analyzed.

## References

- Friends of the earth, Wuppertal Institut. **Toward a Sustainable Europe**. Friends of the Earth, Amsterdam, 1995
- Manzini, Ezio; Vezzoli, Carlo. Tradução: Astrid de Carvalho. **O Desenvolvimento de Produtos Sustentáveis**. São Paulo: Edusp - Editora da Universidade de São Paulo, 2002
- May, P.; Lustosa, M. C.; Vinha, da. **Economia do Meio Ambiente: Teoria e Prática**. Rio de Janeiro: Elsevier, 2003.
- Papanek, Victor. **Design for the Real World: human ecology and social change**. Londres: Thames and Hudson, 1995
- PNUD / IPEA / FJP / IBGE. **Desenvolvimento Humano e Condições de Vida: Indicadores Brasileiros**. Brasília: PNUD, 1998
- UNEP. **Product-Service Systems and Sustainability. Opportunities for Sustainable Solutions**. Paris: UNEP, 2002
- Vezzoli, C., **A new generation of designer: perspective for education and training in the field of sustainable design**. Experiences and projects at the Politecnico di Milano University, Journal of Cleaner Production, 2003.
- \_\_\_\_\_. **ABIC – Associação Brasileira da Indústria de Café**. Available online at <http://www.abic.com.br/estatisticas>, 2005
- \_\_\_\_\_. **SDO**. Available online at <http://www.mepss-sdo.polimi.it>



# POSTER Are sustainable electricity production and use possible?

*The Hungarian case*

Edina Vadovics<sup>a</sup>, Benigna Kiss

*Central European University, Department of Environmental Sciences and Policy,  
Budapest, Hungary*

*<sup>a</sup>ephvae01@phd.ceu.hu*

## 1 Introduction

Attention towards sustainable energy use and energy conservation first arose during the 1970s in relation to the energy crisis and in the alarm of fossil fuel depletion. Later, concern about global environmental problems and climate change added to the existing awareness, and even supplanted that (Abrahamse et al., 2005; Shove, 1998). Today in Europe, energy security fears culminate again (EC, 2005b) and volatile prices drive public concern about energy consumption. Significant efforts have been devoted to curb the increasing energy demand and related CO<sub>2</sub> emissions in technological, political and to some extent in social sense.

Energy efficiency improvements between the 1970s and today are substantial (Figure 1). Without policies, campaigns, legislative and regulatory framework for energy efficiency, the energy demand in the EU would be 2500 Mtoe, close to 50% more than it is the actual demand in 2003 (EC, 2005b).

Similarly to energy efficiency, the use of renewable energy sources (RES) has increased significantly during the last decades. Figure 2 shows the example of wind energy capacity that has grown in the EU from practically zero in 1990 to 40,000 MW power in 2005 (Amon, 2006), with which the EU target for 2010 was reached in 2005 (EWEA, 2006). Wind energy was growing 6% per year in the beginning of the 2000s, facing administrative and grid obstacles rather than a market limit to increase capacity and demand (EWEA, 2005). Other renewables have experienced a more moderate boom, nevertheless the average growth of renewable capacity in the EU has been noteworthy, 3.3%/year between 1990 and 2003 (EEA, 2006).

*Proceedings: Sustainable Consumption and Production: Opportunities and Threats, 23-25 November 2006, Wuppertal, Germany. Launch conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6<sup>th</sup> Framework Programme.*

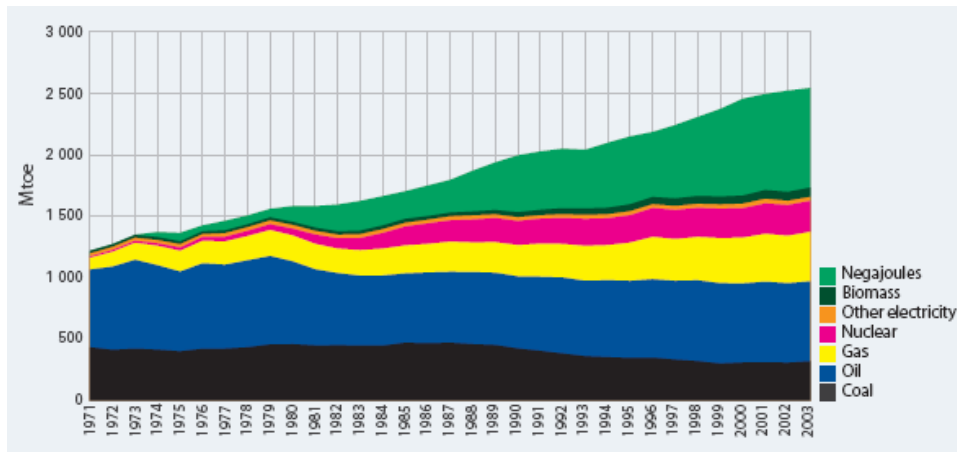


Figure 1: Development of energy demand and “negajoules” in the EU25. Negajoules are energy savings calculated using the 1971 energy intensity (EC, 2005b based on EUROSTAT data)

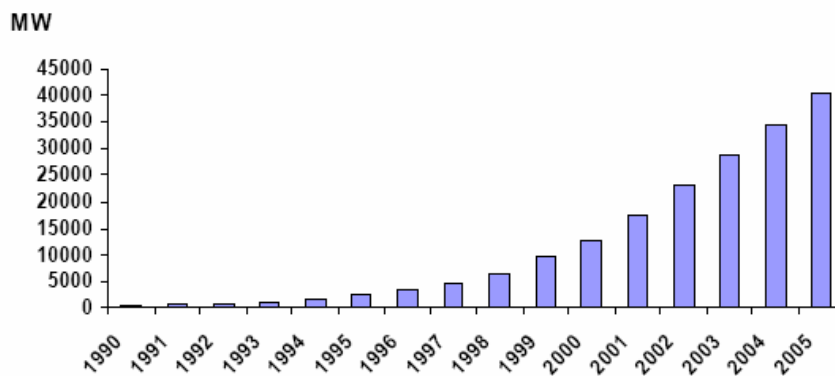


Figure 2: Cumulative installed capacity of wind power generation in the EU15 (EWEA, 2006)

Such progress broke the hitherto typical linkage between energy need and GDP growths; decoupling started to take place and the energy intensity of the economies of the developed countries decreased by a third between 1970 and 2003 (EC, 2005b). Since then; however, improvement is less significant, less than 1%/year.

In spite of the significant attempt to increase the sustainability of energy use and production, the Living Planet Report 2006 – among others – confirms that we are using the planet’s resources faster than they can be renewed (WWF, 2006). Humanity’s Ecological Footprint, has more than tripled between 1961 and 2003, and the largest contributor to the Footprint is energy generation.

In the case of Hungary, the ecological footprint followed a different path, basically mirrored the political, and resulting economic changes in the country, as can be seen in Figure 3. Still – although Hungarians have the smallest per capita footprint in the EU -, just the energy-related footprint in

the country is larger than the world average available biocapacity (based on 2001 data, WWF et al., 2005).

From these data it is clear that in order to achieve sustainable energy systems, an integrated approach to the problem needs to be taken, and it is not possible to direct our focus exclusively on demand or on supply, or indeed on energy vs. sustainable consumption and production separately. The EU and our countries need to adopt a strategic approach to rapidly increase the sustainability of the energy systems as compared to unsustainable uses and production processes.

The current paper does not provide the solutions or sets out this strategic approach, it is more of an exploration of the situation in a specific country (Hungary) that is also part of a larger community, the EU. Thus, what follows below is an attempt to describe the existing situation with indications for future research directions in order to achieve sustainable electricity production and use in Hungary and in other EU countries.

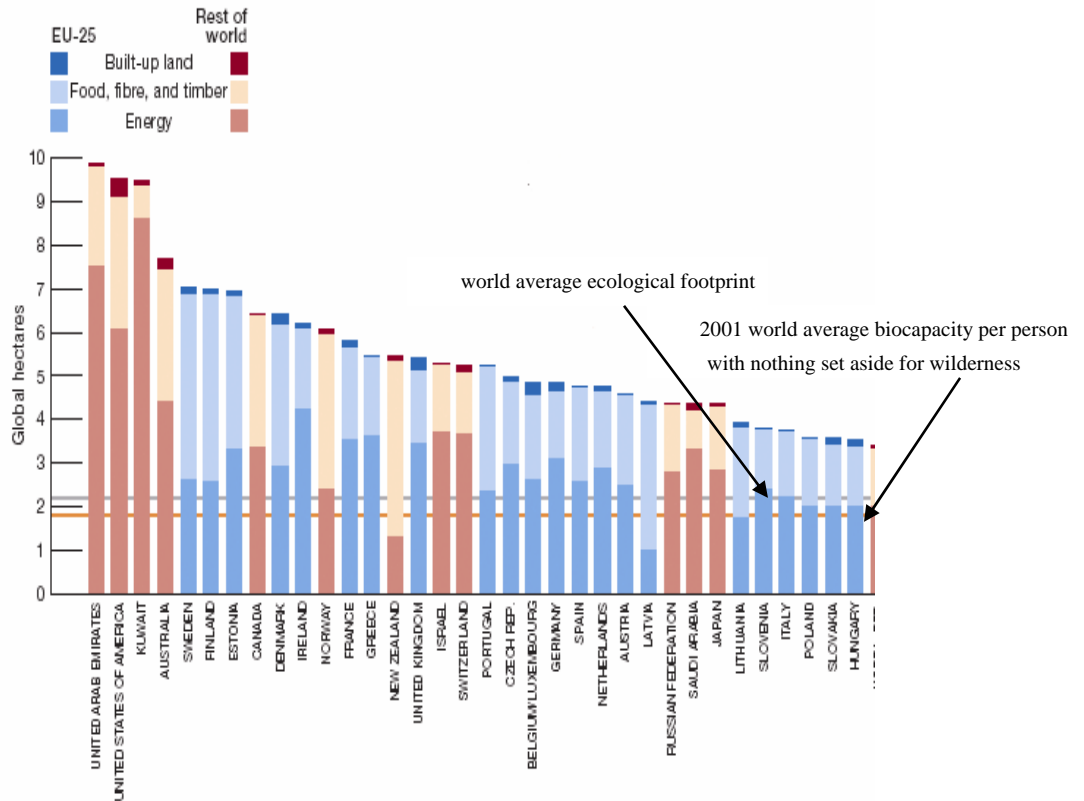


Figure 3: Hungary’s per capita footprint is the smallest in the EU, but still larger than the world available per capita biocapacity or world average per capita footprint (adapted from WWF et al., 2005)

## 2 Current energy situation in Hungary

The Hungarian economy, similarly to the neighboring post-communist regimes, has been undergoing significant structural changes. The country has engaged in privatization and liberalization of – among others – the energy sector during the 1990s and 2000s respectively (INFORSE-Europe, 2006,

Urge-Vorsatz et al., 2003). Key characteristics of the energy supply in Central Eastern Europe (CEE), thus in Hungary, are the low source diversity, high dependence on monolithic fuel mix, large share of nuclear energy, and particularly high level dependence on Russian energy imports. At the same time, the result of the Soviet energy policy is a well-developed district heating system and similarly developed gas-distribution system, which allows these countries to use one of the least polluting fossil fuel sources in a large share (almost half of the energy supply in Hungary is natural gas). Legacies from the socialist era are both positive and negative; however, the most problematic area is the wasteful energy production and use as a result of the socialist attitude (Molnar, 2004; Urge-Vorsatz et al., 2003). The change of regime had significant positive impacts on energy use in terms of environmental impacts and energy efficiency.

The country accessed the European Union in May 2004. EU membership has had further positive impacts on the energy sector (liberalization, prioritizing energy efficiency, RES targets, strategic thinking as few examples), and the obligation to meet the EU political agenda is straightforward. However, the effective and true implementation of the EU agenda poses significant financial, political and social challenges (Urge-Vorsatz et al., 2003).

Final energy intensity has changed from 0,438 koe/00 PPP of GDP in 1991 to 0,285 koe/00 PPP of GDP in 2004 (Elek, 2006). Figure 4 illustrates the development of the final energy demand of the main sectors in Hungary. Energy demand in the production sectors (industry and agriculture) has decreased substantially, mainly due to the economic collapse and closure of energy intensive heavy industry during the 1990s and the following restructuring and efficiency improvements, while the result of the growth in service sector and economic development resulted in growing energy demand in the domestic and tertiary sectors (Figure 4).

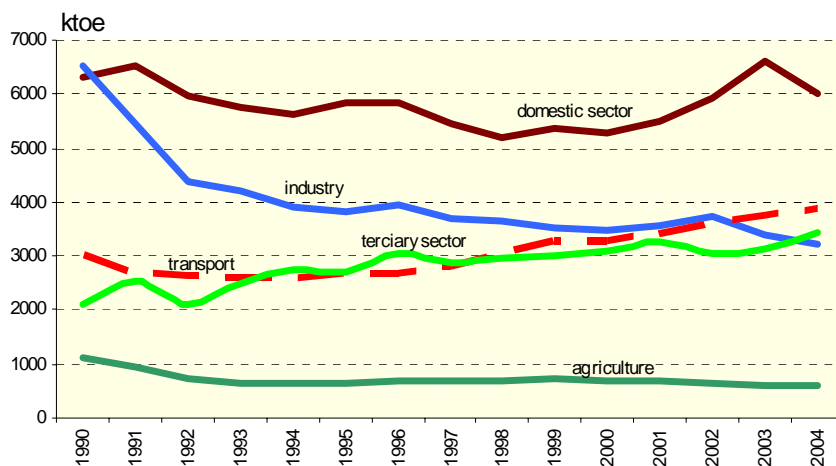


Figure 4: Final energy demand trend by sectors in Hungary (Elek, 2006)

At the same time, the fuel mix has moved in a more environmentally friendly direction: the share of coal decreased from 21 % to 14%; while the



share of gas increased from 31% to 46 %, and the share of renewables increased from 1.3 % to 3.4 % in 1990 and 2003, respectively (INFORSE-Europe, 2006). The share of renewables in electricity production is over 4% as of 2006, which means that the country has already surpassed the RES target of 3.6% for 2010 (INFORSE-Europe, 2006).

## 2.1 What is available for the basis of a sustainable energy system in Hungary

### 2.1.1 Energy source diversity

Figure 5 depicts the evolution of the primary energy supply in Hungary. It shows that the importance of oil and coal are slightly decreasing, while that of gas is decidedly increasing. The share of nuclear has been fairly constant since the beginning of the 1990s.

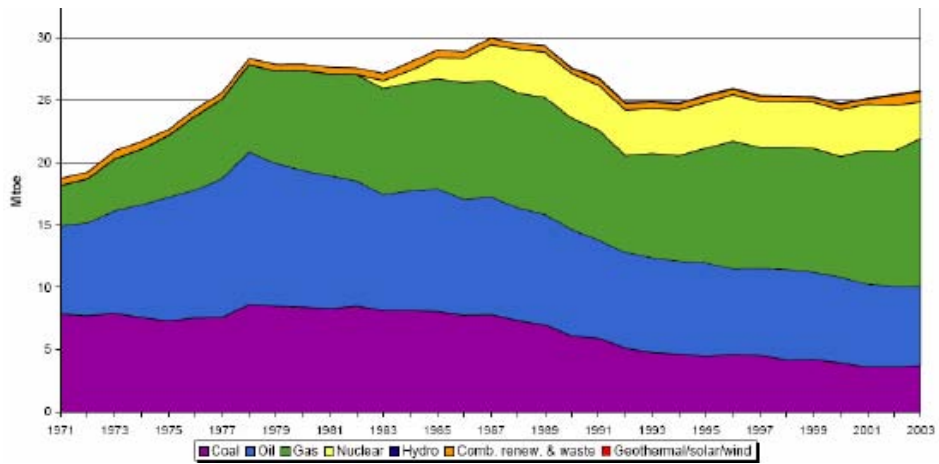


Figure 5: Evolution of Total Primary Energy Supply from 1971 to 2003 in Hungary (Amon, 2006)

The picture is somewhat different if the role of the different types of fuel in electricity production is examined (Figure 6). It can be seen that in this case, looking at 2003 data, production is dominated by gas and nuclear, closely followed by coal, with oil and renewable sources having a much smaller share, 5% and 0.9, respectively.

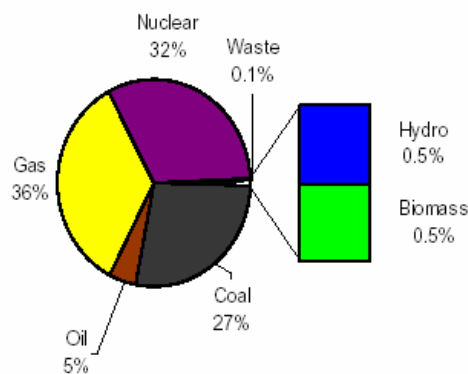


Figure 6: The share of different energy sources in electricity production in 2003 in Hungary (INFORSE-Europe, 2006 based on IEA data)

Nuclear energy is probably the most controversial issue of the Hungarian energy sector. It is the major source of electricity in the country, accounting for almost 40% of total national electricity production. Hungary is the 11th country with the highest share of nuclear in the electricity production according to the International Atomic Energy Agency (IAEA 2006).

### 2.1.2 *Energy security*

Energy dependence in Hungary is significant (71%), as only 19% of the gas and 26% of the oil is produced in the country. The situation is better in the case of coal, of which 85% is domestic. However, local production is declining, between 1990 and 2003 Hungary produced 40% less gas and 35% less coal. Thus, in order to satisfy growing needs (i.e. increasing consumption) as well as to reduce the dependence on imports, there is need for a more sustainable energy policy (GKM, 2005; INFORSE-Europe, 2006; Tihanyi et al., 2006).

### 2.1.3 *Renewable energy sources (RES)*

The integration of renewable energy sources into individual energy systems differs significantly from country to country, as can be seen in Figure 7. As it has already been noted, the Hungarian national target is 3.6% of electricity production from renewable sources by 2010, and it was already achieved in 2005, and is expected to reach 5.8% by the target date (INFORSE-Europe, 2006; Energia Klub, 2006). Estimations for the RES potential in the country range between 10-250% of the current energy consumption (Energia Klub, 2006). The type and share of renewables in electricity production in Hungary depend on a variety of factors, including the limited but still significant local potential, low grid flexibility, varying economic value, as well as social and political acceptance.

As pictured in Figure 7, Hungarian renewables application is particularly low. The share of renewables in electricity production has been increasing rapidly in the recent past, even doubling in some years. INFORSE-Europe (2006) provides a detailed overview of each source.

Half of the renewable energy comes from biomass. In fact, increase has been most considerable in this sector, in 2004 electricity production from biomass was 5 times that in 2003. Unfortunately, biomass based electricity production can be questioned and should not fully be accounted to the renewables share, because 90% of this electricity is produced in refurbished thermal plants with low efficiency and often relying on indigenous forests (Energia Klub, 2006). Energy plantations have started to be used more commonly only in 2005 (INFORSE-Europe, 2006).

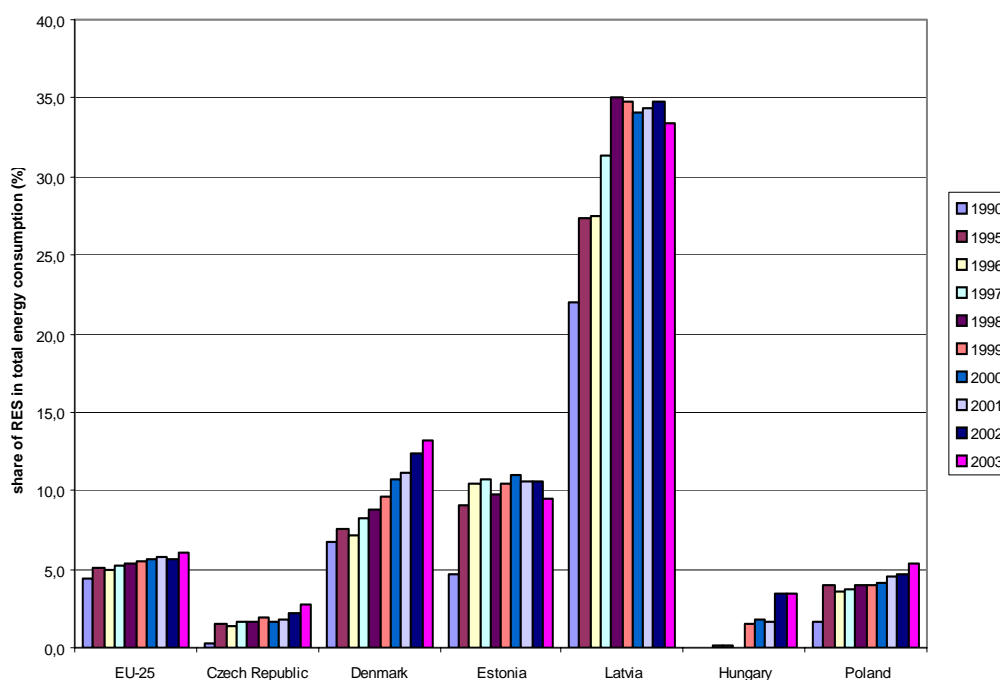


Figure 7: Development of share of renewables in total energy consumption in selected EU25 countries, including Hungary (Data source: EEA, 2006)

Another half of the renewable-electricity comes from hydropower. There is a 55 MW installed capacity currently, and further potential is estimated at low values, 10-15 MW for small hydro-plants.

Finally, wind-power played a insignificant role until recently. Permissions were issued up to 330 MW capacity, at which point the Hungarian Energy Office stopped authorization due to fear of grid fragility (Pataki, 2006).

#### 2.1.4 Public awareness

In the past, the Hungarian public was repeatedly found to be little interested in environmental problems compared to other countries. In the early 1990 surveys, such as the 1992 mammoth poll, the “Health of the Planet” survey, it was demonstrated that Hungarians cared the least about environmental problems among the 22 surveyed countries (Dunlap et al., 1992; Dunlap, 1994). The situation changed somewhat during the 1990s. In 1996, Hungarians underlined a number of environmental problems as serious (Meszaros, 1996), nevertheless, environmental problems without direct immediate impacts on the respondents were not considered to be grave.

News and information about the environment started to attract the attention of the public after 2000. In 2001, a Eurobarometer survey was conducted in the Accession Countries regarding their attitudes to the EU and issues related to the EU and the EU decision-making, such as the environment (EC 2002). Almost half of the New Member States’ respondents (48%) declared to be interested in environmental news. However, many other issues (youth, education, social issues, enlargement, etc.) were ranked to be more important. One year later, another Eurobarometer survey showed that environmental developments were the

top interest issues (61%) in Hungary; being ranked even higher than medicine, genetics or astronomy (Hungarian Gallup Organization 2003).

An ALTENER project in 2002, the 4CE (Consumer Choice and Carbon Consciousness for Electricity) survey analysis found that concern about the impacts of electricity is rather high in Hungary (around an average of 7-8 points on a scale of 10), above European average (Palmer, 2003; Kiss, 2005). In 2004, in the scope of the special Eurobarometer survey 32% of Hungarians chose climate change as one of 5 most important environmental problems that they were worried about from a list of 15 items (EC, 2005c). The ratio fits well into the NMS average, however staying way below the EU15 average (47%).

Energy saving awareness is significant in Hungary. The recent surveys (e.g. the special Eurobarometer EC, 2006; Valko, 2003) have shown that over 50-60% of the population pays particular attention to environmental/energy saving information on a product when shopping. Energy saving is among the top priorities that Hungarians actually do as environmentally friendly behavior (Lang, 2000). Valko (2003) found that respondents prioritize energy saving measures as means to reduce environmental impact.

#### 2.1.5 *Willingness to pay (WTP)*

In the 1992 Gallup research (Dunlap et al., 1992; Dunlap, 1994), people could also report on their personal concern and willingness to act in the form of, for instance, having avoided certain products in the light of environmental protection. 41% of the Hungarians had done so. This ratio rose to 51% in 1994; nevertheless, Hungarians were still in the lower third of the world in this respect.

Gallup and Gallup conducted a study in Hungary on the public opinion about prices of energy, consumption of energy, and about taxing environmental damages and energy consumption (Gallup and Gallup, 2004). According to the survey, two thirds of the population support that the state should tax more those activities that exert a larger pressure on the environment. At the same time, 7 out of 10 oppose to pay more tax, even if the income would be spent on improving the environment. This attitude definitely makes it hard for the policy-maker to take harsh actions. Similar results were arrived at recently (EC, 2006), where 40% of those surveyed supported increasing tax incentive in order to increase energy efficiency. This option was the most favored among policy measures that national governments should engage in (even for more information “only” 36% voted). However, 66% would not be prepared to pay more for electricity produced from renewables, and nobody would be willing to pay more than 10% above current bills (EC, 2006). As shown in Figure 8, Hungarians are among the least willing-to-pay nations, but still score better than most of other New Member States, i.e. countries with similar historic, economic, sociological background. These findings reflect the results from 2003, when Valko found 40% of the survey participants to be sure to pay for environmentally friendly products and 30% unsure, i.e. not directly negating. He considered this level to be satisfactory (Valko 2003).

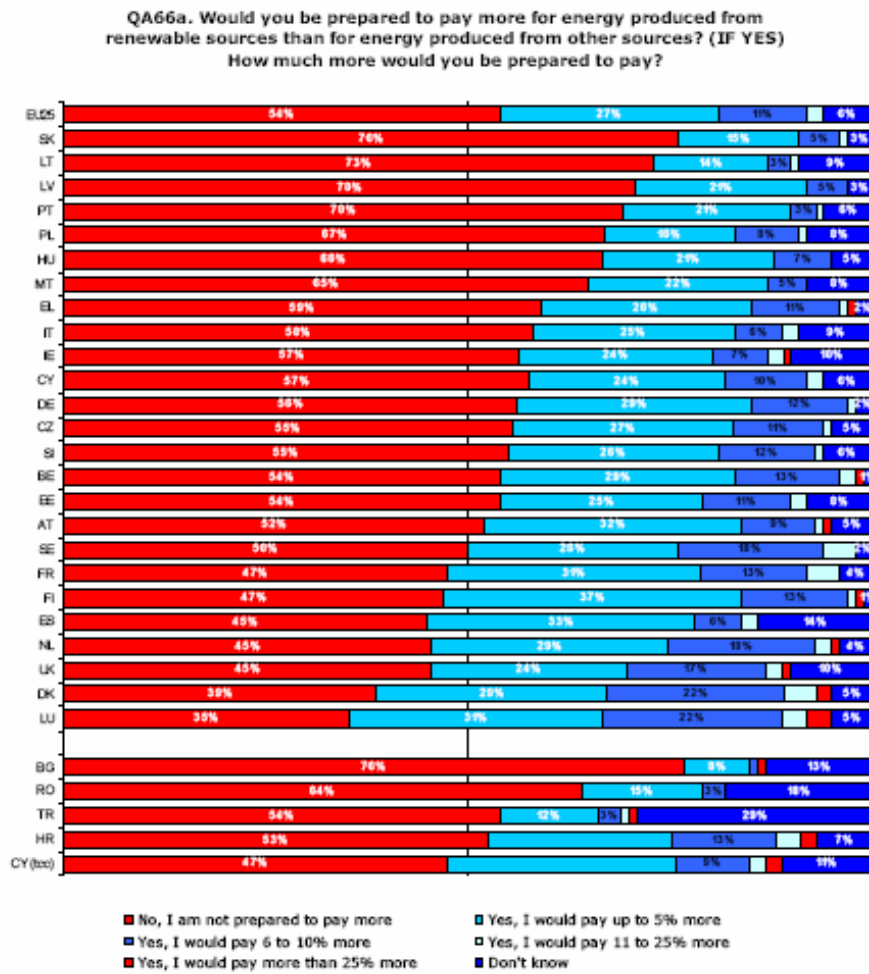


Figure 8: Willingness to pay (WTP) for electricity produced from renewables (EC, 2006)

In another survey; however, 85% of the respondents would not mind paying maximum 5% more for electricity if it was produced (at least partially) from wind-power (Callis Energetika Rt., 2006).

These data indicate that the Hungarian population has developed much in the sense of being sensitive to environmental problems. People are willing to act themselves and save energy as well as support the increasing of RES in the country. To some extent, and more so than countries in a similar position, they support higher taxes/prices even if it affects their own finances, a level can that can be regarded as reasonable. Thus, these findings call for more support for the public to increase their sustainable energy use, in the form of financial incentives, loans, rebates, besides the generally quoted awareness raising and price adjustment practices.

## 2.2 Policy framework and support schemes

The most recent strategic energy document is the 1993 Energy Policy Concept (Resolution 21/1993 (IV.9) OGY). The Energy Policy Concept to some extent in fact can be considered as a modern energy strategy regarding its targets and focus. Nevertheless, it does not fully correspond with current

priorities (Hatvani, 2006), and it is definitely out of date (building on a earlier energy, economic, social, political situation of Hungary), as well as somewhat one-sided because of its emphasis on supply-side interventions (Energia Klub, 2006). Among the targets, the Energy Policy Concept already identified the objective of increasing the share of RES to 5-6% of primary energy (IEA, 2003). At the moment, the Hungarian Government is in the process of preparing a long-term (2006-2030) energy strategy (INFORSE-Europe, 2006; Hatvani, 2006; Tihanyi et al., 2006).

Currently, energy policy in Hungary is determined by global, EU and Hungarian policies and guidelines. At the global level, the most important agreement from the point of view of energy policy is the Kyoto Protocol. Satisfying the requirements of the Protocol is embedded into EU and Hungarian policies and guidelines, so we are taking a summary look at them mentioning only those that are relevant to the discussion in the present paper.

The EU adopted the Green Paper on Energy Efficiency in 2005, which aims at reducing costs in the energy sector and promoting energy efficiency. In line with the Green Paper – Towards a European Strategy of Energy Supply (2000), it observes that increasing demand for energy cannot solely be met by renewable energy sources but have to be supplemented with measures for high efficiency in production and use. The Green Paper on Energy Efficiency sets the target of reducing energy use by 20% solely through efficiency measures. To comply with the guidelines and targets laid down in these documents, member states need to draw up national energy efficiency strategies, inform households, improve the energy efficiency of buildings, adjust taxes on energy so that they reflect real pollution levels, and introduce appropriate fiscal measures. (Tihanyi et al., 2006)

The EU and member states financially support the achievement of the above-mentioned aims from five basic sources, through:

- the EU community programmes such as the research framework programmes, the Intelligent Energy for Europe programme, etc.;
- the applications and tenders relating to the Hungarian National Development Plan and the Cohesion Fund;
- Hungarian national funding;
- national financial support mechanisms such as feed-in tariffs, purchase obligations, guaranteed prices, etc.; and
- other sources, for example bank loans, International Financial Institutions, initiating and encouraging private sources. (EC, 2005a; Tihanyi et al., 2006)

Although the aims and objectives in terms of more sustainable energy production and use are clearly stated in various policy documents, the amount of funding available, for example for renewable energy sources, does not necessarily reflect them.

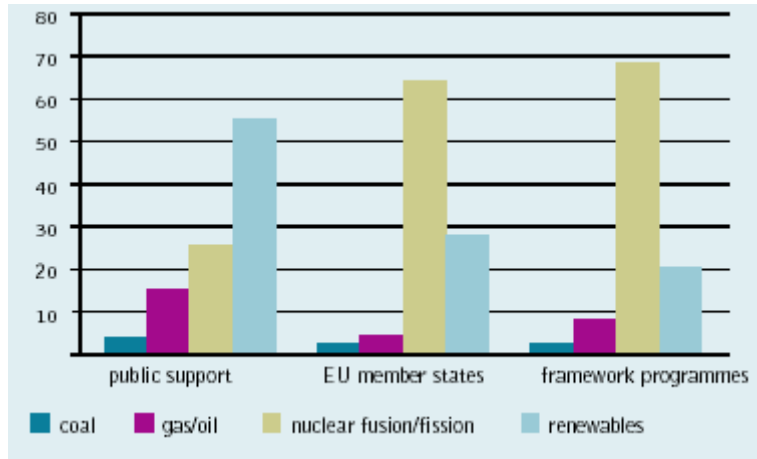


Figure 9: Support for R&D budgets for energy technologies vs. actual allocations (%) (Eurobarometer and European Commission Framework Programme, both quoted in Greenpeace, 2005)

Greenpeace (2005) collected data on the distribution of EU research and development funding spent on the different energy sources. Based on data from Eurobarometer and the European Commission, they found that although the public would support research on renewables, most of the funds are spent on nuclear energy research (Figure 9). This seems to hold for the 7<sup>th</sup> Framework Programme as well (Figure 10).

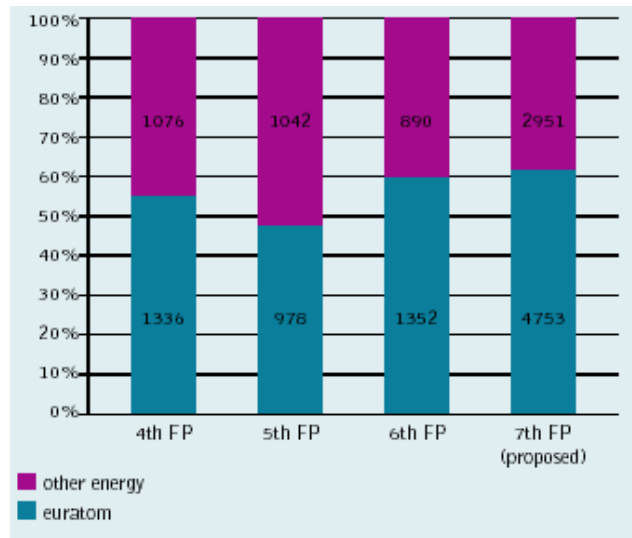


Figure 10: Comparison of energy and nuclear research and development budgets (million EUR) (Cordis and European Commission, both quoted in Greenpeace, 2005)

The same can be said for the European Investment Bank (EIB) that has a larger lending portfolio than the World Bank. Based on data from the Bank and Bankwatch Network, only 5% of its lending was spent on renewables – the same amount as on coal, while most (61%) went to gas and electricity networks (Greenpeace, 2005).

In Hungary, compared to larger and economically better performing countries, only a very limited amount of resources are available for research and development in general. Based on 2005 data from the DG for Research, the average amount of financial resources spent on research in the EU25 is 1.93% of the GDP for the government, and 1.23% for business enterprises. The same numbers for Hungary are 0.95% and 0.35%, respectively. (Tihanyi et al., 2006)

At the same time, there are several important sustainable energy production and consumption support mechanisms in Hungary that need to be mentioned. First of all, the Electricity Act (VET 2001 CX) introduced a feed-in tariff system for renewable electricity from January 2003 (INFORSE-Europe, 2006). Secondly, the government has been operating a National Energy Efficiency Programme since 2000 introduced by the Governmental Decree of 1107/1999 (X.8). This sets the target of increasing the share of renewables to 5-6% of the total energy supply by 2010. The National Energy Efficiency Programme had support programmes in eight different areas, offering part-financing for households, local authorities, homesteads, SMEs, etc. Table 1 shows that the funding available in the frame of these programmes is less than there would be demand for. Furthermore, there is an increasing number of households as well as organisations interested in increasing the energy efficiency of their building and utilising renewable sources for energy generation (Fodor et al., 2005).

Year	Programme	Planned funding million HUF	No. of applications	Claimed funding million HUF
2000	households	150	289	150
	all programmes	910	638	910
2001	households	700	3751	1133
	all programmes	3000	4337	3490
2002	households	2900	7432	2308
	all programmes	4000	7678	3054
2003	households	1213	4523	1440
	all programmes	3240	4785	2951
2004	households	850	4311	1441
	all programmes	2550	4601	2515
2005	-	-	-	
2006	households	183	7500	no information is available yet*

Table 1: Funding for energy efficiency programmes in Hungary (adapted from Fodor et al, 2005, based on data from the Hungarian Ministry of Economics and Transport)

Unfortunately, the National Energy Efficiency Programme was stopped indefinitely in 2005 due to lack of resources (Tihanyi et al., 2006; Fodor et al., 2005). In 2006, it was re-opened for households for a very short period

\* The Ministry originally planned to fund 500 (!) households.



of time (ten days!), during which an overwhelming number of applications were handed in as indicated in Table 1, supporting our claim above that households would indeed be ready to change to renewable energy sources and more energy efficient solutions should the supporting funding and infrastructure be available.

Although the programme was discontinued, a different mechanism for improving the energy efficiency of block houses was set up and is still rather popular and successful since 2000 (Tihanyi et al., 2006).

Nevertheless, as the conversion to renewable electricity sources requires long-term thinking and investment, the temporary abandonment of financial support results in high levels of uncertainty and low levels of commitment especially on the part of households and organisations lacking capital for investment (Tihanyi et al., 2006).

### 2.3 Energy subsidies

The European Environmental Agency (2004) states that “There is some evidence that, in historical terms, renewable energy subsidies in the EU15 are relatively low in comparison with other forms of energy during periods of fuel transition and technology development.” (pg. 5.)

There is no harmonised reporting framework for energy subsidies, thus it is difficult to know exactly how much and what form of funding is available for the various energy generations and efficiency methods (Irrek, 2002; OECD, 2002; EEA, 2004). The 2004 EEA report on subsidies, nevertheless, claims that “At current levels of political and financial support, the EU 15 renewable energy targets for 2010 will not be met.” (pg. 6.) This is even though renewable energy sources offer reduced environmental impact and increased energy independence or security, all of which are the proclaimed objectives of the EU.

#### 2.3.1 *Negative or environmentally harmful subsidies in Hungary*

Several EU-level reports and studies acknowledge that there would be need to create a harmonised reporting system for all energy subsidies – positive and negative – at the EU, national and sectoral levels (OECD, 2002; EEA, 2004; Greenpeace, 2005). At the moment; however, no such system exists, which makes data collection and comparison between countries and, indeed, sub-sectors (e.g. fossil fuel and renewables) extremely difficult if not impossible.

To further complicate matters, there is no agreed definition for subsidies (Irrek, 2002; EEA, 2004). As Irrek (2002) claims, it is possible to apply a narrow (i.e. direct support from the government that can be identified in the national accounts) or a broad (i.e. any measures that result in altered prices of preferential treatment) understanding. The study conducted in Hungary (Kiss, 2006) adopted the latter definition, and identified the following four types of environmentally-harmful subsidies in the country:

- direct and indirect budgetary subsidies;
- under-valuation of natural resources;
- failure to impose external costs; and
- harmful infrastructural development funded from public funds.

Specific subsidies given to the energy sector, relating more specifically to the extraction of fossil fuels:

- royalties that were not or were only partially collected from fossil fuel extraction companies,
- indirect support for the opening of new mines, and funding recultivation from public funds after closure;
- failure to impose external costs; and
- support based on import prices, applying the more favourable import price.

Apart from subsidising extraction, the Hungarian state also provides support for electricity generation and distribution (Kiss, 2006). These are the following:

- electricity prices in Hungary, in comparison to EU15 countries, are relatively high, increasing the profit of the companies;
- people employed in the electricity generation and distribution sector are allowed to purchase electricity (20 000 kWh/person/year) at a substantially reduced price that is included in their remuneration package and thus reducing the wage-related expenditure of electricity companies and associated taxes and contributions payable to the state; and
- external costs not imposed.

### **3 Scenarios and projections for the future**

Based on a study conducted for the Ministry of Economy and Transport (GKM) in Hungary as a background for the preparation of the new energy policy and strategy, demand for energy is projected to increase in the next couple of decades. The increase, based on preliminary data, is calculated to be between 0.4 and 1% for primary energy, and between 1 and 3% for electricity (GKM, 2005). As we argued earlier, growth in GDP is decoupled from growth in CO<sub>2</sub> emissions for the time being (Archibald et al., 2004), partially due to the restructuring of the industry. However, CO<sub>2</sub> emissions are projected to start rising again (EEA, 2005).

There is still a huge potential for energy efficiency improvement in Hungary, one of the largest (30%) for the household sector (Energia Klub, 2006; Nilsson, 2006; Figure 11). With this, and the European Union target of 20% energy saving potential in mind it should be possible to substantially increase the amount of energy saved, or in other words Hungary has a significant “negajoule” potential (Energia Klub, 2006).

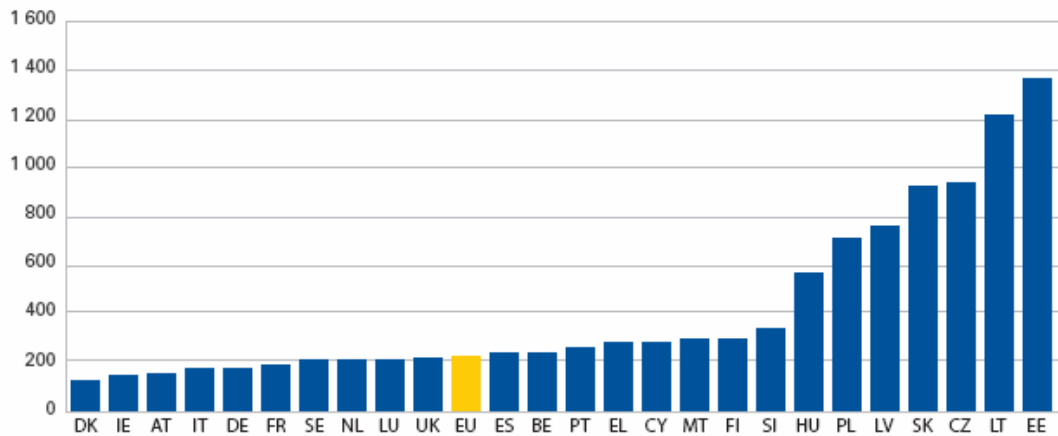


Figure 11: Energy intensity of EU Member States in 2003; toe/million EUR of GDP at 1995 market prices (EC 2005).

The estimated potential for renewable energy sources varies to a great extent as can be seen from Figure 12. Based on the high estimates, it seems possible to satisfy more than twice the current Hungarian energy demand using solely renewable energy sources. As today only a very small percent of the low estimate is utilised, in their scenario for a sustainable energy future for Hungary, the Energia Klub (2006) calculated with a modest one fifth of the total high estimate. Figure 13 illustrates the resulting CO<sub>2</sub> emission reductions, which would satisfy the requirements of the Kyoto Protocol as well as create considerable income for the country as emission values would continuously stay below the defined targets.

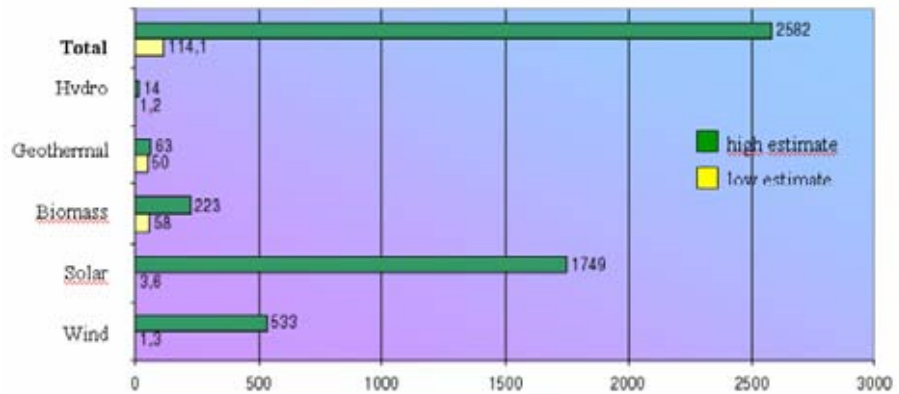


Figure 12: Estimates for renewable energy potential in Hungary, PJ/year (adapted from Energia Klub, 2006, based on data from the Ministry of Economy and Transport, the Ministry of Environment and Water and various studies conducted at Hungarian universities)

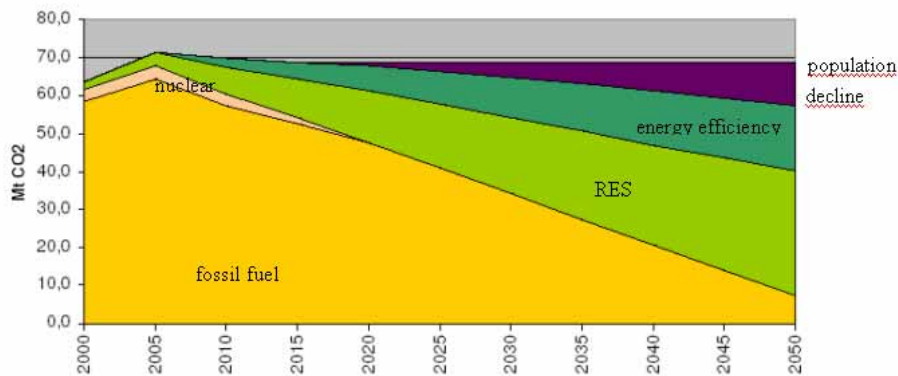


Figure 13: Components of CO<sub>2</sub> emission reductions in Hungary in the case of a sustainable energy future scenario (adapted from Energia Klub, 2006)

The sustainable energy future scenario is built on the assumptions that

- compared to the base year of 2005 energy efficiency and energy saving measures result in a 30% reduction in per capita energy use;
- nuclear energy is not used anymore after the useful lifetime of the current blocks is completed; and
- the utilisation of renewable energy sources will be nine times more of their current use – an amount that is still about one fifth of the high estimate in Figure 12.

Obviously, at the moment this is merely one of the options and strategies suggested. As it has been stated several times, the energy and climate change strategy of Hungary are currently being debated (Tihanyi et al., 2006; Energia Klub, 2006; <http://www.gkm.gov.hu>)

At the same time, in order to be able to meet existing requirements related to renewable energy utilisation and support mechanisms, Hungary will need to take concrete steps soon. The EC (2005a) found that renewable energy support policies in Hungary are not coordinated sufficiently and there is a varying degree of political support that makes coordinated action and long-term planning, on part of investors, producers and consumers very difficult. Furthermore, the implementation of the guarantee of origin process required by Article 5 of Directive 2011/77/EC to move towards more transparency is only at the very initial stage in the country.

### 3.1.1 Case studies that point toward a more sustainable future

In this section, it is our intention to show that in spite of not particularly supportive policy and financing conditions, a growing number of voluntary and consumer-initiated more sustainable energy use and production oriented case studies exists. Many of these are organised and coordinated by NGOs that focus on different aspects of sustainable energy consumption and production, starting from

1. awareness raising, advice on energy efficiency at home and at work as well as teaching people how to build their own solar panels and wind turbines;

2. informing and influencing policy making; to
3. creating and maintaining demonstration sustainable energy use and production examples.

Selected examples for each of these categories include the following:

1.
  - Operation of an energy advisory network, the Green Energy Network (ZEH) established by a number of environmental NGOs, the members of the network provide free advice on renewable energy and energy efficiency to households,<sup>1</sup>
  - NGOs organising workshops for people so that they can build their own solar panels and wind turbines,
  - NGOs motivating and taking part in the creation of the Energy Efficient Local Authorities Network,
  - Creating an NGO, the Carbonarium Association<sup>2</sup>, the members of which keep track of their own CO<sub>2</sub> emissions, compare them with one another, implement mitigation measures, and pay the membership fee based on their calculated CO<sub>2</sub> emissions.
2.
  - An interesting example of this kind of activity is the Climate Change Campaign of Friends of the Earth Hungary that encourages individuals of all ages to take their own climate change “vows”, collect these and forward them to policy makers both in Hungary and at the global level. They do this in order to educate people, on the one hand, and convince policy makers on the other to take more action (e.g. provide more support for public transport and household level renewable electricity generation) because people are ready to change.<sup>3</sup>
3.
  - Operating training and eco-tourism facilities that are heated and lit solely by renewable energy sources. A particularly good example for this is the Gömörszőlős sustainable village initiative in Northern Hungary where the NGO that developed and manages the project also involved the local people in the construction phase so that they learn that sustainable energy is available for everyone.<sup>4</sup>

<sup>1</sup> More information is available at <http://www.energiaklub.hu/en/?PHPSESSID=dd6209cfe47575d268a9119765fc8edd>

<sup>2</sup> More information is available at <http://www.carbonarium.com/>

<sup>3</sup> More information is available at [http://www.mtvsh.hu/programok\\_list.php?which=12&PHPSESSID=d2a2b4749635e67bdf285dd82a050956](http://www.mtvsh.hu/programok_list.php?which=12&PHPSESSID=d2a2b4749635e67bdf285dd82a050956)

<sup>4</sup> More information is available at <http://www.ecolinst.hu/ecolinst/html/index2.html>

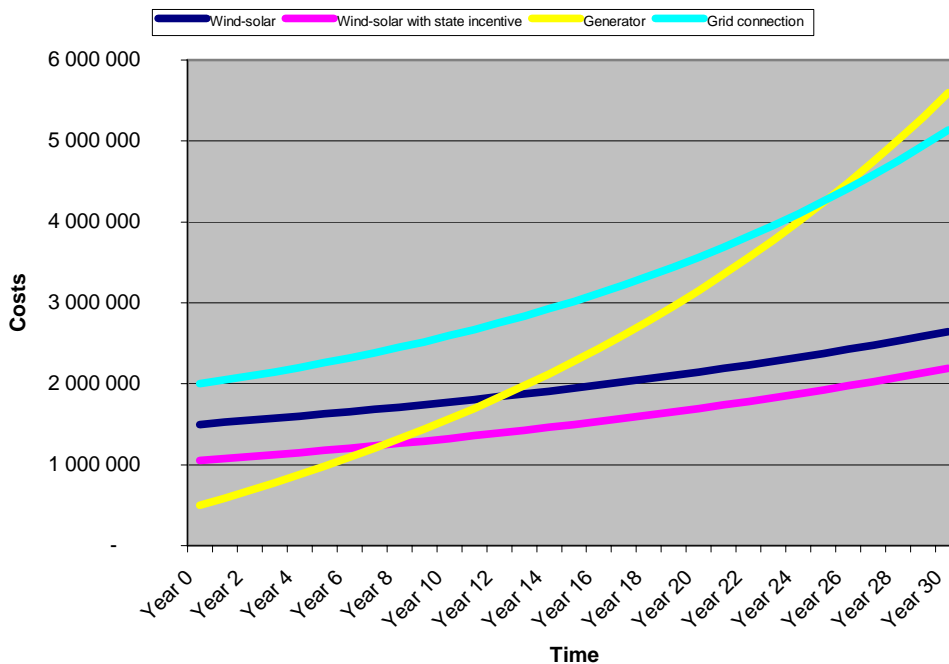


Figure 14: Payback time of the different options calculating with inflation and energy price increase (costs are in HUF) (Halmay, 2005)

Finally, several individual households decide to construct their own independent power system, if they are lucky with state incentive through taking part in the National Energy Efficiency Programme that was described above, or relying on their own funds. An individual project providing an example for how people can reduce the payback time of a renewable energy based independent power system is described by Richard Halmay's master's project (2005). He bought a small farm in the Great Plain region of Hungary that had no electricity supply. As the farm is situated some distance away from the nearest village, he was not sure that connecting to the grid would be the best solution, so he examined three potential options, which were the following: connection to the grid, operating a fossil fuel powered generator and constructing a wind and solar power based individual system. His calculations show (Figure 14) that although the individual RES based system requires more investment than the fossil fuel powered generator, in the long run, with funding from the National Energy Efficiency Programme after 8 years, it becomes the most competitive option economically as well.

#### 4 Conclusion and considerations for future research

It is now accepted in the scientific community that in order to reach sustainable development, or using the vocabulary of ecological footprinting, reduce humanity's overshoot, consumption and production also need to become more sustainable. Human impact on the environment is determined by the size of the population, the amount of resources this population consumes and the intensity with which the resources are consumed (WWF et al., 2006). The ways in which energy is produced and consumed play an important part in determining both the amount of resources consumed and

the intensity of consumption. Thus, it clearly has a very important role to play in sustainable consumption and production (SCP) research. Indeed, it would be of great importance to encourage more discussion between energy and SCP experts to arrive at a better understanding of the issues and engage in a more successful dialogue with policy makers.

The paper addressed quite a large number of issues, and is still far from providing an all-encompassing picture of the Hungarian energy scene, which, of course, is integrated into regional and global systems. On the basis of our discussion, the following issues seem to be the most pressing or need further investigation.

1. Much more detailed studies are needed to uncover and map all types of support available for the different forms of energy in order to analyse whether the various financial support mechanisms indeed encourage sustainable consumption and production. This outcome is in agreement with the EU's Sustainable Development Strategy (Council of the EU, 2006) that sets the objective that "By 2008, the Commission should put forward a roadmap for the reform, sector by sector, of subsidies that have considerable negative effects on the environment and incompatible with sustainable development, with a view to gradually eliminating them." (pg. 24.) This should be supplemented with investigation at the national level.
2. The above is of vital importance as data and trends seem to suggest that not enough financial and political support is available, so neither can renewable energy capacity utilised to its best potential nor can the willingness and readiness of the population as expressed, for example, in the number of grant applications handed in, be harnessed.
3. From the point of view of effective CO<sub>2</sub> emission reductions, on the basis of the paper, and the literature (Gerlagh and van der Zwaan, 2006; Nilsson, 2006), an integrated and at the same time diversified approach appears to be most effective. This means that a debate (often experienced recently) on whether to finance energy efficiency or renewable electricity development would be more urging does not seem neither appropriate nor necessary, as both of them are needed to achieve the CO<sub>2</sub> emission reduction outlined in the different policy documents and agreements. This approach, however, should be implemented at the regional and local levels with consideration to their characteristics and capacity from the point of view of energy consumption and production (Figure 15).

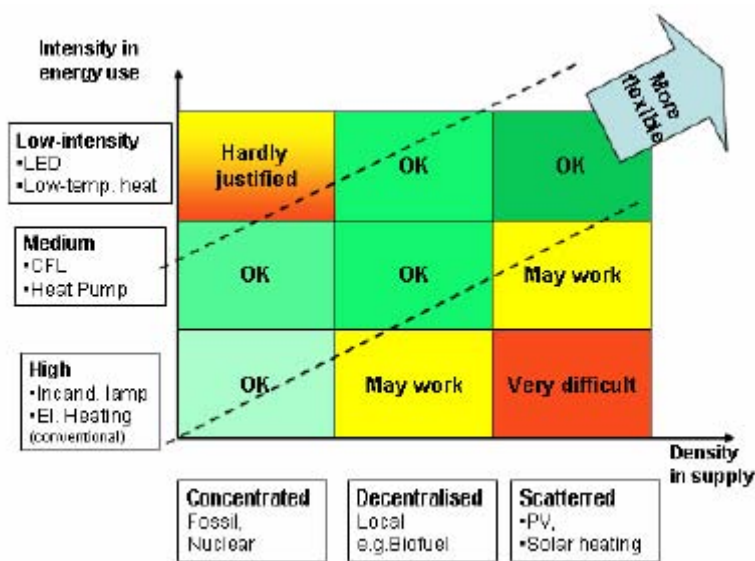


Figure 15: System combinations of energy intensity in use and energy density in supply – how energy efficiency and RES come together to an integrated sustainable energy system (Nilsson, 2006)

4. At the same time, as the surveys conducted about the level of awareness on environmental and energy related issues indicate, there is a great need for the education of all segments of the population, including consumers, producers as well as decision makers. In order to achieve more sustainable energy consumption and production, people need to understand the link between environmental problems and their energy related practices. Thus, again, cooperation between energy and SCP experts would be essential.
5. There is need for more research on the environmental impacts of the various energy technologies throughout their lifecycle with reference to local circumstances as well as future potential for use. This is necessary in order to overcome the great uncertainty about the impact of different technologies (Figure 16) and their potential to satisfy demand in a sustainable way.



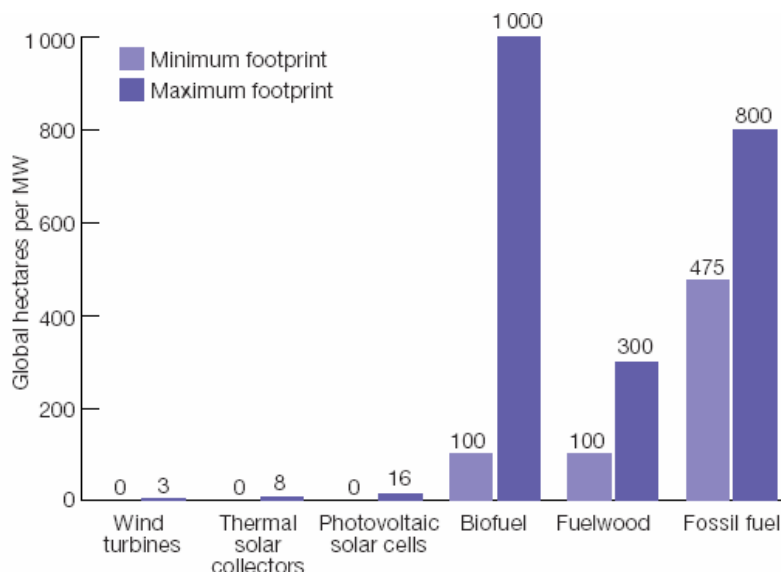


Figure 16: Comparing the footprints of different energy technologies (WWF, 2004)

## References

- Abrahamse, W., Steg, L., Vlek, C., and Rothengatter, T. (2005). *A review of intervention studies aimed at household energy conservation*. *Journal of Environmental Psychology* 25: 273-291.
- Amon, A. (2006). *Magyarországi Fenntartható Energiastratégia [Hungarian Sustainable Energy Strategy]*. Presentation at the Conference “A klímapolitika és a klímaváltozás főbb kérdései” [major Issues in Climate Policy and Climate Change] at the Hungarian Academy of Sciences, Budapest, Hungary on 14 September 2006.
- Archibald, S. O., Banu, L. E. and Bochinarz, Z. (2004) *Market Liberalisation and Sustainability in Transition: Turning Points and Trends in Central and Eastern Europe*. *Environmental Politics* 13(1): 266-289.
- Callis Energetika Rt. (2006). *Public Opinion Poll on Energy*. Available at URL: <http://www.callis.hu/callis/?page=15&lang=hu&msg=8&PHPSESSID=d34249c6068c0220dc13b66113dccb92> [consulted on 26 October 2006].
- Council of the European Union (2006). *Renewed EU Sustainable Development Strategy*. Brussels, Belgium.
- Dunlap, R. E. (1994). *International Attitudes towards Environment and Development*. In *Green Globe Yearbook of International Co-operation on Environment and Development*, eds. H. E. Bergesen and G. Parmann. Oxford University Press, Oxford, UK.
- Dunlap, R. E., Gallup, G. H., Gallup, A. M. (1992). *The Health of the Planet Survey. A Preliminary Report on Attitudes toward the Environment and Economic Growth Measured by Surveys of Citizens in 22 Nations to Date*. Princeton, The George H. Gallup International Institute, New Jersey, USA.
- European Commission (EC). (2005a). *The support of electricity from renewable energy sources*, Brussels, Belgium.
- European Commission (EC). (2006). *Attitudes towards Energy. A Special Eurobarometer*. European Commission, Brussels, Belgium.

European Commission, DG Press and Communication (EC). (2002). Candidate Countries Eurobarometer 2001. European Commission, DG Press and Communication, Brussels, Belgium.

European Commission, DG for Research EUROBAROMETER (EC). (2002). Energy: Issues, Options and Technologies Science and Society EUR 20624

European Commission, Directorate-General for Energy and Transport (EC). (2005b). Green Paper on Energy Efficiency – Doing More with Less. COM(2005) 265.

European Commission, DG Press and Communication (EC). (2005c). The Attitudes of European Citizens towards Environment. A Special Eurobarometer. European Commission, DG Environment, Brussels, Belgium.

European Environmental Agency (EEA). (2004) Energy subsidies in the European Union: A brief overview. Copenhagen, Denmark

European Environment Agency (EEA). (2005). *Analysis of greenhouse gas emission trends and projections in Europe 2004*, Technical report. Luxembourg: Office for Official Publications of the European Communities

European Environmental Agency (EEA). (2006). EN29 Renewable Energy. Copenhagen, Denmark.

Elek, L. (2006). Energiahatékonysági indikátorok Magyarországon [Energy efficiency indicators in Hungary]. Presentation at the Energy Efficiency Indicators in the EU and Hungary, organized by the Hungarian Energy Center, in Budapest, Hungary, on 5 October 2006.

Energia Klub. (2006). Magyarországi Fenntartható Energiastratégia [Hungarian Sustainable Energy Strategy]. Energia Klub, Budapest, Hungary.

The European Wind Energy Association (EWEA). (2005). News Release. Available at URL: [http://www.ewea.org/fileadmin/ewea\\_documents/documents/press\\_releases/2005/Statistics.pdf](http://www.ewea.org/fileadmin/ewea_documents/documents/press_releases/2005/Statistics.pdf)

The European Wind Energy Association (EWEA). (2006). News Release. Available at URL: [http://www.ewea.org/fileadmin/ewea\\_documents/documents/press\\_releases/2006/060201\\_Statistics\\_2005.pdf](http://www.ewea.org/fileadmin/ewea_documents/documents/press_releases/2006/060201_Statistics_2005.pdf)

Fodor, B.; Kiss, K.; Szabó, S. and Szabó Z. (2005) Támogatások, ökológiai célú pénzügyi ösztönzők. Európai Műhelytanulmányok, a Miniszterelnöki Hivatal és a Nemzeti Fejlesztési Hivatal Kiadványa

The Gallup Organization and the Hungarian Gallup Organization (Gallup and Gallup). 2004. Public opinion about the relationship between energy prices and energy consumption, environmental taxation of environmental damage and energy consumption, as well as on knowledge and support for Clean Air Action Group. Gallup, Budapest, Hungary.

Gazdasági és Közlekedési Minisztérium [Ministry of Economy and Transport] (GKM). (2005). Az új magyar energiapolitik tézisei a 2006-2030 évek közötti idpszakra, 3. fejezet: A hazai energiaigény prognózisai és az azokból levont következtetések. Budapest, Hungary

Gerlagh, R. and van der Zwaan, B. (2006). Options and Instruments for a Deep Cut in CO<sub>2</sub> Emissions: Carbon Dioxide Capture or Renewables, Taxes or Subsidies? *The Energy Journal*, Vol. 27. 3:25-48.

Greenpeace (2005) Invest in a Clean Energy Future! Greenpeace exposes the EU's dirty energy subsidies. Available from: <http://www.greenpeace.org/international/press/reports> (cited on 26 October, 2006)

Halmay, R. (2006) Sustainable Energy Solution for a Small Farm – Case Study of an Independent Power System. Master's Project, University of San Francisco, San Francisco, California.

Hatvani, Gy. (2006). A magyar energiapolitika [The Hungarian Energy Policy]. Presentation at the Energy Efficiency Indicators in the EU and Hungary, organized by the Hungarian Energy Center, in Budapest, Hungary, on 5 October 2006.

Hungarian Gallup Organization. (2003). Public Opinion in the Countries Applying for European Union Membership. CC-EB 2002.3 on Science and Technology. Eurobarometer, Brussels, Belgium.

International Atomic Energy Agency (IAEA). (2006). Power reactor Information System. Available at URL: <http://www.iaea.org/programmes/2a/>

International Energy Agency (IEA). (2003). Energy Efficiency Update. OECD/IEA, Paris, France

- International Network for Sustainable Energy – Europe (INFORSE-Europe). (2006). A Study of the Introduction of Renewable Energy in the EU. A report by INFORSE-Europe for the EU-Japan Centre for Industrial Cooperation. EU Japan Centre for Industrial Cooperation. Available at URL: [http://www.inforse.dk/publications\\_pro.php3?id=28](http://www.inforse.dk/publications_pro.php3?id=28)
- Irrek, W. (2002) Subsidy reform – moving towards sustainability. Wuppertal Institute for Climate, Environment, Energy.
- Kiss, B. (2005). Climate Change Literacy in Old Member States and New Member States of the EU. Master's Thesis, Department of Environmental Sciences and Policy, Central European University, Budapest.
- Kiss, K. (Eds.) (2006) Tiltandó támogatások. Környezetvédelmi szempontból káros támogatások a Magyar gazdaságban. L'Harmattan Kiadó in cooperation with Corvinus University, Budapest
- Lang, S. (2000). Greener with Accession? Comparative Report on Public Perceptions of the EU Accession Process and the Environment in Hungary, FYR Macedonia and Romania. Regional Environmental Center: Szentendre, Hungary.
- Meszáros, J. (1996). Attitudes about environmental protection and the state of environment. TARKI, Budapest, Hungary.
- Molnar, L. (2004). Energy efficiency issues in the energy and building sector of the Economies in Transition in the UNECE region. Presentation at the International Conference on Improving Energy Efficiency in Commercial Buildings "IEECB'04" in Frankfurt, Germany on 21-22 April 2004.
- Nilsson, H. (2006). *Financial Incentives for Dispersed Investment in Sustainable Energy*. Final Draft of Concept Paper. Available at Leonardo Energy at URL: <http://www.leonardo-energy.org/drupal/node/986>.
- OECD (2002) Sustainable Development. Defining and Measuring Environmentally-harmful Subsidies in the Energy Sector. SG/SD/RD(2002)4
- Palmer, J. (2003). Telephone survey analysis: A paper prepared as part of the ALTENER project "Consumer Choice and Carbon Consciousness for Electricity (4CE)". Environmental Change Institute, London, UK.
- Pataki, I. (2006). A magyar energia hivatal szerepe az energetikában - mit csinál a jó regulátor az energiaiparban [The role of the Hungarian Energy Office in Energy Issues – what is the responsibility of a „good” regulator]. Presentation at the Energy Efficiency Indicators in the EU and Hungary, organized by the Hungarian Energy Center, in Budapest, Hungary, on 5 October 2006.
- Shove, E. (1998). Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. *Energy Policy* 26(15): 1105-1112.
- Tihanyi, L.; Giber, J.; Imre, T.; Nagy, Z, and Szunyog, I. (2006) Az új Magyar energiapolitika tézisei a 2006-2030 évek közötti időszakra, 15. fejezet. Az energetikai kutatás-fejlesztés szerepe. GKI, prepared for GKM (Ministry of Economics and Transport)
- Urge-Vorsatz, D., Mez, L., Miladinova, G., Antypas, A., Bursik, M., Baniak, A., Jánossy, J., Beranek, J., Nezamoutinova, D., and Drucker, Gy. (2003). The impact of structural changes in the energy sector of CEE countries on the creation of a sustainable energy path. Final report for project No. iv/2002/07/03 for the European Parliament. Central European University, Budapest, Hungary.
- Valko, L. 2003. Fenntartható/környezetbarát fogyasztás és a Magyar lakosság környezeti tudata [Sustainable/environmentally Friendly Consumption and the Environmental Awareness of the Hungarian Population]. Aula Kiadó and Budapesti Közgazdaságtudományi és Államigazgatási Egyetem, Budapest, Hungary.
- WWF (2004) *The Living Planet Report*. WWF-World Wildlife Found for Nature, Gland, Switzerland.
- WWF, Global Footprint Network and NC-IUCN. (2005) Europe 2005, The Ecological Footprint. WWF European Policy Office, Brussels, Belgium
- World Wide Fund for Nature (WWF), Zoological Society of London (ZSL), and Global Footprint Network. (2006). Living Planet Report 2006. eds. Chris Hails, Jonathan Loh, Steven Goldfinger. WWF, Gland, Switzerland.

