Chapter 5
LCA and Sustainability

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Abstract LCA is often presented as a sustainability assessment tool. This chapter analyses the relationship between LCA and sustainability. This is done by first outlining the history of the sustainability concept, which gained momentum with the Brundtland Commission's report 'Our Common Future report' in 1987, and presenting the most common interpretations of the concept, which generally comprise four dimensions: (1) measures of welfare, (2) inter-generational equity, (3) intra-generational equity and (4) interspecies equity. The relevance of environmental protection for dimensions 2 and 4 is then demonstrated, and the strategy of LCA to achieving environmental protection, namely to guide the reduction of environmental impacts per delivery of a function, is explained. The attempt to broaden the scope of LCA, beyond environmental protection, by so-called life cycle sustainability assessment (LCSA) is outlined. Finally, the limitations of LCA in guiding a sustainable development are discussed.

Learning Objectives
After studying this chapter the reader should be able to:

- Explain the most common interpretations of the definition of sustainable development from Our Common Future.
- Account for the relevance of environmental protection to sustainability.
- Describe the type of sustainability strategy that LCA may support and discuss its limitations.

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5.1 Introduction

In 1987, the United Nations' World Commission on Environment and Development published its report *Our Common Future*, which is sometimes referred to as the *Brundtland Report* after its chairperson, Gro Harlem Brundtland (WCED 1987). The report was a response; on the one hand to the growing disparity between North and South and on the other hand to the increased awareness that many of the natural systems on which we depend were under increasing stress. Development of the South was seen as urgently needed, but the development had to be achieved in an environmentally sound way which would allow for a continued thriving of the world's population—also in the future. The development in other words had to be sustainable. While the term "sustainable development" was already introduced in 1980 by the International Union for the Conservation of Nature, the publication of *Our Common Future* created a widespread awareness of sustainable development and provided its most well-known definition: "… development that meets the needs of the present without compromising the ability of future generations to meet their own needs". By coupling the concern for the present and future generations, the concept of sustainable development, as defined in *Our Common Future,* provided a framework for thinking these two increasingly pressing global challenges together in one immensely influential term.

The ability of present and future generations to meet their needs depends strongly on the life support functions of the earth and inherent in the definition of sustainable development is thus a concern for the health of the environment. The development of LCA can in many regards be seen as stemming from the same concern for environmental protection (see Chap. 3). A natural question may therefore be; How does LCA and sustainable development relate, and to what extent can LCA be used as a methodology for informing decisions towards sustainability?

To answer these questions we will start by giving an overview of how sustainable development is understood in literature, followed by an analysis of the possibilities and limitations for LCA to support it.

5.2 What Is Sustainability?

Since the publication of *Our Common Future*, many different definitions of "sustainable development" or the related term "sustainability" have been presented. In this chapter we will use these two terms interchangeably, but it should be mentioned that in literature, these concepts can be used with different connotations. It is, for example, sometimes asserted that sustainable development is primarily about development (sometimes seen as synonymous with economic growth), whereas sustainability gives priority to the environment. Others have argued that the difference is rather that sustainable development should be seen as the process or journey to achieving sustainability.

Proposals for definitions of sustainable development have been booming after the publication of *Our Common Future*, and have added several nuances and potential modifications to this definition. For example, some have argued against the one-sided focus on human needs. In the definition of sustainable development given above, there is little room for considering other living species than humans, unless these species directly serve as means to meet these human needs. In line with this, it has been argued that the definition is too narrow, and that other living species should be considered as well.

Others have debated the word "need", and suggested several others and in many regards related words such as "wellbeing", "utility", "welfare" and "aspiration".

Finally, it should be mentioned that the researchers, especially within the economic discipline, have omitted the focus on the needs of the present and claimed that sustainability is simply about ensuring that the total utility or welfare of a society can be maintained over an infinite time horizon (Pezzey 1992).

Despite these variations, there is a large degree of common ground in definitions of sustainability. Sustainability can be seen as comprising by the following four dimensions, with varying emphasis:

1. The first dimension relates to *measures of welfare* that is to be achieved in the population comprised by the definition (see Dimensions 2–4). This measure of welfare comprises several different concepts, such as "need", "utility", "happiness" and "aspiration". Several others can be found in literature.
2. The second dimension relates to the concern for *inter-generational equity*, i.e. a concern for the equity in the welfare (as defined by the first dimension) between this and future generations. In most cases, these future generations comprise anyone born in the future, i.e. from tomorrow till infinite time has passed. This concern, together with some version of the first dimension, is found in all definitions of sustainability.
3. The third dimension relates to *intra-generational equity*. Within this dimension, we consider the extent to which the measures of welfare are equally distributed within a generation both on a macro-scale (i.e. among developed and developing nations) and on a micro-scale (i.e. the equality within a given nation, region or local community). As noted above, there is a large difference in the definitions with regards to whether this dimension is considered at all.
4. The fourth and final dimension relates to *interspecies equity*, relating to whether it is only the welfare (however defined) of humans which is a goal, or whether also the thriving of other living organisms (independent of their potential to contribute to human welfare) is considered. It should be noted that most definitions (including the original definition given in *Our Common Future*) are anthropocentric (i.e. human centred) and therefore do not include this dimension.

5.3 Sustainability and the Environmental Concern

Except from the fourth dimension of sustainability, which is typically not considered, there is no explicit consideration of environmental conservation in most definitions of sustainability. It may therefore seem odd that environmental protection is often seen as being more or less synonymous with sustainability. The reason should primarily be found in the concern for inter-generational equity. The rationale behind protecting the environment from a concern for inter-generational equity is that the natural resources and the services that nature provides are seen as the foundation for society. Without a functioning environment we will not be able to cultivate crops, secure clean air, be protected from ultraviolet radiation from the sun, etc. The idea is thus that protecting the environment is necessary to give future generations the same possibilities for achieving the levels of welfare that current generations are experiencing.

Thus, besides the concern for intra-generational equity, which is not ensured simply by protecting the environment, but which calls for initiatives related to combating poverty, sustainability includes a concern for environmental protection. The extent to which the environment should be protected as a condition for the inter-generational equity dimension of sustainability is, however, not clear-cut. Clearly, human needs cannot be met if humans cannot breathe due to air pollution or lack of oxygen. But the more detailed dependency of human needs on specific functions or qualities of the environment is disputed. For example, will the potential for meeting human needs be violated if the panda bear becomes extinct? And to what extent can technology replace the services and functions provided by ecosystems?

While keeping this discussion in mind, researchers have attempted to quantify carrying capacities of ecosystemsthat must not be exceeded to maintain functions and other ecosystem aspects of interest. For example, the carrying capacities of different terrestrial ecosystems in Europeand elsewhere towards deposition of acidifying compounds (sometimes termed critical loads) have been calculated (Hettelingh et al. 2007). At the global scale planetary boundaries have been proposed and tentatively quantified. Planetary boundaries can be interpreted as carrying capacities for the entire Earth System towards various anthropogenic pressures, such as greenhouse gases and interference with nutrient cycles. If exceeded there is a substantial risk that the Earth System will change from its well-known and relatively stable state that has characterized the Holocene geological epoch in the past 12,000 years to an unknown state (Rockström 2009; Steffen et al. 2015a). According to estimates, this exceedance has already happened for four of the nine proposed planetary boundaries, as shown in Fig. 5.1.

As this chapter is about the role of LCA in the environmental protection needed to achieve sustainability we will only address the part of the sustainability definition pertaining to the environment. Chapter 16 addresses the development of what has been termed Social LCA, addressing the social dimension of sustainability.

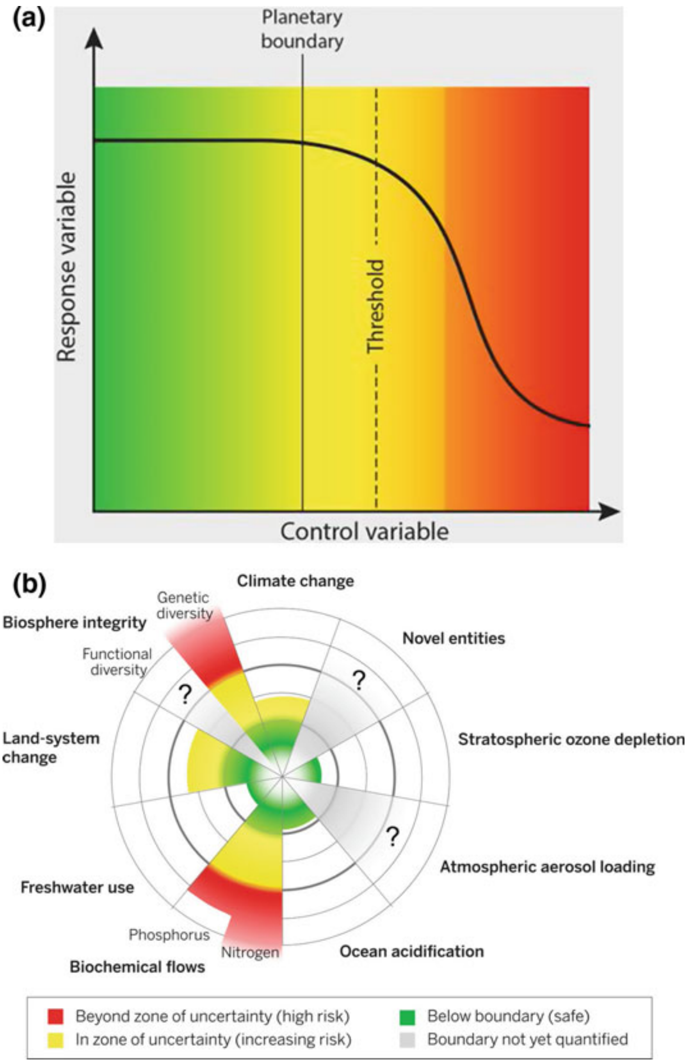

Fig. 5.1 Planetary boundaries. **a** Illustrates the concept of thresholds and boundaries in relation to an ecosystem's response to increasing human pressure. **b** Shows the proposed nine boundaries (two of them subdivided for specific pressures) and that mankind has currently exceeded four of them, two beyond the zone of uncertainty (Steffen et al. 2015a). Reprinted with permission from AAAS

5.4 Sustainability and LCA

If sustainability entails that the environment has to be conserved, the question is How can we conserve the environment? What are the overall drivers that lead to environmental deterioration?

These questions were first addressed in Holdren and Ehrlich (1974), whose work in a modified form lead to the formulation of the so-called IPAT equation, or

$$I = P \cdot A \cdot T \tag{5.1}$$

where (*I*) is the environmental impact, (*P*) is the population, (*A*) is the per capita affluence and (*T*) is the technology factor.

The formula expresses that the overall impact on the environment is controlled by the number of people on the planet, their affluence, expressed in material affluence per person, and technology's environmental intensity, expressed in environmental impact per material affluence.

Figure 5.2 shows the global development in population and various indicators of affluence, such as GDP, transportation and paper production, along with indicators of environmental pressures and impacts from 1750 to 2010. Figure 5.2a shows that while the world population has almost tripled from 1950 to 2010, all the indicators of affluence have increased at higher rates, meaning that the per capita affluence ("*A*" in the IPAT equation) has increased in the period (note that this increase has been unequal—income differences between and within countries have increased in the period). Figure 5.2b shows that the combined effect of an increasing population and increasing per capita affluence ("*P*" and "*A*" in the IPAT equation) has led to increases in environmental pressure and impacts ("*I*" in the IPAT equation). This means that technological improvements in environmental impact per material affluence ("*T*" in the IPAT equation) have been insufficient for maintaining environmental pressures and impacts at a status quo, let alone for decreasing them.

With the historical development in mind, the IPAT equation shows us that we, in theory, have three overall knots and handles to manipulate to ensure that loads on the environment do not exceed carrying capacities. Two of these three parameters, the number of people and their affluence, have been difficult to handle. In relation to the number of people, this can either be regulated by increasing mortality or reducing fertility, and in most parts of the world issues like these are not on the political agenda. In some parts of the world, for example in the EU, Russia and Japan, it is even seen as a political aim to increase fertility. However, despite this, projections show that the world population may stabilize around 10 billion in 2050.

With regards to the affluence, we have already established above that to increase the intra-generational equity, there is a need for increasing the affluence of the ones mostly in need. Reducing the overall affluence while increasing the affluence of the poorest inevitably calls for a decrease in the affluence of the richest part of the world population which is a difficult program for a political party striving for (re-)election

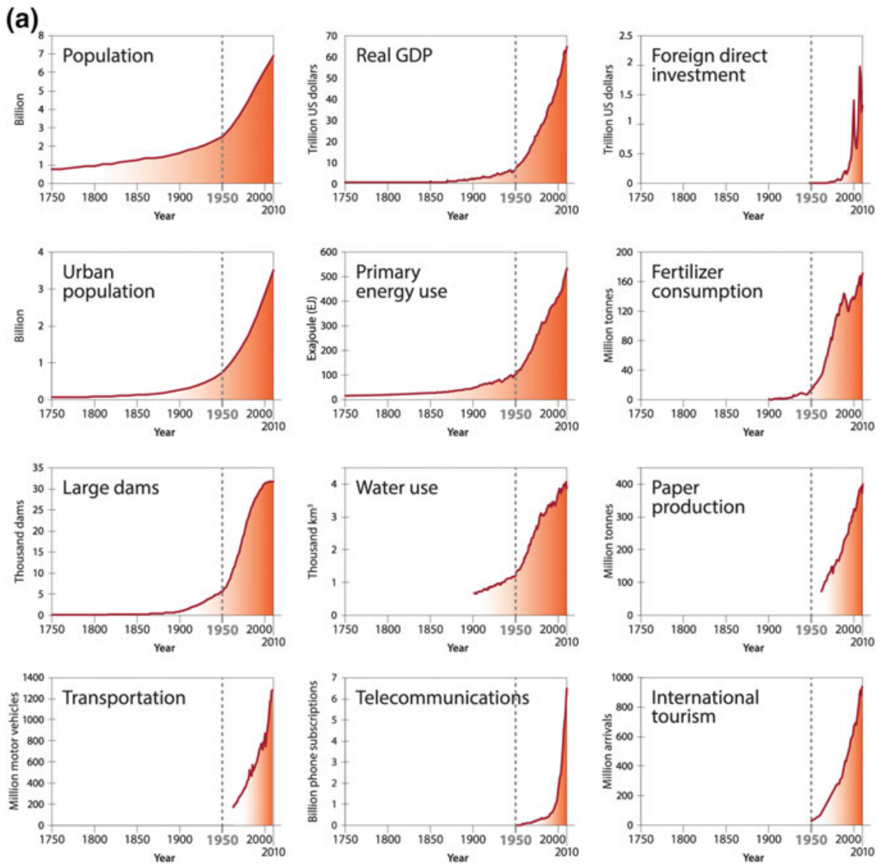

Fig. 5.2 Global development in a selection of **a** socio-economic indicators and **b** pressures and impacts on the environment from 1750 to 2010 (Steffen et al. 2015b). Reprinted by Permission of SAGE Publications, Ltd.

in a liberal democracy as found in most affluent societies today. The "*A*" in the IPAT equation above is therefore expected to increase over time.

What is left is the development of technology, which can allow us to regulate the environmental impact per consumed unit (the '*T*' factor in the IPAT equation). To increase the output or functionality while keeping a constant environmental impact corresponds to increasing what is often termed eco-efficiency. According to the World Business Council of Sustainable Development "eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life cycle to a level at least in line with the Earth's estimated carrying capacity" (WBCSD 2000). By increasing the eco-efficiency of existing products and technologies, the idea is thus that we will be able to consume the same, or more, while at the same time lowering the overall

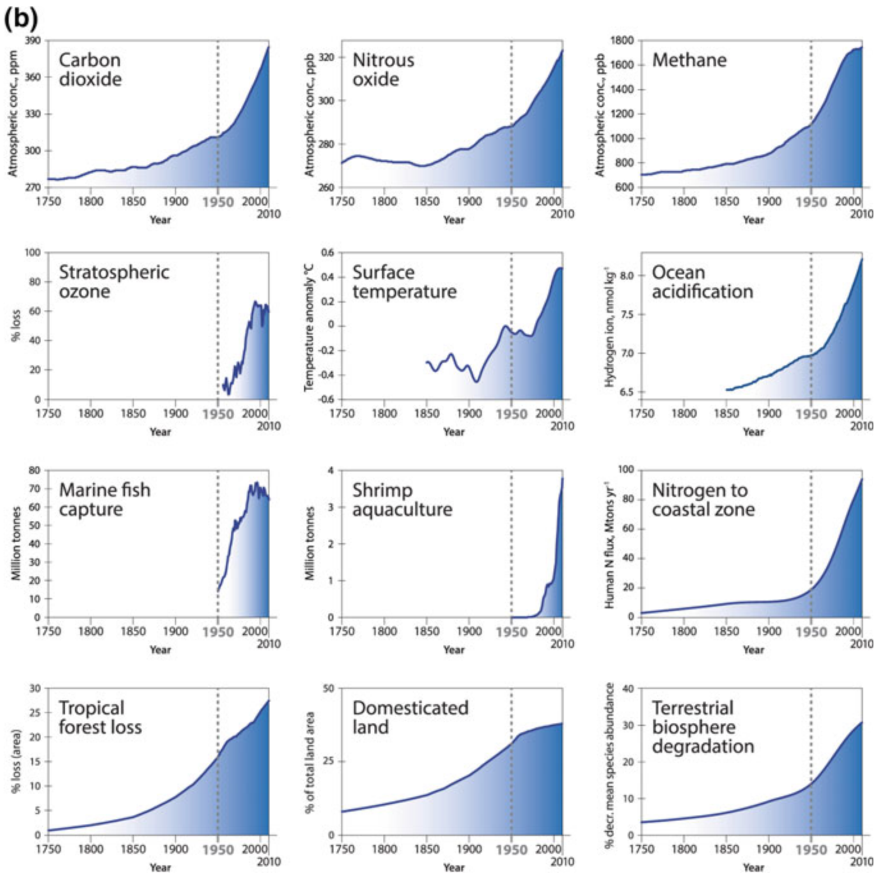

Fig. 5.2 (continued)

environmental burden of this consumption to a level that does not exceed carrying capacities.

As outlined in the chapters above, and as will be further detailed in the remaining parts of this book, LCA shows how a specific functionality can be achieved in the most environmentally friendly way among a predefined list of alternatives, or in which parts of the life cycle it is particularly important to improve a product to reduce its environmental impacts, in other words, increase its eco-efficiency. LCA can therefore be seen as a methodology that can guide decisions towards improving one of the three dimensions in the IPAT equation, namely the technology ("*T*") dimension.

5.5 A Note on Life Cycle Sustainability Assessment

It has been proposed to expand LCA into life cycle sustainability assessment (LCSA) to also encompass socialand economic aspects, in addition to environmental aspects of sustainability when analysing product life cycles (Kloepffer 2008; Zamagni 2012). The idea of LCSA builds on the so-called "three pillars" (or three dimensions) interpretation of sustainability, according to which sustainability is composed of an environmental, social and economic pillar. This interpretation gained momentum with the concept of the "Triple bottom line" by Elkington (1997), who proposed that businesses should manage environmental, social and economic aspects of sustainability in the same quantitative way that financial aspects are typically managed inaccounting. Accordingly, Kloepffer (2008) proposed the following scheme for LCSA:

$$\mathrm{LCSA} = \mathrm{LCA} + \mathrm{LCC} + \mathrm{SLCA} \tag{5.2}$$

LCC is an abbreviation for life cycle costingwhich aims to quantify all costs associated with the life cycle of a product that is directly covered by one or more of the actors in that life cycle. S-LCA is an abbreviation for social life cycle assessment, which has the goal of assessing the social impacts of a product over its life cycle. LCC and S-LCA are detailed in Chaps. 15 and 16 of this book. An important requirement of LCSA is that the three pillars of sustainability must be assessed using the same system boundaries, i.e. that the same elements of a product life cycle are considered in all three assessments (Kloepffer 2008) (see Chap. 8, for an elaboration on system boundaries).

While LCSA is much less mature than LCA and there is a little agreement of how to actually perform it, two fundamental aspects of LCSA deserve highlighting in this chapter:

1. LCSA seems to be based on the assumption that sustainability is something that can be balanced between an environmental, social and economic dimension. This is hinted by the scheme proposed by Kloepffer (2008), according to which a decrease in one sustainability dimension (e.g. environmental) can be compensated by an increase in another dimension (e.g. social). This conflicts with the concept of carrying capacity, according to which the meeting of human needs depends on a minimum level of environmental protection, as mentioned in Sect. 5.2. In our view it would therefore be misleading to assess a product that has a relatively good performance in an LCC and an S-LCA, but a relatively poor performance in an LCA, to be overall sustainable, because the bad performance in an LCA may be contributing to the exceedances of carrying capacities, which in the long term threatens the meeting of human needs and thus social (and economic) sustainability. This perspective is reflected by a popular quote, attributed to Dr. Guy McPherson: "If you really think that the environment is less important than the economy, try holding your breath while you count your money" (McPherson 2009).

2. LCSA includes an economic dimension of sustainability. This is consistent with the common "three pillar" interpretation of sustainability, but it can be questioned how relevant LCC is for sustainability assessments. This is because the costsquantified by LCC are only relevant to sustainability if these costs apply to the poor, which are of concern to the intra-generational equity dimension of sustainability (Jørgensen et al. 2013). Yet, quantifying the monetary gains or losses for the poor is already an aspect commonly included in S-LCA (see Chap. 16).

5.6 Limitations to the Strategy for Achieving Sustainability Through LCA

Even though LCA gives us the very valuable possibility of choosing the most eco-efficient way of achieving a specific functionality or service, this approach has some important limitations in regards to ensuring (environmental) sustainability.

Following the IPAT equation, and knowing the projections for the population growth and the goals for the increase inaverage affluence, it has been estimated that a factor 4, or higher, increase in the eco-efficiency of technologies or products is needed just to ensure a status quo with regards to our impacts on the environment (Reijnders 1998). But as shown in Fig. 5.1, status quo, with regards to some environmental impacts, is not good enough if we are to guarantee a sustainable development, because a number of planetary boundaries have already been exceeded. For some technologies and products an increase in "*T*" closer to a factor 10 may therefore be required.

It is evident that a factor of 10 increase in the eco-efficiency of technologies or products in many cases will be difficult to achieve. For example, even the most eco-efficient cars are far from a factor 10 more efficient than the average car, both regarding energy consumption during use and material consumption during production (Girod et al. 2014). In other cases, however, a factor 10 increase in the eco-efficiency of products has been achieved in isolated areas. Freon and other ozone depleting gases used in for example refrigerators have more or less been phased out as a result of the Montreal Protocol, leading to an eco-efficiency increase on this isolated area, far better than a factor of 10 (WMO 2014).

However, one thing is to increase the eco-efficiency of the product, another is how we administer the gains achieved through the increased efficiency. History has demonstrated that the level of services that we want from products and technologies is not static. As soon as new possibilities evolve we tend simply to expand our wants and expectations (which might not be the same as needs, depending on the interpretation of sustainability). Evidence suggests that increases in eco-efficiencies in some cases due to changes in wants and expectations lead to so-called "rebound effects". An example of a rebound effect could be if an increase in eco-efficiencyof the car engine leads the producer to increase the power of the motor, add extra comfort to the car, or if costumers travel longer distances due to an improved fuel economy, reducing or eliminating the effect of the increase in eco-efficiency. Another example is seen in the lighting technologies: Since the light bulb was invented there has been an enormous increase in the energy efficiency, which has equally lead to a dramatic decrease in the price of light. But as our appetite for more light seems insatiable this increase in eco-efficiency has been met by a corresponding increase in demand—with no signs of saturation. In fact, it has been found that the fraction of GDP spent on light has remained almost constant, close to 1% over the last three centuries in the UK and that this fraction is similar in other countries spanning diverse temporal, geographic, technological and economic circumstances (Tsao and Waide 2010).

In sum, this implies that while LCA may help identify the most eco-efficient solution among a range of alternatives, the actual eco-efficiency that we may achieve through redesign and technological inventions is in many cases insufficient. Furthermore, the increases that are gained in eco-efficiency on the product or technology level may be counterbalanced by increases in demand. Impacts on the environment quantified using LCA can be put into a sustainability perspective by relating them to environmental carrying capacities (Bjørn et al. 2015). This can facilitate an absolute evaluation of whether a studied product can be considered environmentally sustainable, and if not, how much further environmental impacts must be reduced for this to come true. Such an absolute perspective can complement the common relative perspective of LCA which is about identifying the product system that is better for the environment, but that might not be good enough from a sustainability perspective.

Yet, even when an absolute perspective is taken LCA cannot, by itself, cover all relevant aspects of sustainability. Many sustainability researchers have argued that the narrow focus on eco-efficiency simply will not suffice. They propose that we have to look at the necessity of the services, and not only at providing the services in the most eco-efficient way. In other words, these researchers talk about the necessity to adjust the "*A*", the affluence, in the IPAT equation. In this relation, the LCA falls short—it is a tool to find the most eco-efficient way to deliver this service among a list of predefined alternatives—not a tool for identifying the importance of various services.

Increases in eco-efficiency are high on the agenda in many companies, not least because of the often accompanying cost reductions, and on this journey there is no doubt that the LCA will be an invaluable tool to show the way. However, at the same time, we have to be open to the possibility that we may need to discuss not only how different services should be provided, but also the more sensitive and political question—whether a service should be provided at all, if we are to ensure that the future generations are given the same possibilities for meeting their needs as we were given.

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