Appendix

A multitude of procedures exists, with which to examine the environmental compatibility of products, facilities and a variety of human activities. In the chapter "Environmental policy today," we wrote about them. Here we have brought together some details about the most important procedures.

Life Cycle Analyses

Of all the different concepts, the term "Life Cycle Analysis" has gained the greatest publicity. The German "Umweltbundesamt," or Federal Bureau of the Environment, has dealt with this issue[1], and in the coalition agreement for the twelfth legislative term of the German Parliament, the "establishment of Life Cycle Analyses through the parliament for the assessment of products and materials" was adopted. The term has begun to stand for all strategies dealing with the assessment and balancing of accounts with respect to environmental effects of human activities.

The idea of a Life Cycle Analysis developed out of the realization that serious distortions could creep into the ecological assessment of processes, goods and services, if all stages and aspects related to these products were not analyzed: raw material procurement, production, use, recycling and disposal.

In anticipation of new processes and products, the consideration of ecological criteria is of considerable importance in order to optimize the spectrum of marketed products over the long term. To actually do that, one already needs to know at the planning stage how each of the considered alternatives affects the environment.

The task force of the *Umweltbundesamt* suggests the following definition of the term:

The Life Cycle Analysis involves the most comprehensive comparison possible of the environmental effects of two or more different products, product goups, systems, procedures or behavioral patterns. It is to aid in the process of uncovering weak points, in the improvement of environmental characteristics of products, in the decision making with respect to both procurement and purchasing, the promotion of environmentally friendly products and procedures, the comparison of alternative behaviors, and the explication of behavioral recommendations. Depending on the underlying question, this comparison may be complemented by other aspects, such as an assessment of the relative efficiency of funds spent for the purpose of environmental protection.

The goal of a Life Cycle Analysis, according to this definition, is not an absolute assessment of a product or service, but rather it is to provide the conditions for making a comparison or optimization. In the ideal case, such an analysis provides detailed information about the entire life cycle of a product, from resource use and production to purchase, use, transport and eventually the disposal after use. It could provide decision making help for someone shopping; helping to cut a swath through the multitude of offerings and the jungle of advertiser promises.

That is the ideal case. In practice, it looks a bit different. Considerable difficulties arise in the commensurability of the available data. The German institutions instructed to make use of this tool are struggling to operationalize the theoretically well-articulated precepts. The existing studies seem to lack the rigor and uniformity to be of use to anyone trying to make a comparison.

If one looks closely at the areas in which Life Cycle Analyses have so far been undertaken, one becomes suspicious as to whether this instrument, which is in principle so important, is not being used to carry on the fight against the "pollutant of the week" at a higher level. Even worse, with the ways in which the "eco-arguments" are gaining a foothold in advertising, the Life Cycle Analysis is being misused as a weapon of persuasion, using un-reconstructable numbers. Nuclear power plants are suddenly ecological saviors because the assessment criterion, "CO_2 emissions," has been so overexposed that all others fade by comparison.

In 1990/91, in a study performed for the European Union, the Institute for Ecological Economic Research (IÖW) in Heidelberg examined 112 publications covering 132 Life Cycle Analyses, most of which were from Germany and Switzerland[2]. Most of these Life Cycle Analyses ended with the conclusion--insofar as they dealt with products--that *one* of the examined products was least harmful to the environment; as it turned out upon closer inspection, it was always the product manufactured by the client commissioning the LCA. The spectrum of topics was highly arbitrary, and could only be explained with reference to the spectrum of popular issues in the environmental debate:

Verpackungen	44,7%	oder	59	Bilanzen
Chemikalien	9,1%	oder	12	Bilanzen
Baustoffe	8,3%	oder	11	Bilanzen
Windeln	7,6%	oder	10	Bilanzen
Abfall und Recycling	3,8%	oder	5	Bilanzen
Geschirr	3,0%	oder	4	Bilanzen
Sonstiges	23,5%	oder	31	Bilanzen
	100%	oder	132	Bilanzen

Let us recall: Life Cycle Analyses, we have said, should provide decision making help before the product is on the market, or before we purchase it. A tool designed to do this cannot possibly be in worse shape than if its methodology is found to be contestable. The reason that packaging studies made up such a large proportion of the Life Cycle Analyses reviewed is actually not that surprising: at least one party would always disagree with the findings, whereupon they would commission a further analysis, either with a different question or with slightly altered data. We don't intend to discredit any of these Life Cycle Analyses, as any number of studies and counterstudies with different results are possible as long as no agreement has been reached on what constitutes a Life Cycle Analysis, and which factors are relevant to such an analysis. With the current situation, all parties can point to inadequacies in the attempts of the others to evaluate a given lineup of products.

Four paths lead out of this dilemma:

First of all, we could decide to forget the whole enterprise, and reassure ourselves that these studies will always reflect the interests of the those who commission them.

Secondly, we could invent a new system of analyzing the life cycle that is absolutely objective--at least in the case in which we use it, or as long as no competing study is commissioned--at which point someone else will produce an even better approach. . . .

Thirdly, we could attempt to standardize the procedure, in the hope of reducing the arbitrariness to a minimum. If it is not possible to eliminate such arbitrariness, then at least we should know at which points the analysis involves subjective criteria.

Fourthly, in setting up a Life Cycle Analysis we could reference a standard that relies on verifiable numbers, with which we can assess the major environmental damage potential of human activities, and which can be applied anywhere on earth with a minimum amount of time and cost required. Such a standard can only deliver a rough estimate. More than this is rarely possible in the economic day-to-day, and for a first assessment of a product, a process, or a service; more is not even necessary, if the standard is selected in such a way that it reliably points in the right direction.

If, after a first screening of the environmental stress intensity, it turns out that more detailed information is required in order to come to a decision, then the analysis can obviously be expanded--with a requisite increase in effort. We have already introduced our candidate for such a standard: MIPS.

For the time being, we wish to stick with the Life Cycle Analyses as they have been discussed and implemented to date. According to the suggestions of the task force of the *Umweltbundesamt*, the third approach listed above can be divided into four stages; into a "standard model of product Life Cycle Analyses"--leading to the standardizationwhich has so far remained elusive.

Step 1: defining the goal of the analysis

This step should yield a clear formulation of the desired results of the Life Cycle Analysis. Not until it has been clearly stated what the goal of the analysis is, what kinds of products are to be analyzed, which aspects are to be ignored, and how the investigation will be spatially and temporally delimited, can the results be either meaningful or comprehensible to those observing.

If products are being compared, this part of the analysis should define what the authors in the *Umweltbundesamt* call "functional equivalence." This means that products can only be meaningfully compared on the basis of their use; in the GATT negotiations, the term used is "like products." In this book, we say that products can only be compared on the basis of the service they provide.

Step 2: the Life Cycle Inventory

The Life Cycle Inventory compiles the database which serves as the foundation for all further work. It should be possible to get away without subjective evaluations. The Life Cycle Inventory consists of four building blocks.

The first block is a *vertical analysis*. The life of a product can be represented on paper in such a way that the initial resource extraction appears at the top of the page, and the eventual disposal of no longer useable garbage at the bottom. Next to each step, we list which materials were taken from the environment, which entered into the production, and which intermediate or linked products result, as well as all accruing wastes.

Linked products are economically useful by-products, the production of which was not necessarily intended. In raising cattle, for instance, manure is generated in considerable quantities. This--often liquid--manure can be disposed of as waste, or it can be utilized as a by-product--as fertilizer. Still, no one would ever raise cattle for the sake of the manure alone. Especially in the chemical industry, much imagination has been devoted to turning by-products into useful linked products.

This vertical delineation of the life stages of a product is the vertical analysis. The product's life stages are divided up into various modules. Each module can be examined separately--independent of the others. It has its own "entrances" and "exits." The product "exit" of one module is associated with the product-"entrance" of the next module. For instance, at the exit of the module "production," the finished product is passed on to the module "use." Therefore, the material flow at the product entrance to the "use" module must be equal to the material flow at the exit of the "production" module. Besides the product entrance and exit, each module has further entrances for auxiliary materials and exits for wastes. These side entrances and exits account for the fact that the material intensity of the product increases or decreases while passing through the module. At the end of the vertical analysis, the results of the individual modules must simply be added together. The point of the subdivisions into modules is to simplify the analysis. A "transport" module can, for instance, be used in other contexts--naturally using different data. Furthermore, the total analysis can be more easily corrected, by substituting other numbers at the requisite--and easily located--stages.

One problem already appears in the context of the vertical analysis, and will accompany us through the entire Life Cycle Analysis: we must decide what we *don't* want to take into account. Many modules and material flows that one would want to consider in a precise analysis increase the effort considerably, but they do not necessarily increase the accuracy of the results. Some examples: If the goal of a Life Cycle Analysis is to compare a digital with an analog wrist watch, is it important to consider the watch band, even though it is the same in both cases? Is the drop of lubricant on a bicycle or sewing machine a material flow that will decisively alter the analysis? Can I perhaps even omit entire modules from the analysis because they scarcely change the material flow analysis, compared to the others? One example would be the construction of factories in which products are manufactured. Finally, are there phases or material flows about which I am unable to obtain any information, that I must consciously leave out? The vertical analysis must make clear where the limits of the analysis are to be.

It is always risky to delimit one's evaluative territory. It is very difficult to know ahead of time how significant a partial material flow is going to be. In order to exclude it, one must have a fair idea of how large and how relevant it is. Therefore a rough estimate that includes all partial material flows is necessary. Even after that, however, such delimitations can be problematic. Once the decision has been made to exclude several small material rivulets, it could well be that--taken together--they amount to a considerable flow.

The greater the experience with Life Cycle Analyses , the greater the certainty will be as to where such delimitations should be made. Basically, it is better to include as many of the secondary or partial flows in one's analysis as possible. In order to keep the effort as small as possible, it would be sensible to create uniform data sets for those partial flows that occur repeatedly.

If, as we suggest in this book, material intensity is adopted as the standard measure of environmental burden through products, processes and services, many of these problems cease to be so important. For instance, it would not be necessary to assess the relative ecological risks of partial material flows because the material intensity implicitly contains such a risk assessment already.

The second building block of the Life Cycle Inventory is the *horizontal analysis*. This analysis concerns itself with the aforementioned side entrances and exits of a module; in other words, with the primary energy input, the raw materials, the water for cooling or cleaning, etc., as well as emissions into the air, effluents and solid waste.

The third building block is the consideration of the life span criteria. It takes into account a linking of the modules. To remain with our graphic analogy of the Life Cycle Inventory, the "arrows" connecting the modules are examined more closely here. Some of them--as in the case of recycling or reuse--may also point in the other direction. A simple linkage of the "use" module exit and the "disposal" module entrance conveys nothing of the length of time the product was in use, or whether is was, or could be, repaired. A simple linking of "production" and "use" does not show whether the user received the product in good condition, or whether it was packaged in such a way that it quickly spoiled. And it is also important for the Life Cycle Analysis to know whether a product that was produced with greater material and energy effort isn't perhaps especially environmentally friendly or easily recycled or reusable for just that reason.

Data must be collected for all these vertical and horizontal analyses and life span criteria in a Life Cycle Inventory. The effort required to do this can be considerable, even if the delimitation criteria are selected carefully. One of the many problems associated with undertaking a Life Cycle Analysis is coming up with all of the data. The more controversial the product or service is, the less likely an agreement with respect to which categories should be eliminated will be reached. This will lead to ever more modules and the inclusion of ever more material flows.

The effort increases in step with the differences between the services that are being compared. It should be fairly easy to compare a bicycle with an aluminum frame to one that has a steel frame, as the service they provide is roughly the same. But even the seemingly straighforward comparison of reusable and disposable packaging requires the compilation of two different data sets. Reusable packaging often has to be cleaned with aggressive chemicals to meet rigorous hygienic standards. In the case of disposable packaging, this item does not show up at all. Instead, one has to look very closely to what happens to them in the incinerator. A very thorough set of data is required for both modules (cleaning and incinerating). Such data collection really becomes difficult when the environmental effects of different services such as transportation by highway, rail, air or water are to be compared.

This undertaking leads to a careful consideration of the fourth building block: the *selection of the data*. Perhaps the most difficult problem in conjunction with performing Life Cycle Analyses is that both in setting up and evaluating them, it often cannot be determined from where the data came, or the data are deemed incommensurable because they were obtained using different methods. The task force of the *Umweltbundesamt* in charge of evaluating the implementation of Life Cycle Analyses found the data to have been selected more or less at random.

We mention here an example of the attempt to arrive at potentially consensus-reaching data, for several reasons, not the least of which is that the scientists involved did an exemplary job of delimiting their methodology. The case is one of the many Life Cycle Analyses of packaging systems. The results were published in September of 1992[3].

The authors indicate that "the order of magnitude of environmentally relevant substances contained in the air and water known to humans is 100,000," the precise number being considerably higher. They go on to point out:

> *Simply for practical reasons it is impossible to include all materials, even if this were theoretically desirable. It is not feasible to include all environmentally active quantities in setting up an LCA. The next question is which quantities to include.*

The authors see themselves in a dilemma--the same one in which all who try to put together an LCA find themselves: one can decide at the outset which kinds of data one will admit into the analysis, in which case it is understood that some kinds of information will not be considered. This may or may not precipitate serious assessment mistakes. Or if one wishes to avoid this and leaves the list of admissable information open, then an unrepresentative result is likely. In that case, it is also probable that the product about which the most information was obtainable will fare the worst. Other products, that may not have been examined previously, fare well, simply because one has less information about them.

In order for the results of LCAs to be more transparent, the *Umweltbundesamt* has suggested establishing semi-official databases. It is imaginable that an internationally recognized organization could be put in charge of maintaining them. These databases would include the kind of information that are always needed in LCAs--so-called *general data*. This could consist of data-sets about the environmental burden associated with, for instance, the transport of one ton of goods by rail, highway, water and air, or information about comparable manufacturing procedures of paper, steel or other mass-produced goods. Transport, paper and steel will be needed in a very large number of LCAs, so a considerable simplification in the whole undertaking would occur if everyone could at least reference the same data in these categories.

Alongside these general data, each LCA also requires specifically calculated data, that describe a particular manufacturing process or certain characteristics of a product. Such information is frequently only to be had from within the company in question. In many cases, such information belongs to the well-kept secrets of the firm. They protest any attempts to publish such data, for the understandable reason that they may lose what little advantage they have over the competition. An LCA that relies on such data is self-evidently not going to be verifiable.

In the long-run, however, this cannot be in the interest of the companies either. The LCA as an instrument would by then be so discredited in the public's view, that it would only be useful for internal optimizations. Firms can voluntarily help to guarantee a minimum of verifiability and still maintain industry secrets. They could pass such information on to a "scrambling authority," entrusted with guaranteeing the anonymity of the information, while making it available to those compiling databases for LCAs. No firm-specific details would need to leak to competitors in this arrangement.

The Life Cycle Inventory becomes difficult when the boundaries of the study must be drawn very wide, or when the behavior of the user, that can only be roughly gauged, might influence the result in important ways. Other, equally difficult problems should not be understood as part of the Life Cycle Inventory. These include the determination of relative toxicities, aspects of convenience and user-friendliness, or quantifying the risk-potential (nuclear energy).

Step 3: the Impact Assessment

In the strict interpretation, the Impact Assessment is supposed to compile data just as the Life Cycle Inventory. These data are supposed to describe how the material flows that were included in the Life Cycle Inventory affect the environment.

Several problems emerge in this context. The most obvious is that we don't know a thing about how the majority of the 100,000 or more chemicals that are moved about in the economic cycles affect the environment. The Impact Assessment is therefore the point in the LCA where the most current, but still preliminary, knowledge about the metabolic activity that goes on between humans and nature enters the picture.

The second problem: the Life Cycle Inventory compiles the materials which are created during the life of the product and are passed on to the environment--the emissions. But emissions are not what hurt plants, rivers and buildings. Immissions do that (what is *received* by plants, rivers and buildings). This is not necessarily the same thing. Dilution, breakdown and chemical transformation can completely neutralize the environmental effects of a substance, or they can make entirely new effects possible. What happens in particular cases is either not to be determined at all, or only with considerable difficulty. If the Impact Assessment is set up using the emissions data from the Life Cycle Inventory, great care is in order.

The third problem: the Impact Assessment is supposed to pair each material or process with one or more environmental effect(s). This requires there to be an identifiable cause and effect relationship. But such an effect is a function of when and where the material was released into the environment. A simple example from an engineer at the *Umweltbundesamt*[4] serves to illustrate this:

Which environmental repercussions are to be associated with the discharge of thirty-five ml of salt per liter of water?

Answer: it depends! If the saline solution is released into the North Sea then it should be appreciated as a discharge of uncontaminated water (as 35g/l is the exact concentration of salt in the North Sea). It would be irrelevant in most any quantity. If, on the other hand, it were discharged into fresh water somewhere, the ecological effects could be catastrophic at even small amounts.

In the Impact Assessment, each material is to be paired with so-called impact-indices, which, taken together, describe the environmental damage potential relative to others. A simple example: when burning petroleum, 1.4 times as much CO_2 is produced than when burning natural gas. While CO_2 is, in principle, a "harmless" gas, it does contribute to the greenhouse effect, warming the earth's surface. When the criterion is "reinforcing the greenhouse effect," petroleum is thus 1.4 times as harmful as natural gas. In the case of anthracite coal, the effect-index is 1.8, and for lignite coal it is 2. If one were to compare the four fuels with a different effect-standard: the overburden generated in the context of resource extraction, for instance, or the dangers posed to wildlife in ecologically sensitive coastal areas, the weightings would obviously be divided differently. A comparative judgment is only possible once a comprehensive view of all effects has been achieved.

But what are "all effects"? Or, less ambitiously, what are the most important effects? We have already noticed in the section on Life Cycle Inventory how difficult it is to remain on firm terrain. In moving to Impact Assessments, we have now unequivocally encountered the slippery slopes of subjective, interest- and time-dependent judgments.

At a 1991 workshop of the Society of Environmental Toxicology and Chemistry (SETAC) the following list of significant effects was suggested[5]:

- global warming
- ozone depletion in the stratosphere
- human toxicity
- environmental toxicity
- acidification of waterways
- discharge of oxygen-binding chemicals into waterways [chemical oxygen demand (COD), leading to a "turning over" in waterways]
- formation of photo-oxidants (summer smog)
- surface area demand
- disturbances (smell, noise)
- occupational safety
- solid wastes (dangerous and non-dangerous)
- effects of waste heat on bodies of water.

Should we therefore examine 100,000 chemicals for their ozone-destructive potential? That would be absurd. So what qualities should we examine in which chemicals? And besides, why is noise on this list? Are we interested in it for ecological reasons?

We do not wish to examine this list in detail, but the first two points, the ones SETAC deemed most important, are worth mentioning briefly: global warming and ozone depletion. In the mid-eighties, neither of these points would have ever made it to the top of such a list--in all likelihood they would not have placed at all. Within less than a decade, these two points have advanced to the head of the list--and not merely in the public eye, but in international scientific debates as well.

Without a doubt, in today's view, these two points belong to the most powerful environmental problems generated by human activity. But how can we know that in, say, ten years they will still be the most important? How can we know what the state of our knowledge will be in ten years? If we do not know whether these two points will still head the list in ten years, what do we hope to gain from LCAs that are based on such a hierarchy?

If LCAs are to fulfill their mission, they must be developed today, implemented tomorrow, for the products of the day after tomorrow. Should we not formulate priorities that are less dependent on the most recent discoveries and the potential for the public to get excited over them?

To guard against any misunderstandings: even a "rugged" catalogue of priorities is still obliged to register a highly visible "minus" in the LCA every time a chemical change in the earth's atmosphere occurs. We should have no doubts about that. But as long as we concern ourselves with individual effects of human activities on the environment, lists like the one above will either get longer and longer, or they will be ever-changing, and no less able to prevent surprises down the road. We need a criterion that is more general and that will guarantee an estimate that comes down on the right side of the fence. Material flows are well-suited to defining such a criterion that at least always points in the right direction. If material flows that are induced through human activity, including those material flows that are displaced in the context of providing energy, are made the criterion for environmental burden, then automatically the outcome will identify the emission of large amounts of CO_2 into the earth's atmosphere as an environmental problem. At the political decision making level, the outcome would likely be the same. This outcome, however,. would have been obtained independent of the most recent discoveries regarding the temperature gradients in the atmosphere. This is exactly the point. Only this independence from current discoveries can give us the chance that our decisions today will still be correct tomorrow. It is a chance, and no more.

Step 4: the Balance Assessment

In the Balance Assessment, conclusions must be drawn from the work compiled up to this stage. As the name implies, relevant judgments must be made that can be used in political decision making. This step is particularly difficult to carry out with objectivity. For that reason, it should be carried out separately and with the utmost care.

At the conclusion of both the Impact Assessment and the Life Cycle Inventory it is very likely that enormous amounts of data will have accumulated. The LCA-task force that has already successfully generated a conclusive statement from these data is to be commended! In that case, two or more fairly similar products may have been compared. One of them was obviously superior in environmental respects, without exhibiting any negative qualities when compared to the others. In such a case, the LCA is completed; the result is easy to formulate.

In reality, this will occur only in exceptional cases. It is more realistic to take the worst of all possible cases: each of the examined products has advantages and disadvantages, and the plusses and minusses are as randomly distributed as if someone had applied them with a salt-shaker. In such a case, an entirely new and difficult set of questions arises:

- which environmental disadvantages are so weighty that products which exhibit them should be disqualified unequivocally?
- are there environmental advantages that make up for an environmental disadvantage? According to which criteria is this to be decided?
- in general, is it possible to add up the plusses and minusses in such a long list? In

other words, can one compile the many effect-indices into a total index?

It would be ideal if such a summation were possible--giving out eco-points, as it were. The product (or the service or process) with the most points would then be selected. But how is one to commensurate, for instance, toxicity, surface area demands, greenhouse potential and the pollution of waterways on one scale?

Several different procedures exist for setting up such scales. But all have their limitations. They generally postpone the problem of making a value judgment and do not actually solve it. For example, some attempts focus on defining critical loads or a maximally permissible load, while registering the load generated by a product or process as a fraction of these thresholds. But how much of a pollutant can a body of water, the air or the soil "take"? And if other pollutants enter the picture, does that change the level considered acceptable? If so, in what way? All of this is either unknown or disputed. Similar problems arise in the context of trying to express the expected environmental burden in monetary units to make comparisons easier. Besides, these methods can only reflect the degree to which water, air and soil are changed through the discharge of *pollutants*. The fact that humans themselves displace water, air and soil in ecologically relevant quantities is not captured at all in this approach.

Life cycle analyses, as they are set up today, try to take into consideration a multitude of influencing factors, as no simple measure exists with which to measure environmental stress. The larger the number of factors that are included, the more difficult it becomes to evaluate the result. Therefore, only one method exists to date for assessing such an analysis, that guarantees a minimum of transparency, if the authors go to the trouble: a verbal-argumentative assessment. Just as the goal of the LCA is to be delineated in clear and straightforward terms, the conclusion can also be articulated in an understandable manner, a step or two down from the scientifically measurable world and into the realm of assessment, judgment and contemplation. In this line of argument, we obviously have to do without "eco-points" that make presenting a winner of the competition an easy matter. But along these lines, the authors are first of all forced to lay open their criteria, and secondly, every LCA that uses this procedure cannot hide the difficulties involved in reaching a final assessment.

One can go a step further, and leave the balance assessment to a group of experts from a variety of fields, previously uninvolved with the procedure. This procedure, which does not sit well with scientists used to precision--having the air of a vote--is no longer uncommon in the realm halfway between science and politics, and it increases the credibility of an analysis considerably. On the other hand, this procedure is very time-consuming and expensive. To make it the standard would likely burden the LCA as a tool even more than the enormous demand for data already does. (The Intergovernmental Panel on Climate Change, or IPCC, is an example of a group entrusted by the UN with the assessment of the data on climate change).

Product Line Analyses

We already furnished a definition of this term in the chapter "Environmental policy today." The goal of a Product Line Analysis is to expand the LCA in one aspect that is usually (deliberately) excluded there: the behavior of consumers. Going beyond the assessment of material flows, the Product Line Analysis asks about the usefulness of a product and about consumer habits. A Product Line Analysis is therefore not merely charged with comparing existing products, as in the case of an LCA, but with rendering abortive societal developments visible and charting alternatives to deeply rooted consumer habits.

The danger of drifting off into the sphere of valuation and ideologies is fairly high here. We have shown in the section on LCAs in this Appendix how difficult it can be to agree on a unified and comprehensible procedure for such evaluations. All efforts of those working seriously on LCAs are geared toward excluding subjective and interest-bound influences, as otherwise all hope would be lost in trying to make LCAs an instrument for assessing products, recognized and accepted across interest groups and even across national boundaries. Such efforts are definitely not helped by having socially existing conditions measured according to the yardstick of what is deemed ecologically desirable.

It is thus not surprising that the *Umweltbundesamt* considers the expansion of the LCA into a Product Line Analysis to be neither desirable nor feasible. One would have to agree, if, as we argue in this book, it is considered desirable to find a simple measure of ecological stress that can be integrated into our everyday lives. Every form of social assessment will serve as a hindrance to reaching this goal, as it is generally very difficult and often impossible to achieve any kind of societal consensus on these kinds of assessments.

On the other hand, especially the people in the industrialized countries won't get around having to rethink their consumption patterns--and re-*thinking* won't be enough, either. As long as wealth is so closely allied with material possessions and the consumption of raw materials, as is presently the case in industrialized nations, an ecological optimization of products alone will not suffice to reach the goal of stabilizing the biosphere. More will be necessary to achieve that, something we have called a "new conception of wealth." LCAs or any of the other procedures for determining the least ecologically harmful of the wide array of products and services will never lead to a change in consumption patterns, or to a new, more ecologically benign concept of wealth. But they can be an important step in the right direction and should therefore not be burdened with too much ballast before they have gotten a chance to lift off. That which holds true for LCAs also holds for any extensions. Collecting and summarizing data should be carefully separated from questions of valuing. Thus a Product Line Analysis as an extension of an LCA is only appropriate if the LCA itself can be set up as a separate, and separately useable, module.

Environmental labelling

The "Blue Angel," invented by Edda Müller more than fifteen years ago, and awarded jointly by the "environmental labelling jury," the *Umweltbundesamt* and the "German Institute for Quality Control and Labelling" (RAL), has become a trademark and a much-used decision making aid.

In 1992, the European Union decided to introduce a similar label in all EU member countries. In the corresponding regulation, tests are required that essentially turn out to be LCAs. The environmental label is thus no more than the attempt to focus the results of an LCA on a radically simplified system of "eco-points." It isn't exactly a surprise that the *Umweltbundesamt* has to field so many complaints about the "Blue Angel."

If an LCA has been performed, then at least the significant environmental effects of the product should be known. If, in addition, it is possible to ascertain maximum allowable limits for these effects, then perhaps it could be determined where on such a scale--or set of scales--a tested product should be classified. If, then, certain products stand out by remaining far below the maximum levels in all categories, they deserve the environmental label. As an LCA is the basis for awarding such a label, they both share the same problems and points of contention. They need not be repeated here.

Someone who considers the automobile to be the worst environmental evil will naturally shake their head if a car company or model receives the "Blue Angel." (This has happened, but in the meantime cars can no longer be awarded the label). This head-shaking can be the expression of a simple misunderstanding, a very widespread one at that, namely that the label expresses an absolute valuation. But that is, as we have pointed out, not the purpose of the labelling scheme. It renders more visible a comparison. It declares that a certain product exhibits certain narrowly defined characteristics, which, in a comparison with other functionally equivalent products, make it ecologically preferable. These need not even be "ecological" qualities. A lawnmower that is particularly quiet is more pleasant for the user and the neighbors, but it reduces a form of environmental stress that has no significant effect on the ecological coherence of a given system. The ecologically problematic thing about the lawnmower is precisely not the noise, but the production of a material intensive appliance with production runs in excess of several hundreds of thousands, that is then only used for a few hours every month.

The head-shaking can also signal deeper and very justified doubts. Precisely because such environmental labels are accepted by consumers, they have a considerable directive power in the market. A product with an environmental label is bought more frequently than others that lack it, and the competition orients itself according to the standards of the labelled product. This is good, as long as the ecological standards are wisely chosen. If the standards are a bit off, then the results of the LCA will also be a bit off, and the environmental label points the market in the wrong direction.

But even this is not fundamentally an argument against an environmental label. It is an argument for quality LCAs, for comprehensible, clear standards in the context of registering and assessing environmental effects. If such standards were in place, much could be said in favor of environmental labels. On the path to an ecologically transformed, sustainable economy, it will be necessary to provide producers and consumers with simple and easily grasped signals like the environmental label we have been discussing. The market reacts first and foremost to price signals, and from an ecological perspective, these signals presently point in the wrong direction. Environmental labels can--in the transitionary phase of ecologically false prices--serve as substitute signals to the market's "invisible hand"--the consumers. The Blue Angel has already proven itself, if for no other reason than that producers and consumers can be motivated to react to an environmental signal within the economic sphere. It would be highly appropriate if this signal were awarded according to comprehensive and directionally stable standards.

It is essential that scientists try to understand the full complexity of the interplay between humans and the biosphere. But if these discoveries are not finally summed up into a simple measure that can prevail in the day-to-day, then it is not very likely that these efforts will bear fruit in the political realm and in people's everyday lives any time soon. It becomes all the more important to carry on the discussion about such a handy and directionally stable measure. The result of such a summary will always be something that resembles an environmental label.

Environmental audits

It can turn out to be sensible for a firm to examine production facilities and procedures for their environmental effect for two reasons: First of all, a reduction in environmental effects is an increasingly effective advertising argument, and secondly, it is not at all unlikely that economically relevant weak spots will appear. "Environmental auditing" is thus employed by an increasing number of firms to ferret out internal weaknesses. Often such an examination is the first opportunity for examining the energy and material flows that flow into and out of a firm--at least in the comprehensive sense required by an environmental audit. In doing this, it is also possible to detect emissions into the air and discharges of effluents into the water, that were perhaps never before registered in the cost calculations, having played no economic role.

In this sense, an environmental audit is a systematic and regular examination of the environmental stress intensity of a firm, with the goal of finding ways to improve the situation. Examined areas could include the following:

- purchase selection, from the materials used in offices all the way to the investment in machines, facilities and buildings;
- reduction of material and energy flows for operating the facilities;
- marketing the manufactured products and services offered, from the use of advertising media and transport procedures and hauling distances to the arguments used to sell the products;
- improvement of the ecological quality of the products and services offered;
- architectural/constructional changes to the facilities and their immediate environs, such as parks, recreational spaces and access roads;
- influencing staff and their families to consider more ecological behavior in the private sphere; a firm can offer consulting services here;

Environmental audits can supply valuable information on a higher level for a restructuring of the economy. Nowhere else is information generated on the amount of material and energy that is displaced for the production of a good or service. From an ecological perspective, this should be an important optimization criterion for the economy. The fact that it is not, at present, and that environmental audits are necessary at all, is a particularly striking example of how imperfectly the market is operating. In a competitive environment, capital and labor costs must be minimized if a firm wishes to keep up. The costs of raw materials and energy, on the other hand, are so very low that the market mechanisms fail at this level.

Materials Reports

Materials Reports are supposed to describe the effects of a chemical compound on humans and the environment according to a differentiated matrix. This matrix is predicated upon existing international conventions. In the eighties, the OECD put forth a suggestion that was subsequently adopted by the WHO. An EU guideline lays out the criteria according to which a material is to be categorized as "dangerous to the environment," while Germany's own category of "water-quality-threatening materials" is divided into four sub-categories. The German *Chemikaliengesetz* dictates that chemical compounds should be tested with the help of four indicators:

1. How strong is the exposure of the environment to the compound? The "exposition" is gauged according to how the compound distributes itself, how it enters the environment and how heavily it is concentrated in the respective introduction sites.
2. How does the compound degrade? Are chemical reactions the basis for its decomposition, or do biological processes take care of this? How quickly is this accomplished, and which decay products emerge?
3. Does the compound accumulate in the environment? Among other characteristics, the solubility in fat and other means of accumulation in biological organisms are examined.
4. How does the compound react in the environment? In these tests, certain organisms are exposed to the compound: water fleas, earthworms, certain fish, algae and some higher plants. The ability of the compound to change the genetic makeup is tested for in particular.

A materials report is supposed to represent as comprehensive a Impact Analysis as possible, but it is not intended to provide a materials balance from cradle to grave. Resource extraction, transport, manufacturing and disposal are not taken into consideration. A materials report can be considered one of many building blocks of an LCA.

[1.1] Umweltbundesamt, Ökobilanzen für Produkte--Bedeutung, Sachstand, Perspektiven. eds., (brochure) Berlin, 1992.

[2.2] Frieder Rubik and T. Baumgartner (IÖW Heidelberg), Evaluation of Eco-Balances. A publication in the context of the SAST project of the EU, No. 7, September 1992.

[3.3] Projektgemeinschaft "Lebenswegbilanzen", Methode für Lebenswegbilanzen von Verpackungssystemen. München, Heidelberg, Wiesbaden, September 1992.

[4.4] Stefan Schmitz, Sachstand Ökobilanzen. Kurzfassung eines Vortrages beim Journalistenseminar "Ökobilanzen" der "Information Umwelt" beim Forschungszentrum Mensch und Umwelt (GSF) in Heuherberg by Munich, 10 February 1992.

[5.5] Umweltbundesamt, Ökobilanzen.

Glossary

Biosphere The totality of all life on earth, including all habitats.

Capital In the language of economics this consists of the total assets in money, machines, facilities as well as land. If only the monetary portion is meant we speak of financial capital.

Capital productivity The amount of goods or services that is produced per given unit of capital employed. If the same product can be produced in the same quantity and quality on two different machines; using the cheaper of the two machines yields a greater capital productivity.

City-car

Directional stability If the outcome of a comparative analysis yields enough information to reliably rank the various entities compared, we have directional stability.

Dissipative The use of a material within the environmental media air, water and soil in such a way that it cannot be retrieved. This includes paints, agrochemicals and other like substances.

Ecology Ernst Haeckel's definition follows:

> By ecology we mean the body of knowledge concerning the economy of nature--the investigation of the total relations of the animal both to its inorganic and its organic environment; including above all, its friendly and inimical relations with those animals and plants with which it comes directly or indirectly in contact--in a word, ecology is the study of all those complex interactions referred to by Darwin as the conditions for the struggle for existence (translated in Allee et al., 1949, Principles of Animal Ecology. Philadelphia, Saunders.).

Eco-toxicology A branch of **toxicology**. Eco-toxicology concerns itself particularly with the effects of toxic materials on ecological coherence.

Efficiency The level of effectiveness with which available means are employed (in contrast to **productivity**).

Environmental media Soil, water and air are meant by this.

Externalities The side-effects of a production process or activity which do not have any direct bearing on the process--that do not register in either a technical or a monetary way with the producers--are considered external effects, or externalities. The public is often burdened with such externalities over long periods of time. Externalities of smoking, for instance, are the health risks of "second-hand smoke"; an externality associated with burning fossil fuels is the deterioration of historic buildings through airborne pollution. Internalizing externalities can be accomplished in several ways. One way is to raise the price of the respective product, thereby informing the consumer of the "price" which society had previously been paying in ecological or health terms.

Green Dot (Grüne Punkt) The system of

Greenhouse-effect When sunlight reaches the earth it is converted into heat and is reflected back into space. Some particles of the earth's atmosphere, especially water vapor and CO_2, succeed in retaining some of that heat. If we did not have this natural greenhouse-effect, the average temperature on earth would not be 59 degrees F, but about zero degrees F. Humans are in the process of changing the amounts of several important greenhouse gases. Included in this list are carbon dioxide, methane, nitrous oxide, CFCs and ozone. In this fashion, the natural greenhouse-effect is complemented by an anthropogenic one--capable of changing the climate of the earth.

Labor productivity Measured in the amount of goods or services produced per hour and per working person. Labor productivity can be raised by increasing the **efficiency** with which the available labor force is utilized. Much larger increases are usually brought about in the course of introducing entirely new modes of production (machines, organization etc.). Such an increase can lead to a **productivity revolution** or an **eco--efficiency revolution**.

Law of Mass Action A law of chemistry, formulated in 1867 by Guldberg and Waage. It describes the processes occurring within a mixture of different substances that react with each other. The law states that the concentration of the various starting substances and the products already obtained determine the direction of the chemical reaction.

Nanogram A unit of measurement. The prefix **nano** means "one-billionth."

OECD Organization for Economic Cooperation and Development. Twenty-six countries are members, including. . .

Person-kilometer A unit of hauling capacity. If a person is transported one kilometer, the hauling capacity of one person-kilometer was accomplished. It is effectively the same, whether two people are transported one kilometer, or if one person is transported two kilometers (see **Ton-kilometer**).

ppm The abbreviation for parts per million. The parts of one substance as a fraction of one million parts of the other substance.

Productivity The ratio of goods or services produced per quantity of inputs. While **efficiency** describes the effectiveness with which the available means are employed, productivity only measures the result--the yield in products or services, independent of the means.

Resource productivity This denotes the quantity of goods or services produced per unit of resources (material or energy) employed.

Technosphere The subset of the **biosphere** which includes all changes and technology attributable to humans.

Ton-kilometer A unit of hauling capacity. It is equal to hauling one ton of goods for one kilometer.

Toxicology This is the study of toxins and their effects.