Chapter 13
From Sustainable Production to Sustainable Consumption

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Abstract The objective of this chapter is to explain which secondary environmental consequences (often called rebound effects) life cycle assessment (LCA) and life cycle management (LCM) of products need to consider in addition to the conventional product LCA, and which roles different actors in society have in the context of environmentally sustainable consumption. The key issue is that any consumption decision affects the consumer's household resources of available income, time, and space (volume, area), what leads to additional or reduced overall consumption, within the limits of further consumption constraints and cross-category effects. Exactly how any additional resources are used by the consumer strongly affects the overall consumption. Moreover, this chapter considers the consumption on person, on national and global level, with some focus on sustainable lifestyles, and concludes with recommendations on next steps towards better measurement and management of the environmental secondary consequences of consumption.

Keywords Consumption constraints • Life cycle assessment • Life cycle management • Rebound effects • Secondary consequences of consumption • Sustainability • Sustainable production • Sustainable consumption

1 Introduction

Sustainable consumption has been defined already very early in explicit relation to the life cycle perspective: "*The use of services and related products which respond to basic needs and bring a better quality of life while minimizing the use of natural*

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resources and toxic materials as well as emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations." (Norwegian Ministry of the Environment 1994, adapted). Beyond the product perspective to life cycle management (LCM), this definition highlights the needs fulfilment, or utility, of the products. Indeed, but there are other aspects that differ when taking a consumption perspective on products: "*Sustainable consumption is often seen as a concept mirroring the production side. While sustainable production has a production and upstream perspective searching opportunities to alter production processes and related activities in a more sustainable direction, sustainable consumption is directed to how and why goods and services are demanded, used and consumed.*" (Thidell 2011). This indicates why there is a controversy about the "right" way to assess the environmental performance of products, which the authors try to explain in the following, before explaining the details:

Life cycle assessment (LCA) of products guided by ISO 14040 (2006a) and 14044 (2006b) is a well-established framework for analysing, improving and comparing the environmental performance of products. ISO LCA is also the core basis for life cycle management (LCM), while further standards that are based on ISO 14040 and 14044 support it. With the current framework ISO 14044:2006, the interim product and waste flows as well as the interventions with the environment are taken into account as the inputs and outputs of the analyzed system. The effects on other, not functionally connected products and infrastructures, are, however, not addressed in the framework and also not implied.[1] In other words, the current framework of LCA is taking a product perspective, not a consumption perspective.

This product perspective and ISO LCA itself has been criticized (e.g. by Girod et al. 2010) for lacking to capture the various secondary consequences of consumption decisions, including due to changes in the available income, time, and other household resources.[2]

In this chapter, instead of asking for changing product LCA, the authors follow a different approach, namely that of proposing differentiated life cycle modelling methods for the two fundamentally different perspectives: the product perspective and the consumption perspective, resulting in dedicated approaches for different actors and applications (Lundie et al. 2007; European Commission 2010; Wolf et al. 2012): different applications imply a different purpose and scope of supported decisions and hence require a differentiated guidance. The Product Environmental Footprint (PEF) guide (European Commission 2013), that largely builds on the product-decision support ("Situation A") guidance variant of the ILCD Handbook (European Commission 2010), is an example of such application-specific guidance.

The authors argue that the product perspective is a very useful logic for product developers: The decisions by the consumers beyond the use and end-of-life man-

[1] The system expansion to include functions within the system boundary of the analysed product serves exclusively to render two products of an only partly identical set of functions comparable.

[2] Such rebound effects and economy-wide consequences can also be environmentally positive, i.e., result in a negative environmental impacts, why we adopt here the more inclusive term "secondary consequences" of the ILCD Handbook, instead of "rebound effects" that implies a negative effect.

agement of the purchased product itself is essentially beyond the influence of the producer of the analyzed products. The authors derive that there is no requirement to integrate such consequences outside the analyzed product into its analysis. To provide data on the environmental performance of a product over its life cycle is the essential step for developing more sustainable products. It is also a core contribution, when looking at products from the consumption perspective. However, if the consumption of products is the viewpoint of the analysis or the evaluation of lifestyle concepts, additional components should be added to the analysis: This methodological extension to the consumption side and the secondary consequences that consumption decisions cause is the main scope of this chapter.

There is, however, another aspect where the consumption perspective goes beyond the product-perspective: expanding from the product's functional unit to the contribution to human needs fulfilment.[3] This aspect will at least briefly be addressed in this chapter.

This chapter hence aims at providing an overview of the secondary consequences of consumption and the products' contribution to the human's needs fulfilment. This draws on the works of Hofstetter et al. (2006), Weidema (2008), Girod et al. (2010) and others, and ends in an outlook of recommended next steps to further develop, differentiate, and deploy LCA as a tool that equally well supports efforts towards sustainable consumption as it already supports decisions on sustainable production and products.

Still, both perspectives "product" and "consumption" initially serve exclusively the concept of relative sustainability, i.e. of better efficiency. To expand the view to absolute sustainability, one needs to bring in further elements, e.g. breaking down the planetary boundaries (Rockström et al. 2009) to the individual citizen's environmental impact budgets. This next step is not part of this chapter.

2 Secondary Consequences of Consumption Decisions

2.1 Overview

This section provides an overview of the secondary consequences that purchase, use and end-of-life of a product can induce outside the actual product system itself. These consequences go beyond functional relationships with other products, i.e. beyond part-system and system-system relationships that are part of regular product LCA, and which are described in the ILCD Handbook, Chap. 7.2.2.

The following consumption-induced secondary consequences and aspects that modify them can be differentiated (compiled from Becker 1976; Eyerer and Wolf 2000; Hofstetter et al. 2006; Weidema 2008; Girod et al. 2010, with additions):

[3] The authors build here on the concept of human needs developed by Maslow (1954) and expanded by Max-Neef (1991) and others over the following decades.

- Changes in the available household resources income, time, and space, as well as further constraints to consumption, particularly food calories uptake capacity, drink intake capacity, skills and information availability, and access to products
- Use of the freed household resources (or restrictions in case of reduced household resources)
- Cross category effects
- Mental secondary consequences

The above listed secondary consequences cause additional or reduced consumption.

Beyond these, other secondary consequences occur on local, regional, national or international scales that are not addressed in this chapter.

In three additional sub-sections the authors look briefly into higher order consequences due to economic transactions, present a new measure of the environmental life cycle performance of products from consumption perspective and reflect on possible harm due to needs over-fulfilment.

2.2 Changes in Available Household Resources and Consumption Constraints

The following household resources have been considered for studies on sustainable consumption (compiled from Becker 1976; Eyerer and Wolf 2000; Hofstetter et al. 2006) Weidema 2008; Girod et al. 2010, with own additions and examples):

- Available income[4]
- Time
- Space (volume, area)

Moreover the following elements, which are better understood as constraints to consumption, are to be considered (Hofstetter et al. 2006):

- Food calories uptake capability
- Drink intake capability
- Skills and information
- Access to products and technologies

2.2.1 Available Income

Changes in available income – always a decrease – occur with any purchase decision, while decisions during use (e.g. more efficient use, shared use) and when selling a used product, the available income can increase compared to the default case. This additionally available income allows for additional consumption.

[4] *Income is the sum of all the wages, salaries, profits, interests payments, rents and other forms of earnings received… in a given period of time*. (Case et al. 2014)

2.2.2 Time

While each purchased product initially reduces the consumer's time budget, due to the purchase process, some products have relative time saving advantages compared to the average product and others enable to actually increase the available time budget of the consumer on a net basis: car navigation systems or apps with traffic avoidance, integrated washing and drying machines, crease-free shirts, faster internet connection, etc. all save time. This time is made available for additional consumption but also for other activities (e.g. economic activity to generate extra income, or resting, i.e. (near) non-consumption).

2.2.3 Space

Space (volume and area) to store or use goods is a physical limitation. Examples are the living area that limits the amount of furniture that can sensibly be put, storage space to keep clothes, parking space in cities that may relevantly limit the option to have a second car, the consumer's skin surface that can only so many times per day be treated with crèmes or lotions, or storage space on storage media in a computer.

However, many products offer the possibility to increase or better use the available space, either as a secondary product property (e.g. a Smart car may be an option as second car even in city centres with severe parking space limits), or as a primary property (e.g. vacuum bags for storing bed clothes, shelves, external hard disks, etc.). While each Euro can only be spent once, and the number of things one can do at the same time is limited, spatial limitations are arguably less absolute, while at least an asymptotic saturation of the available space can be observed in reality.

2.2.4 Food Calories, Drink Intake

The amount of calories that we can digest is also limited. The market growth potential of the food industry therefore lies in selling further processed food with higher value added as well as in convenience food in smaller packages at a higher per calorie price. Diet food is another key option to sell more food without surpassing the individual's overall calorie uptake limit. Eating more calories is formally one way to expand this limit, although again not limitless and with possibly harmful consequences (see Sect. 2.8). Still, certain limits exist in the volume that people can or at least want to eat.

Similar limitations exist for drinks, while our body is better able to put through water than carbohydrates, proteins, and fat.

2.2.5 Skills and Information

Skills and available information can be an important limitation to consumption, but we argue that they are of a different nature than the previously listed ones: with the purchase of a good or service the consumer is not negatively affecting his or her

skills and available information, in contrast to the situation for money, time, and space. If anything, they would be increased. Skills and available information are however a constraint to consumption of those goods that require a higher level of skills or information.

Next to absolute limitations of personal aptitude, the necessary money and time needed to acquire the specific skills can be a relevant obstacle to consumption. Examples are leisure activities such as operating a small sailing boat, constructing the own furniture, or playing the piano. However, the idea of a knowledge based society and the growing offers of online courses for virtually everything and instructions and courses offered by do-it-yourself markets are however eroding the limitation of information.

At the same time, the process of learning the required skill may be a key part of the activity and the success to have mastered the skill can be an important contribution to the individual's needs fulfilment. Legend are however the households that have a piano with nobody in the family being able to play it.

2.2.6 Access to Products

Similarly, limitations to access products are an obstacle, but they are not affected by the consumption of individual other products, while the wider consumption pattern can strongly affect them, particularly if consumption thresholds need to be surpassed to make them economically viable: A good example of such limitations is the availability of car sharing outside the larger cities' centre. Such access restrictions are partly a matter of relative demand limitations – while in a hen-and-egg situation, where limited demand means that the necessary threshold is not achieved to make the product available – but partly also absolute, where a frequent public transport service would not be economically or even environmentally sensible for very remote places with virtually no population.

2.2.7 Interchange Ability of Household Resources

While these household resources and other constraints have their own budget, we note here that compensation across some of these is possible to a large extent, firstly time and money: a consumer can free additional time by hiring another person for cleaning or other household work, or by buying time-saving equipment. Similarly, space and money: the available space can be extended by using some of the available household income for renting a larger flat or extra storage. And we have given already the example of using time (and potentially money) to acquire new skills or information. Finally, investment of time can mean to take up extra economic activities to increase the available household income.

However, where money transactions are involved – such as in the example of contracting a cleaning service – the service provider received additional household

income, hence can consume more. We will come back to this characteristic of money being conserved, and what this implies for sustainable consumption.

2.3 Use of Freed Household Resources

2.3.1 Overview

Where the availability of any of the listed household resources is reduced by a consumption decision, other products that require the same resource(s) may be affected: most prominently, money can be spent only once. Reduced time availability can be compensated only in certain cases (e.g. doing two things in parallel – see chapter "Cross Category Effects"). Reduced space means space has to be freed by another product, while with the above-mentioned individual flexibility to expand the available space or accept a further cramping of the available space. Eating food calories means that less other food (with calories) will generally be eaten, with the above-mentioned, limited flexibility for compensation.

It is important to note that for consumption studies, the individual options how to react to reduced household flexibility will be of less interest, but the average situation and patterns of effects will be the focus of analysis. Individual flexibility however adds to the variance of the average situation and provides options for scenario definition on different systematic ways how to react to reduced household resources availability.

Inversely, increased availability of any of the household resources allows the consumer to use it for additional consumption: more available income can be spent e.g. on a further away holiday destination (as Eyerer and Wolf (2000) have exemplified), a larger TV set, or any other good or service.

It is relevant for quantifying the environmental impacts of the changed availability of household resources, which products are quantitatively affected by the changed consumption. Expanding on the proposal by Girod et al. (2010), we see four distinctions:

- More of the same product
- More of the same function or need fulfilment
- Marginal shift to better fulfil the less well fulfilled needs
- General increase of average consumption

This first variant of using the freed resource is – if the household resource is income – also termed direct rebound effect, substitution effect, or pure price effect (Greening et al. 2000). The direct rebound effect for energy-efficiency increase has first been postulated already by W.S. Jevons in context of increased coal efficiency (Jevons 1875), cited in Gillingham et al. 2013), and in the more recent discussion on energy-efficiency policies again by Khazzoom (1980). The last three variants are also called indirect rebound effect, income effect, or secondary effect (Greening et al. 2000).

2.3.2 More of the Same Product

"More of the same product" means that the consumer will e.g. drive more kilometres, if the new car is faster (saved time) or more energy efficient (saved income). Or he/she will eat two servings of the low calorie desert, etc.

2.3.3 More of the Same Function or Need Fulfilment

"More of the same function or need fulfilment" (originally termed "More of similar" by Girod et al. (2010)) means that e.g. saved time due to a faster car will be used to generally increase travelling, also with other transport means. In support of this effect, Schafer and Victor (2000) have compiled data from a survey that shows that the average time per day and person spent on travelling across a wide range of cultures worldwide and the entire scale of city/villages sizes and over several decades essentially does not differ and ranges between 50 and 90 min per day. While such average values have to be interpreted with care, we could derive that the reduced travel time (e.g. due to home office) will be used 1:1 for other travelling. Kitou and Horvath (2008) have shown such an effect of e.g. home-office staff joining colleagues for lunch, while in that case interpreted largely due to less congested roads, as the study looked at wider adoption of home office work. While in this example the need that is fulfilled is a different one, the same function of personal transport is affected.

On the level of the same need, an example would be that eating the reduced calorie desert would result in eating other food in addition, whether at the same meal or at another time. It should be noted that in this last example, the calorie uptake is both a human need and also limit to consumption.

2.3.4 Marginal Shift to Mix of Less Well Fulfilled Needs

Thiesen et al. (2008) have assumed for their calculations that freed household resources – in their case for additional available income – will be used for the delta between the consumption profile of the analysed income level and that of the next higher level. Example if some money is saved in the lowest income level, the money was assumed to be spent to a larger-than-average share for dwelling use and maintenance (based on spending statistics), and to a lower degree on a range of other products.

In a more general perspective, we argue that it makes sense to assume that on average the individual would spent any saved resources on those needs that he/she feels are least well fulfilled. Example if time is saved by a single mother, she may spent it primarily on playing more with her child, while a stressed single manager might spend it on mental relaxation exercises or seeing friends. The logic behind this concept is that the use of the available household resources is optimised by the individual, plus that more basic needs are fulfilled first. Only when these are

fulfilled, higher needs are increasingly met. While this variant of how additionally available household resources are used is the least well defined one, we argue it to be the most plausible one, if looking at the individual consumer.

2.3.5 General Increase of Average Consumption

Finally, as a default option on the other end of the range, the consumer may just increase its average consumption. While this logic may be less accurate for the individual, particularly if the individual is barely able to meet his or her most basic needs, it may be a robust and quite accurate approach when looking at the average consumer in society.

2.4 Cross Category Effects

Cross category effects (Hofstetter et al. 2006), also termed technology rebounds by Weidema (2008)), relate to technology changes that affect the availability of other technologies or alter their effect on the available household resources. An example is the parallel use of a product A, enabled by a new product B, while not relevantly impacting on each other's functions. An example is the use of a laptop during a train travel (enabled by the portability of the computer and by the trains power outlet and Wi-Fi access). This situation can be argued to free time, as the work on the laptop is working time, if assuming that total working time is not increased.

Other effects are more indirect and can interact with other mechanisms on society level, affecting e.g. infrastructure availability.

2.5 Mental Secondary Consequences

The knowledge (or sometimes only belief) that a product X is more environmentally friendly may lead to an additional consumption "*because the product X has less impacts*", as Girod et al. (2010) argue. Examples are the more fuel-efficient car or more energy-efficient lighting that lead to driving further or having more lamps, respectively.

Similar to the use of freed household resources, also the mental consequences can lead to more use of the same product, as in the above examples, of products that fulfil the same function or meet the same need, or of other products or activities (e.g. "*because I separate my waste, it is ok that I …*"). These mental consequences can also be interpreted as having a mental budget for environmental impacts, as Girod et al. (2010) suggest. However, this mental budget is less accurate than the income or time budget and we can easily be misled as to the actual environmental benefit of a product.

Next to such negative secondary consequences that were in focus in previous work, the authors argue here that these can also be positive: the individual may like the good feeling that e.g. the decision of "being a vegetarian for a week" trial gives and he/she becomes fully vegetarian. Or the positive feeling of knowing to do something good for the environment leads to the decision to adopt a more sustainable lifestyle, i.e. consumption decisions in other product categories and meeting other human needs.

2.6 Higher Order Consequences of Economic Transactions

In addition, spending the saved money on other products means that this money is made available to individuals in a different product's supply chain. The net effect of the individual's available household income is hence not only depending on what he/she spends it, but also on the net change in impacts due to changed consumption depending on where the money that is being spent is going: buying a banana from Gran Canaria will – next to the local retailer – bring income to the wholesale/importer and the Spanish farmer. Buying it from Costa Rica will bring the income to people in different countries and cultures. The spending of additional income can be expected to differ between cultures, age classes, education levels, and between different income groups. If we however assume for simplification that the consumption profile of the different supply-chains do not differ from each other, the secondary consequence in the supply-chain is zero and the net effect is exclusively the extra consumption by the consumer.[5]

2.7 Towards a New Measure of the Environmental Life Cycle Performance of Products from Consumption Perspective

The fact that "money is conserved", as e.g. Dragulescu and Yakovenko (2000) highlight, makes it distinct from the other household resources. Saved time, as example, is actually net extra time available for activities and not handed over to the producers of the purchased products, in contrast to the situation for money that is merely transferred when purchasing a product.[6]

[5] This does not yet consider that personal and corporate taxes modify the available income for consumption in the supply-chains. Still, if we assume that the taxes are used for purchase or investment by the governments, the money is still used for consumption, albeit with an again different consumption profile.

[6] Note that also saving money in a bank account means consumption, as it allows other economic actors to take a loan and invest, same as buying on credit by the consumer. The only way to avoid that available household income is available for consumption, is to keep it at home (while that may mean that it marginally affects inflation).

Eco-efficiency, i.e. the quotient of price per environmental impact of a product therefore is a useful indicator: in its most simple form, a twice as expensive product of the same impact effectively reduces the ability of the consumer to spend the money on consuming other goods (Huppes and Ishikawa 2005).

However, we argue here that the concept of eco-efficiency is not considering the effect of additional consumption if the product is only produced cheaper, but a higher profit is kept by the producer: this profit is used for investment by the producing company or distributed to the company owners, e.g. shareholders, and hence available for additional consumption, the same way as it would be available to the consumer of that product if instead the product price would be reduced. More precisely, all profits along the supply-chain (and of consumables during product use and end-of-life services) need to be excluded from the economic component of eco-efficiency, to avoid this distortion.

This insight clarifies from a different perspective that the limiting factor in global consumption is global production, which is obviously limited by the output of the active labour force: If a product is produced with less workforce along its supply-chain, the not anymore required workforce is available for producing more of this product (or other products), hence increasing global production and consumption and hence environmental impacts. And the more qualified this not anymore required workforce is, the more overall production is increased, given the on average higher productivity of the higher qualified workforce. In short: The higher the quotient of the qualification-weighted amount of human working time q*t of a product and overall (i.e. normalized and weighted) environmental impact over the life cycle of a product, the less impacting the product, including considering the secondary effects of freed human work productivity (what is structurally equivalent to the effect by the enabled additional consumption by the product's consumer due to additionally available income).[7] This is called "Environmental work productivity" WP_{ENV} (Eq. 13.1):

$$WP_{ENV} = \frac{\sum_{i=1}^{n} q_i \cdot t_i}{\sum_{j=1}^{m} N_j \cdot W_j \cdot LCIA_j} \tag{13.1}$$

With N being the normalization factor, W the weighting factor, and $LCIA$ the LCIA result of the product, per impact category j.

The price of a product of the eco-efficiency concept is hence replaced by the work productivity, avoiding the distortion due to profits that are part of the consumer price of a product.

If we inverse this quotient, we get a measure for the environmental intensity of human work productivity WI_{ENV} (Eq. 13.2):

[7] Note that the other secondary consequences that were addressed above are, however, not yet included.

$$WI_{ENV} = \frac{\sum_{j=1}^{m} N_j \cdot W_j \cdot LCIA_j}{\sum_{i=1}^{n} q_i \cdot t_i} \tag{13.2}$$

If using the global human productivity and global environmental impact, this is the global average environmental intensity of qualification-weighted human work $WI_{ENV,G}$.

We can use this measure to integrate the effect of different work intensity of a product to correct the life cycle wide environmental impact of the product. By forming the quotient of the product-specific $WI_{ENV,P}$ and the global average $WI_{ENV,G}$, we obtain a normalized factor that expresses the potential net change of environmental impacts due to the amount of human productivity our product binds. Applying this factor to the normalized and weighted LCIA results of the analyzed product yields it's actual impact IMP_{net}, including considering the approximated secondary consequences due to the specific environmental intensity of its production (Eq. 13.3):

$$IMP_{net,P} = \frac{WI_{ENV,P}}{WI_{ENV,G}} \cdot \sum_{j=1}^{m} N_j \cdot W_j \cdot LCIA_{j,P} \tag{13.3}$$

It is important to highlight that this formula does not capture other secondary consequences and that it takes a product perspective.

2.8 Happiness or Harm Due to Need (Over-) Fulfilment

> The whole economy of human society is based on one general and simple principle: I want to be happy…. Denis Diderot (1713–1784), as cited in Elchardus (1991) (see Eckersley et al. (2001)

Hofstetter et al. (2006) propose an explicit approach to measure semi-quantitatively the contribution of a product to the fulfilment of the various needs, i.e. to the consumer's happiness. We can use this idea to expand on the new measure that we have proposed in the preceding subsection by integrating the utility of the product to the consumer, i.e. how much it is contributing to the consumer's needs fulfilment, i.e. happiness. The approach by Hofstetter et al. (2006) needs further refinement and testing, as the authors make clear. Among others, we see as one main aspect for improvement the way of how the different kind of information is aggregated (see also the recommendations in Wolf and Chomkhasmri (2012) on substitutability/orthogonality of criteria). It should also be considered to exclude limitations due to required skills and information, as it can be argued that for the individual, who will make a consumption decision, only those products for which he/she has the necessary skills and information will be considered anyway. Finally and as a

general limitation, the degree of needs fulfilment for the 'softer' needs, such as identity, participation, and so on, will much depend on the individual, and will likely escape a general agreement when trying to quantify a specific product's fulfilment of such needs.

Combining the net environmental impact of the analysed product $IMP_{net,P}$ that we have proposed above with a quantitative happiness-utility indicator of the analysed product HU_P (that we do not further work out here), we obtain a measure for the environmental intensity of needs fulfilment (aka of the product's happiness-utility) HUI_P. Note that this one is yet excluding yet other social and socio-economic secondary consequences other than those captured by the creation of qualified work and income in the supply-chain (Eq. 13.4):

$$HUI_P = \frac{IMP_{net,P}}{HU_P} \tag{13.4}$$

In contrast to the average consumer, to which we refer with this formula, for any specific consumer any specific consumption decision will of course look at activities and products that enable these that best meet that consumer's currently least well fulfilled needs. The indicator would still be the same, but the consumer would only consider those products that contribute to fulfilling his/her specific, most pressing current needs.

Finally, it needs to be highlighted that an over-fulfilment of some of our needs is leading to physical and mental health issues, be it overweight, dependence on alcohol, nicotine and other drugs (including on medication, gaming). Also information overload and the limited ability to keep abreast with new technologies can be understood to potentially counteract needs fulfilment and happiness.

Hence, maximizing needs fulfilment in the sense of summing up the happiness-utility results has limits for some of the needs. Also the linearity and the balance across the needs should be observed when looking at the overall needs fulfilment of a person.

Further work is needed here.

3 Sustainable Consumption on Different Levels

3.1 Product Level: From Functional Unit to Needs Fulfilment

Comparative product LCA studies analyse the life cycle wide impact products per functional unit of each product; i.e. in relation to "which function(s)" each product provides, "how much" of the function, "how well" and for "how long". This basis serves to compare alternative products.

In a consumption perspective, and particularly for consumer products, it makes sense to expand this functional unit also to the human needs fulfilment: The direct

function of a product ultimately serves to meet a range of human needs. While its primary, technical function of many or most products typically relate to only one of the physical basic needs, e.g. mobility, housing, or food, it always contributes also to meet other, psychological basic needs, such as for example affection, participation, and identity (Max-Neef 1991). The relevance for consumption decisions to meet also needs such as "identity" can be illustrated by the relevance that brands have in clothes consumption decisions. This example also illustrates that it will be an individual judgment how well a product meets these "soft" needs.

3.2 Person or Household Level: Sustainable Lifestyles

Moreover, it should be highlighted that needs fulfilment is often done rather by complex activities, that involve different products in a specific combination that create a new quality, rather than by simply consuming each of them: a simple walk in the park may involve a combination of outdoor clothing, maybe an umbrella, a bus trip to reach the park and for the way back, using the restaurant service to have a cake or ice-cream etc. and – important in the context of secondary consequences – involve an individually decided period of time. While the distance walked and the life time of the shoes have some relevant causal relation, otherwise the duration of many activities can be largely independent from the actual consumption of goods. Particularly the fulfilment of higher needs are less directly related to product consumption, other than more basic needs such as food and shelter.

In view of efforts to a more sustainable consumption and lifestyles, it is important to consider that very different activities – using possibly also the same amount of the household resources, but with a hugely different environmental impact – may still contribute to the same degree to the needs fulfilment and happiness for the same individual person. Using leisure time and money for meetings our "soft" needs can differ as much as taking a longer motorbike ride, playing a game on a smartphone, or practicing yoga, depending on the person's preference. Also meeting our physical basic needs can be done in different ways, while again using the same amount of the other household resources. One of the possibly most widely discussed component of sustainable consumption is eating vegetarian versus a meat-rich diet. As another example, for the need shelter/housing, zero-energy houses have much lower overall life cycle impacts than less well designed and insulated houses, possibly at the same total cost of ownership.

On the next more complete level, we look at the entire consumption of a person or it's household. We agree with the literature that the individual will aim at optimizing the use of his or her household resources to achieve a maximum fulfilment of the needs. Which needs are considered how relevant and how well the individual understands which products best contribute to fulfil these needs, is obviously different for each individual.

The quantification of the impact of consuming a product, i.e. including the many secondary consequences, carries a very high uncertainty, as illustrated in the preceding chapters. Somewhat surprisingly, a much more accurate guidance can be given to individuals if looking at the entirety of consumption: The sum of all consumption – e.g. in form of lifestyle scenarios – has no secondary consequences across the person's available household resources, as they are all covered in the total by definition. This allows to build scenarios of different lifestyles and calculate and compare their overall environmental impacts.

Some limitations will still reduce the accuracy and precision of the results of lifestyle-level studies:

- Accurate LCI data are not available for many specific products yet, respectively approximations are less precise, and available data from different countries is not widely interoperable (see e.g. the findings of a recent survey among National LCA databases globally in Wolf (2014c))
- Secondary consequences on society level are not covered or including them adds a relevant uncertainty, e.g. changes in road congestion if the individual uses public transport instead of a car.
- Effects on changing consumption patterns upstream of the supply-chain, i.e. at those individuals that earn extra income by contributing to the production of the purchased goods.
- Finally, the calculation of how well the specific lifestyle fulfils any specific person's needs will have a high uncertainty.

However, defining alternative lifestyles and assessing their overall environmental impact and utility, using the approach proposed in Sects. 2.7 and 2.8, will allow individuals to reflect on his/her own lifestyle and allow to adopt or adapt a more sustainable one. In summary, sustainable consumption decisions mean to meet the same needs in a less impacting way without overly triggering secondary consequences by changing the available household resources.

3.3 National Level: From Territorial Inventory to Including Burdens of Imported and Exported Products

Quantifying the environmental impact of different lifestyles on national level would have to look at different adoption-levels, as e.g. sparsely distributed electro-charging stations means additional travel to recharge the vehicle and additional transport means to come to these stations and back home or to the office. On a national level of consumption, we can hence capture such effects on infrastructure within the country. The only secondary consequences that escape the analysis are changes in international infrastructure, such as e.g. airports, and via changed amount of imports from those countries.

On the national level, past studies on the nations "footprint" have often looked at the territorial level only. However, since a number of years, more and more studies

also consider the import and export of goods and delivery of international services, and the upstream burdens associated with their life cycles.

An advanced approach to this idea has been piloted in a study commission by the European Commission in 2008 on the consumption-based national resource efficiency (European Commission 2012): Territorial data, mostly based on official statistics, were combined with full process-based life cycle data for the 15 most important traded product groups. These product groups were represented by representative products (e.g. "passenger car" for the product group "road vehicles" or "methanol" for "organic chemicals") and the inventories were scaled up to the amount of goods traded in each product group. The rest of trade was approximated by the mix of those that were explicitly modelled. It was moreover possible to model the inventories of the traded goods for the two or three most important source countries. Despite some weaknesses, particularly in the territorial data, the study could show for many impact categories that a shifting of burdens occurred from Europe to other countries, i.e. while territorial impacts were slowly reducing, due to an increased import or higher processed products, the overall EU consumption-based environmental impact is increasing with time.

The main sources of lack of accuracy and of uncertainty in such approaches – next to the mentioned territorial data that is weak in several impact categories – are limitations in life cycle data on specific products for a range of product groups, particularly more complex consumer products and services. Also, the approximation of a product group by one representative product carries a relevant uncertainty, which can be overcome only by increasing the number of products to approximate a product group. The recent increase in availability of Environmental Product Declarations and Footprints for all kinds of products is a promising development, which can be expected to substantially ease such calculations.

Such studies are valuable to inform policy makers about true consumption-based trends in environmental impact, and to identify the main product groups and trade partners from and to where such a shifting of burdens happens and inform related policies. One key advantage of this approach is that these studies can be tailored and further developed to be very specific on traded products to address specific policy questions. In contrast, Environmentally Extended Input Output (EEIO) studies are limited by the very broad range of whole industry sectors, which cannot well differentiate below industry sectors. Moreover, EEIO is based on economic relations across the economy, hence its life cycle data is closely correlated with money that is an important limiting factor to consumption as discussed above, hence will lead to only rough and possibly distorted results.

3.4 Global Level: The Sum of All Consumption Versus the Planetary Boundaries

Studies on global level necessarily take a more comprehensive perspective, including all human activities. Monitoring the overall environmental impact is a very high-level indicator that can be used also to evaluate in how far we surpass the

planetary boundaries. It shows on the largest of scales and only slowly over years whether all the measures by individuals up to national governments and international agreements show success in terms of slowing or reversing the trend of increased environmental impact on a global level.

One important topic under discussion in the context of sustainable consumption is shifting production to low income countries with potentially lower environmental standards: Cheap products have often been criticized as increasing the environmental impact, as they allow for more consumption. If we moreover assume that the most cheap products are so because the staff in their supply-chain are poorly paid (next to general productivity increase), the cheaper products mean also a shifting of parts of the income and hence consumption from middle or higher income countries to low income countries, but also to richer people (in both low and high income countries), since the cheaper products mean they have additional household income available. As statistics show, the allocation of the available household income considerably varies depending on income level. The net effect of this consumption shift still needs to be quantified.

4 Actors in Sustainable Consumption and Their Possible Roles

4.1 Companies: Sustainable Products

As argued initially, the main sphere of influence for companies is the development and production of goods and the operation of services. It is essential that the environmental performance of these goods and services is improved, based on their functional unit. If these products change the available household resources, it is a consumer choice what to do with any additional resources.

Still, companies might want to better understand the secondary consequences of their products and how well the products meet the individual needs beyond the mere function. This should help companies to be prepared for the discussion on sustainable consumption. In fact, many companies do parts of this analysis already: fashion and lifestyle, time and space saving are key selling points in many product segments. The environmentally negative secondary consequences are however out of the scope of the analysis. This also means that conflicts are to be expected between offering an environmentally more efficient product with time-saving properties to the consumer, while at the same time trying to avoid that this leads to secondary consequences that party or fully compensate the environmental advantages of the product.

A design for sustainable consumption would then be an extension of conventional Ecodesign by considering consumption-related secondary consequences, and – as Hofstetter et al. (2006) argue – basic needs that require satisfaction. A first step would be to provide quantitative information on the effect on the consumer's

household resources, particularly time and space saving, and expand on the information on the cost of ownership, that is currently legally to be provided for some consumer goods only. Regarding food calories, this information is already standard information on food products.

On lifestyle level, companies across sectors may start working together to develop and promote a portfolio of products for sustainable lifestyles and/or ecosystems.

4.2 Citizen: Sustainable Consumption Decisions and Lifestyles

All final consumption is decided on by the consumer, while marketing, the role models that media personalities play, and the media in general, but also family and friends are influencing consumption decisions. For implementing sustainable consumption to reach a sustainable life style, consumers require awareness of sustainability and need to receive sufficient and correct information to support their consumption decisions (Wolf 2014a).

Taking more sustainable consumption decisions means purchasing, using, and end-of-life managing products that – while fulfilling the consumer's human needs in at least the same degree as alternative products do – have a lower environmental life cycle impact, including to quantitatively consider the secondary consequences, including the higher order consequences in the society and due to possibly freeing human working time. In Sects. 2.7 and 2.8 we have already sketched a respective quantitative measure on this last named aspect "Sustainable consumption" has been defined quite early already, such as in (Norwegian Ministry of the Environment 1994).[8]

The entirety of consumption of a citizen is facilitating the person's lifestyle. A lifestyle is – in its broadest sense – "Ways of life, encapsulating representations, values and beliefs, behaviors and habits, institutions, economic and social systems." (UNEP 2011). In context of this chapter however, we refer mainly to the consumption of goods and services that enables the individual to create and live his or her lifestyle, similar to the definition promoted in context of the Marrakech process: "*Sustainable lifestyles are patterns of action and consumption, used by people to affiliate and differentiate themselves from others, which: meet basic needs, provide a better quality of life, minimise the use of natural resources and emissions of waste and pollutants over the lifecycle, and do not jeopardise the needs of future generations*." (Thidell 2011, adopted from CSD 2004).

The individual will aim at maximising the utility of his or her household resources, i.e. optimize the needs fulfilment. In Sect. 3.2 it was explained why it will be more accurate to calculate the environmental impacts of the entire consumption profile of an individual's lifestyle, than of individual products. We therefore argue that it makes sense to define a range of lifestyles and calculate their overall

[8] Unfortunately, in one of the most prominent and recent global efforts to "Develop recommendations for effective policies on Sustainable Lifestyles" (UNEP 2011), the reference to life cycle approaches is essentially limited to the glossary.

environmental profile. Individuals can then learn which lifestyles have which environmental consequences and see if they want to shift their own lifestyle into the direction of one of the less impacting ones.

However, such "model lifestyles" needs variation, not only because of differences in the individual taste and belief, but already because the available household resources vary (e.g. different times and income bound for commuting distances, with/without children, different health, other long-term obligations, etc.).

Moreover, when defining one's lifestyle, people often refer to approaches, rather than individual products or to concepts that would capture the entirety of the lifestyle. "I am vegetarian", "I separate waste", and "I buy local" are a few examples of such approaches. These approaches help consumers to group specific decisions and to communicate them, as well as combining a lifestyle. The challenge is that not all decisions that are taken in line with such approaches are actually environmentally beneficial (already if not considering secondary consequences). Some approaches that are perceived as environmentally advantageous can even be more impacting, see e.g. examples for misconceptions about polymers in Wolf et al. (2010). It will be important to analyse which of these approaches are actually environmentally beneficial, again including considering the secondary consequences on available household resources.

If any such approaches are fully followed, they can also lead to infrastructural changes at the consumer. For example, "I prefer public transport" may lead to the decision to not have a private car anymore.

We would like to add that the above refers implicitly to middle and upper consumers, while families of low and lowest income classes will have less choices to shift to more sustainable lifestyles, in their struggle to meet at least their most basic needs. Moreover, given their low income, they typically have a lower per person environmental impact than better-off families.

4.3 Governments: Facilitating Sustainable Consumption and Lifestyles

Several past and current policies and initiatives have supported sustainable consumption (and production). Starting on the international level, the Sustainable Consumption and Production (SCP) program by the United Nations Environment Programme (UNEP) is based on the achievements of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro (the Earth Summit), and the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg (UNEP 2012). The European Union launched the Beyond GDP initiative, aiming at developing indicators that are as clear and appealing as GDP, but intend to be more inclusive of environmental and social aspects of progress, and the Action Plan on Sustainable Consumption and Production (SCP) that has life cycle thinking in its core, to name a few. Similar programs have been started in many other countries worldwide.

The government itself is a big consumer, with governmental spending in the range of 1/6 of nation-wide spending (e.g. in the EU 2002: 16 %). Green Public Procurement (GPP) is therefore a means that can have a key steering effect for more sustainable products. Continuous efforts are made for better informed GPP with comprehensive, life cycle based indicators (e.g. in the recently started project EURECA for GPP of data centre services (NN 2015)).

Beyond this product-perspective and next to creating markets for less impacting products, the scale of government procurement can also facilitate the creation of infrastructures in support of green procurement by consumers: Governments set the rules of the society and establishes or steers the development of key infrastructures, which can be favouring more sustainable consumption. Government can hence also provide options for less environmentally impacting consumption, e.g. public transport.[9] Similar to the situation of companies that offer cost and time saving aspects of their products for the direct benefit of the consumers, also governments generally follow the approach of saving costs and time for the citizen. Therefore, only by understanding the society-wide implications including due to secondary consequences of their projects and policies, the governments can fully take their role of steering consumption towards a long term stable, i.e. sustainable one. This includes to steer or counteract the transformational effect (Greening et al. 2000).

Identifying or developing elements that make up sustainable lifestyles and facilitating their adoption by implementing the required infrastructure are key tasks. Promoting sustainable consumption and sustainable lifestyles, as well as facilitating them by financial measures are other, main leverages of governments, on the way to a sustainable society. R&D investments into sustainable products and lifestyles and their infrastructure, Green Public Procurement, and education courses and campaigns for schools and university courses, are further examples for suitable governmental activities. On international level, the coordination with other national governments will help improving the common understanding of sustainable consumption and measures. This list above illustrates the crucial role that governments have in steering the society to sustainability.

4.4 Others

A range of other actors play a role in society and also in efforts to a more sustainable consumption:

[9] Such measures can have relevant negative environmental secondary consequences, if they free household resources at the consumer, i.e. if they are cheaper, save time (or allow to do two things at the same time, e.g., working during commuting), as already mentioned. Gillingham et al. (2013) however have found from the analysis of studies that negative environmental secondary consequences of energy-efficiency improvements are typically in the range of 5–30 % and hence less than is sometimes feared and warn that paying too much attention to single cases where the effect is higher may be used as excuse to not take action.

Industry associations – similar to companies – are important sources of high quality life cycle data for products that best represent the industrial reality. They can moreover disseminate information about sustainable products and sustainable consumption aspects to their members and bring in the voice of the represented industry into the public discussion on sustainable consumption.

Green and consumer NGOs can support bringing understanding and knowledge on sustainable consumption to consumers and contribute to the public discussions on sustainable lifestyles.

Research bodies and consultants are essential to help increasing the understanding and knowledge base on secondary consequences of consumption decisions, by developing better methods and models, and by offering software tools and data to support the analysis.

5 Conclusions and Next Steps

Life cycle management as a process has a history that reaches back more than 25 years, while as a term it has risen to prominence only about 15 years ago. Big progress has been made in collecting and analyzing data and information on environmental interventions along the supply-chains and working together to improve the environmental performance of many thousands of products and many tens of thousands of processes, worldwide. The life cycle data availability for this kind of analysis has constantly grown and now allows – while less so for countries with a shorter history in life cycle approaches – to get reliable results also for complex products, particularly, if the producing industry is actively involved and experienced experts support the analysis.

Product life cycle analysis and management was and still is the core also for the slowly developing field of sustainable consumption analysis, which needs to employ in addition to LCA complementary methods and data to also capture the secondary consequences outside the analysed product and directly connected products. While first life cycle based studies on the secondary consequences go back to the late 1990s, given the much more complex effects and higher effort, a much smaller share of studies has looked into it and the body of evidence is growing only slowly.

With increasingly better availability of process-based life cycle data and more and more companies publishing Environmental Product Declarations and Footprints, the evidence and process-based life cycle data basis for consumption and lifestyle studies is now further expanding.

If we want to achieve a reduced global environmental impact, we need to approach this from both the production and the consumption side. Unfortunately, the reduced environmental impact of many products and per functional unit is so far overcompensated by increased overall consumption – more products with a larger function per average person and an overall growing world population.

As recommendations, we consider the most important steps for public and private organisations to support consumers in their consumption and lifestyle choices to be the following ones:

- Increase the availability of interoperable life cycle inventory and impact data, including Product Environmental Footprints and other Environmental Product Declarations, so they can serve for better consumer information and can be combined into lifestyle studies. Agreements on interoperability across industry and governments – ideally on a global level – would be needed for this, in coordination with the software and data developers in consulting and research that support such work.
- Improve the data and evidence base for consumer choices on how freed household resources are reallocated. As interim step, working with scenarios as described in Sect. 3.2 can serve. Governmental research efforts should be directed at this task.
- Develop robust methodologies for capturing the secondary consequences of consumption, expanding on proposed approaches e.g. of Hofstetter et al. (2006) and of the environmental intensity of needs fulfilment, e.g. advancing the approach that we have sketched in Sects. 2.7 and 2.8. Government research funding or dedicated method development calls – as multi-stakeholder projects rather than a research exercise – in support of government analysis would be essential here. In this, it will be important to bring together experts from the fields of economy and life cycle experts: differences in terminology and approaches need to be overcome in interdisciplinary work.
- Stepwise develop a wide set of more environmentally sustainable lifestyles as archetypes for consumers to adopt and adapt from. As argued in Sect. 3.2, it is more accurate to assess the overall environmental impact of a whole archetype lifestyle than for many individual products, because the important secondary consequences on available household resources are automatically covered and zero. Scenarios on lifestyle approaches (e.g. "buy local", "eat vegetarian") should be analyzed and used to support communication with consumers to separate the more efficient and effective approaches from those that only apparently reduce the environmental impact.
- Consider secondary consequences when developing public infrastructure, financial instruments and other legislation directed at more sustainable consumption and lifestyles, e.g. in public transport, internet bandwidth[10] and others.
- Continue and strengthen the efforts for developing and distributing education and information materials for industry, government officials and citizen – the understanding of what makes up a "sustainable products" and sustainable lifestyles is argued here to be very limited outside a few dedicated expert groups.

[10]A recent expert workshop on environmentally sound data centers, organized by the European Commission's DG CONNECT and composed of data centre developers, operators and users, has warned that "*bandwidth growth needs to be better linked to the ability of technological developments to cope with it in terms of the related energy consumption and environmental impacts*" (Wolf 2014b).

Expand this with information on the secondary consequences of consumption – to enable those that are interested to adopt a more sustainable lifestyle have the necessary information to do so and avoid negative secondary consequences and hence largely or fully useless efforts. Edutainment TV programs might be one suitable format to this aim, particularly to reach out to consumers.

While we could not address such topics in this chapter, we would like to point out that the social and socio-economic impacts of consumption must not be forgotten but need to be integrated into the analysis, next to the environmental impacts that were the focus of this chapter.

The challenge ahead for humanity is truly one that needs the combined effort of all actors, globally: The otherwise wanted and fostered increase in the eco-efficiency and energy-efficiency counteracts sustainability, what Hofstetter et al. (2006) call the "efficiency-trap". In consequence and further amplified by continued population growth, the absolute pressure on the environment is increasing, even though the products' environmental impact per functional unit is generally decreasing.

However, it depends on the choice of the individual consumer, i.e. each and any of us, which lifestyle we adopt and how we meet our true needs with our available household resources.

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