FACTOR 10
ECOLOGICAL RUCKSACKS
AND MIPS

F. Schmidt-Bleek

Translation of the book

WIEVIEL UMWELT BRAUCHT DER MENSCH, -
MIPS, das Maß für ökologisches Wirtschaften

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Translated by Reuben Deumling
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Factor Ten Institute

Contents

PREFACE

You have before you the English translation of the first extensive account of the Factor Concept [1]. And here is a bit of history how Factor 10 came about:

It was in 1989 when I realized that our approach to environmental protection could not get us to sustainability. Lack of progress demanded that we had to re-consider getting involved in solving one isolated problem after the after. Our attention had to be switched from the emission side of the economy to the enormous consumption of natural resources. Only this way we could control the outputs and make the right decisions before the damage was done and payments for it became due. And what about energy? Shouldn't we begin to worry about its material intensity, rather than limiting our focus on the associated emissions, like SO_2 and CO_2?

It was a difficult and exciting time. Hardly anybody believed that maintaining a stable ecosphere would require dramatically reducing the use of resources. Factor 10 I said was the average reduction goal for rich countries! What I claimed was that we should measure environmental stress potentials of goods and services with a balance rather than - or at least in addition to - with a gas chromatograph or a mass spectrometer. Megatons, so I declared, were our overriding problem, not nano-grams. And the ecological rucksack was to be the new yardstick for the production of dematerialized goods, and its big brother MIPS for assessing their whole life-cycle.

Ernst von Weizsäcker gave me a chance to solidify my model at the newly created Wuppertal Institute. To some degree he even believed my ideas. As is well known: he reached out for factor 4 later when he began writing about resources and energy. When you ask him about that, he will tell you that a tenfold improvement has to be reached in the long term. His earlier finding that prices do not speak the ecological truth is as true today as ever. And as long as this is the case, sustainability is but a dream.

In my endeavors at Wuppertal I got selfless competent help from young colleagues who had the guts to stand up to doubts, ridicule and even abuse from inside and outside the institute. Without being able to name them all, here are those who made vital contributions early: Stefan Bringezu, Friedrich Hinterberger, Harry Lehmann, Christa Liedtke, Christopher Manstein, Helmut Schütz, Joachim Spangenberg, Hartmut Stiller, Ursula Tischner, und Jola Welfens. I am grateful for their help in bringing my model to life. Without them a large basket of publications would not have appeared, convincing the world slowly that resource productivity of goods and services play a decisive role *if* a future with a future is to be gained.

Lately, industry and the ministers of economy have begun to worry seriously about the continued availability of natural resources. Welcome to the debate on a limited planet earth! One can only hope that nations will *not* apply economic power ruthlessly in the struggles ahead. The poor people would be again the ones to pay the price. And ecologically as well as economically we would continue to move away even further from sustainable conditions.

During the past 20 years we have shown in many enterprises that a radical reduction of resource use for goods and services must *not* lead to a loss in end-use satisfaction.

But the big question stubbornly remains: what does it take for finally breaking away from the old ways and move toward a new economic reality?

---

[1] F. Schmidt-Bleek, "Wieviel Umwelt braucht der Mensch; MIPS das Maß für ökologisches Wirtschaften", Birkhäuser, 1994

SOME CENTRAL POINTS of the text before you

*Humans are in the process of calling into question
the livability of the only earth they have.*

*In order to bring about a sustainable economy
we must approach both: we must search for new models
of prosperity and better technical solutions
for the satisfaction of our machine-dependent needs and wants.*

*Because the markets cannot
by themselves internalize environmental cost,
it is necessary to establish appropriate environmental laws,
institutions and policies to do so.*

Joint declaration by the IMF and the OECD, 1991

*Free trade with today's goods
subsidizes the destruction of the environment.*

*Low prices lead to careless consumption.
People save only where it is rewarding to do so.
Ecologically intact nature has no market price,
at least none that would give it a chance in competition
for use as industrial or residential areas.*

*We must dematerialize our western economies
by an average factor of 10 or more,
as well as de-energize them,
if they are to be sustainable.*

*From a technical perspective,
an average dematerialization by a factor of ten
is realizable in many cases.*

*There is no reason why the social and technical developments
of the next fifty years should be any less exciting
than those of the last fifty.*

*Environmental policy deals most frequently
with the ends of a human activity,
eco-policy deals with the beginnings.*

*The environmental detriment of energy use
does not follow from the environmental dangers of energy.
The energy flows set in motion by human activity
are only of marginal ecological significance.
The problem stems from the material flows
associated with the provision and use of the energy.*

The measure for the environmental stress intensity
is the Material Intensity Per unit of Service
with respect to the entire product life:
in other words, the material consumption
from the cradle to the cradle per unit service or function--MIPS.

Lazing in the sun or feeding fish is always
ecologically preferable to riding a motorcycle.
Meditation and contemplation don't require any fossil energy.

All services require some hardware,
but many services are necessary
if hardware itself is to be of any use.

Orio Giarini and Walter Stahel, The Limits to Certainty—
Facing Risks in the New Service Economy. Dordrecht, 1993.

As long as economic growth and material wealth
are equated in popular belief and behavior,
an ecological economy will not be possible.

ABOUT ENERGY

In the public debate over the state of the environment, energy has always played a major role alongside the focus on pollutants. From an ecological perspective the consumption of energy as such is only secondarily relevant. The material flows associated with the transportation conversion and consumption of energy are what precipitate the important environmental effects. In this context the energy intensity of economic goods and services becomes an ecological question of their indirect and direct stress potential.

Introduction

Rachel Carson's book, Silent Spring[1] was an early warning: watch out, folks, you're poisoning the environment--and with it you

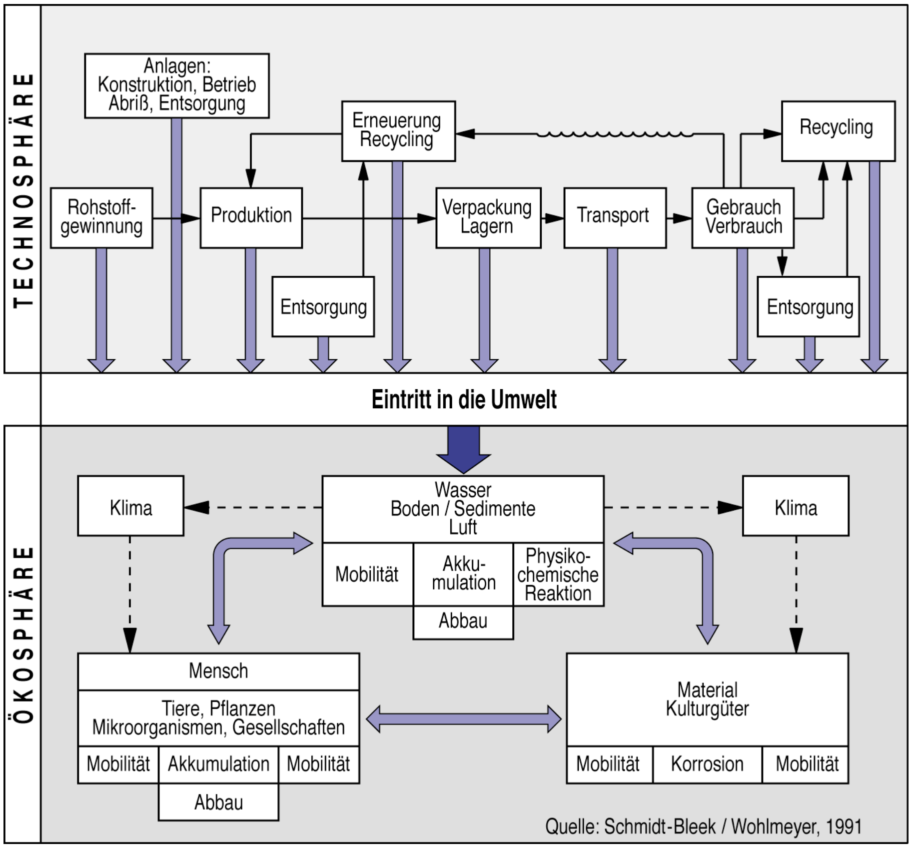
That was about forty years ago.

Ten years passed before Europe began with its environmental policies. Let us take a look at what these policies were like.

The concern for reducing the emission and introduction of "dangerous" substances into the soil, air and water was uppermost. Alarmed by the degree to which humans and other lifeforms were found to be already poisoned, lawmakers in many countries began to regulate and restrict the introduction and discharge of anthropogenic chemicals into the environment. The list included DDT, phosphates, nitrates, sulfur dioxide (SO_2), Nitrous oxide (NO_X), mercury, lead, cadmium, dust, chromium, asbestos, PCBs, pentachlorophenol and others. The rationale behind these attempts was usually a concern for the health of constituents, and so the policies targeted those chemicals which threatened people's health. No economic sphere was left untouched: construction and demolition of buildings, production of goods, energy transformation, provision of services, transportation, packaging, goods themselves, as well as their use and "disposal" (Fig.1).

Many people are of the opinion that not enough has been done, that we have been too cautious about avoiding environmental hazards associated with anthropogenic substances. It is true that to date the use of only a small number of those tens of thousands of synthetic chemicals has been in any way restricted or regulated out of concern for their effect on the environment. It is true that this problem must continue to be a focus of ongoing research, especially with respect to certain categories of chemicals, such as those which contain chlorine.

FIGURE 1



Above all it must be emphasized that without the unfailing initiative of citizens' action groups much less would have been accomplished. But let us also not forget that in working closely with citizens and the chemical industry we began work on the *Chemikaliengesetz* (the German law regulating the production and use of chemicals) and in the mid seventies, long before the news media and sometimes even politicians made it their business to discover the "chemical of the week."

In the public debate over the state of the environment, energy has always played a major role alongside the focus on pollutants. From an ecological perspective the consumption of energy as such is only secondarily relevant. The material flows associated with the transportation, conversion and consumption of energy are what precipitate the important environmental effects. In this context the energy intensity of economic goods and services becomes an ecological question of their indirect and direct material intensity.

Let us summarize: one of the primary goals of environmental policy for the last twenty years has been to curb the introduction of known pollutants into the environment and to bring about extensive restorations. The threat to human health was a primary concern. "End of the pipe" technologies proliferated; referred to as such because they were developed with the goal of separating out the effluents and pollutants generated by existing production techniques and processes at the point of their emission (at the end of the sewage pipe). As it is impossible to destroy matter, these technologies were designed to render the pollutants harmless through burning, or to detoxify them chemically--as with the catalytic converter in the automobile--or to keep them from entering the biosphere through a filtering system. Technically elegant methods were also devised with which to remove contaminants involved in chemical spills of one kind or another.

Additionally, very powerful analytical procedures were developed with which pollutants could be measured in the most minute concentrations, as long as it was agreed upon in advance which substances were being looked for.

This policy of tracking emissions was both necessary as well as quite successful. It was not an inexpensive approach, though, and it has not been able to arrest the steady decline in the condition of the biosphere.

When compared to the incalculable mass and diversity of materials which make up the earth, one is tempted to caricaturize environmental policy as having been preoccupied in its initial phase with "nanograms,"with the effects of comparatively minute amounts of a small number of pollutants generated by human activities. The possible ecological effects of the "megatons" of material flows diverted by heavy machinery and gigantic structures have not been of much political concern. This category includes draining swamps and wetlands; diverting, straightening, and dredging rivers; drawing off rainwater; erosion resulting from plowing or clearcutting, generation of overburden in mining operations, and the earth movements associated with transportion systems; and finally the structures themselves.

One example: in the Ruhr area of central Germany more than 70,000 hectares of land have subsided so much due to collapsing sub-surface coal mines, that surface water would flood them were it not continually pumped off. If one were to add the energy requirements of doing this and the volume of water involved to the mining activity, in the long run a negative materials and energy balance would result. It will then be up to our children and grandchildren to make up the difference--if they are still in a position to do so. We will be returning to such examples throughout the book.

Not only the "megatons" were overlooked in the past. The meticulous search for the "nanograms" was bound to come up against certain difficulties and limitations. We wish to particularly stress at this juncture that it is scientifically impossible to know, simulate, quantify, let alone express in fiscal terms the totality of all effects that even a single material would have on the environment. For material flows characterized by complex and changing configurations this is even more obviously the case. Therefore the Cost-Benefit-Analyses, which the economists like to perform so frequently as a means of determining the environmental costs of human activity or economic production, are fundamentally imprecise and thus a woefully inadequate basis for ecologically and economically meaningful decision making. This for the simple reason that they are based solely on the measurement of *known* pollutants.

From pollutant of the week to an economically useful ecological measure

Focussing the concern over the environment on toxins quite naturally led to the phenomenon of a "pollutant of the week." After accidents, or as the result of scientific research, new materials and new consequences of using these materials on humans and the environment were discovered. Nothing about that tendency is humorous or even ridiculous, even if it may often appear that way in the news media. How else should eco-toxicology proceed, if not by scientific observation of nature, precisely in the wake of such accidents. A systematic and gradual examination of theoretically conceivable cause-effect relationships inside and outside of the laboratory is required to make headway.

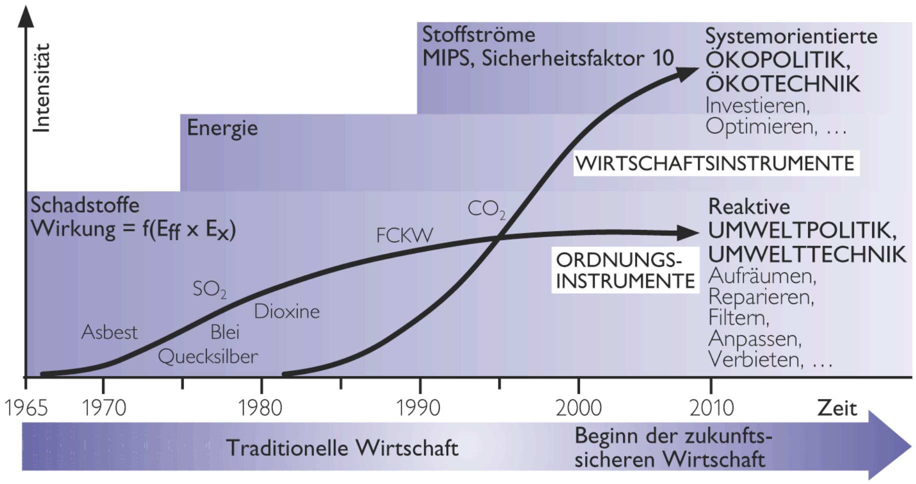
In the 1980s a decisive change occurred. *Waldsterben*, or forest dieback, became a political watchword, and an increasingly international understanding of how chlorofluorocarbons, or CFCs, were destroying the ozone layer propelled environmental policy into a new phase: the concern over the actual and potential harm to humans associated with industrial chemicals was drastically expanded to include the global ecological changes that we seemed to be bringing about.

CFCs were invented by scientists and have been prized for decades as an outstanding achievement of chemistry for physico-chemical reasons, as well as for their toxicologically excellent behavior. Nature does not seem to have deemed them worth "inventing,"or else the composition of the atmosphere would have been different from the beginning. In 1974, Sherry Rowland had already warned of the effects that would result from emitting these compounds into the environment[2]. In 1978 West Germany's Federal Government hosted an international conference on this topic in Munich. But the breakthrough for environmental policy did not occur until very recently: an international "Convention for the Reduction of Ozone Depletion in the Upper Atmosphere" was created.

Carbon dioxide, besides being absolutely essential to life on earth, is an unusually abundant gas in the earth's atmosphere. It has only been a matter of a few years since it made its debut in the political arena in the context of anthropogenic environmental damage. How could that be? A naturally occurring substance--and one of the most important compounds plants require at that--is supposed to be a pollutant? Even a pollutant capable of changing the climate upon which we depend so critically for our survival?

With this case we have reached a crucial juncture for environmental policy. We can no longer avoid looking very critically at the ecological effects of the material flows generated by human activity, even those material flows which have traditionally been considered ecotoxicologically irrelevant or even beneficient. Alongside the traditional "toxicity" of individual materials we must now also include the destructive potential of anthropogenic material flows--which may have hitherto appeared neutral--in our economic calculations. We now understand that such material flows have the capability of threatening global ecological balances or equilibria. We must not solely be concerned with the toxins *introduced* by humans into the environment, but also with the movement, disturbance, diversion, transportation and manipulation of the environment itself, which we are doing on a very grand scale (Fig 2).

FIGURE 2



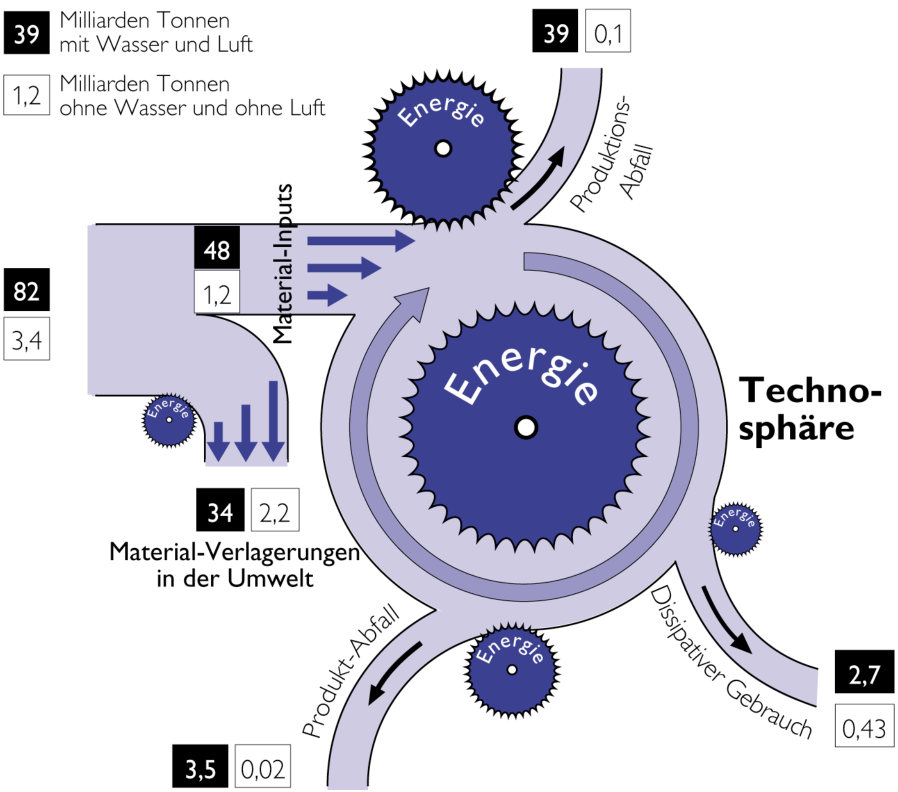
Some people will wish to remind us at this point that within the environment large amounts of material flows are moved though erosion, or even by a volcanic eruption. As we have seen in the example of CO_2, the anthropogenic material flows are not automatically ecologically neutral because they also occur as natural fluxes. Even more important is the consideration of time. Humans are always in a hurry. Time is supposed to be money. They have enormously increased the speed with which the earth's surface and the atmospheric composition are changing when compared to the speed at which geological and evolutionary processes occur. Today humans displace more material than the geosphere. The living world cannot keep pace in terms of its biological makeup and threatens to extinguish itself ahead of schedule.

We must remind ourselves that the volume of materials, the amount of "nature" which we have been moving about, has been steadily increasing. In order to produce the wealth we enjoy; sand, gravel, water, air, overburden, ores, cement, earth and much more must yield to our advances. Each product which we use, each service which we afford ourselves, carries a rucksack of materials around with it which had to be moved or transformed in order for it to become a product or service. The masses which are in these rucksacks are often much heavier than the products themselves (Fig.4). In order to extract one gram of platinum from a platinum mine, for example, we must displace and modify 300,000 grams of rock. Without platinum we would not have the catalytic converter in our automobiles. Two to three grams of platinum are found in one such catalytic converter, in addition to high-quality steels, ceramics and other materials. Thus, the *ecological rucksack* of the catalytic converter, i.e. the total amount of material translocated for the purpose of constructing it, amounts to about one metric ton of environment. This means in effect that the catalytic converter burdens the automobile with as much matter as the car itself weighs. (The calculation looks a bit different if the platinum is recycled from a used catalytic converter.)

If it took only a few years for our disruption of a natural material flow such as CO_2 to advance to our "most pressing environmental problem,"how can we be sure that the extraction and translocation of far greater material flows as well as their alteration and "return" in the form of garbage won't effect fundamental changes in ecological equilibria?

As scientists can only predict the effects of such material flows to a very limited degree, we should perhaps play it safe and anticipate catastrophic ecological effects. This holds true even if--over the next generation or two--we fail to notice many of the changes we may already have set in motion. We have been notoriously bad at taking note of gradual changes, as we have so far missed the opportunity to establish an early warning system for unexpected environmental changes. Furthermore, many of the changes we may have initiated won't appear on a temporal or spatial scale we can appreciate. The causal relationships have often become so complex, that we are no longer able to decipher them.

FIGURE 3



The plausibility principle should become the basis for our economic decision making. In other words, whenever possible, the decision making process should favor alternatives--when such exist--which minimize the environmental stress potential. Only those investments which are ecologically sensible are able to help avoid the need for future attempts at ecological restoration. It is generally accepted that it is better to be safe than sorry--prevention is preferable to mopping up after the fact. The costs of mopping up--of "restoring" the environment--have been regularly paid for with tax dollars, an interesting solution given our professed penchant for market-based decision making.

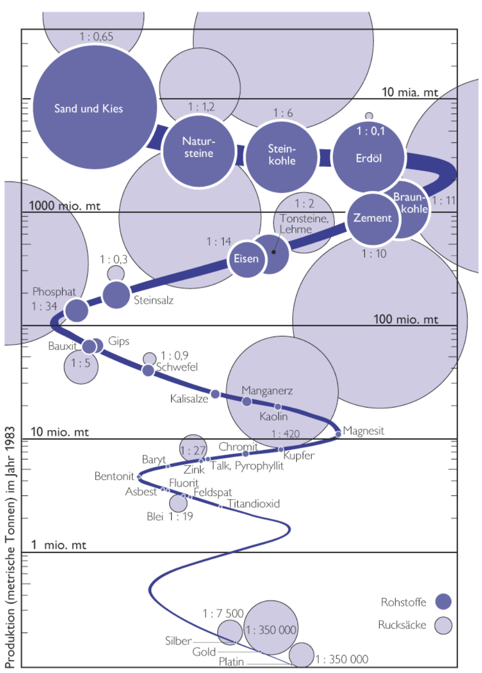
Furthermore, it is completely uncertain and even scientifically unpredictable at what point the ecosystems, upon which we depend so critically for our survival, will collapse in chaos. What is certain is that our inventiveness, our machines and our unbridled urge to acquire more material possessions and ever more elaborate services push us in that direction.

Dematerializing the economy would drastically reduce the volume of solid waste.

It is somewhat surprising that the "quantity-problem" first became a political watchword in the context of municipal solid waste, and not, for example, in the lignite mining regions around Cologne and Aachen, or in the context of the very expensive efforts to divert enormous quantities of rainwater accumulating in large cities. For many years the problem of solid waste was tackled by separating out what were perceived as "toxins"; using ever more complex technologies that were subject to rapidly rising costs. The scientific basis for such a regime was never very explicit, and was predicated upon an effective disregard for the ecological consequences of the ninety-nine percent that was sent to the landfill or the incinerator. In the meantime, the German Parliament has discovered the closed-loop economy as the solution, and German industry has put its money on the *Grüne Punkt* or Green Dot. Both are premised on recycling .

It is obviously correct to use those materials which have been taken from nature and introduced into the technosphere as often and as long as possible, to allow them to yield wealth-increasing services. The question of the ecological and economic price of such a strategy remains, nevertheless. Each time something is recycled, more energy and materials are required, as are additional machines, transportation infrastructure etc. (i.e. material flows). The solution could hardly be to admit ever more matter at the front--from nature into the technosphere--and expel a decreasing amount at the back. Picture the biological and economic predicament of someone trying to emulate this with food. (Fig. 3)

FIGURE 4



This Figure illustrates the weights of ecological rucksacks (lighter spheres) for various base materials used in the 1993 economy. They obviously contribute considerably to the absolute resource intensity of products, services and infrastructures in a "hidden" way. These rucksacks represent averages, as they depend on geological conditions, transportation, and technical processes used for their refinement.

It has been the general rule in environmental policy to recognize individual substances, to judge them with our eco-toxicological measuring stick, and to then do our best to isolate them; but this strategy is really not in line with a precautionary approach. We know that the costs associated with our technical approach to avoiding contaminants within existing technological regimes are considerable. Furthermore such technical follow-up strategies are generally short-lived and prone to failure. The catalytic converter illustrates this.

What we call ecological structural change cannot derive from an approach which merely recognizes the effects of pollutants on the environment. Our knowledge of these linkages changes constantly. Foundations which change continually are not well-suited to long-term planning efforts; especially not when the future well-being of humanity is at stake.

The last twenty years of OECD policies show that internationally harmonizing what are believed to be the environmental dangers of individual substances is difficult and rarely acheived. The very frustrating and expensive results of Life Cycle Analyses to date show that the problem of reducing the multitudinous effects of harmful chemicals to a level at which they can be compared remains unsolved.

The call for a directionally stable and rugged measure with which to represent and compare the environmental stress intensity of processes, goods and services is thus more than justified.

It is difficult to imagine how we could plan, carry out and continue to monitor the progress of ecological structural change without the ability to measure the ecological effects of our economic actions on an international level.

To do this we require a new ecological measure; a simple, directionally stable and reliable indicator with the help of which we could at least approximate the environmental consequences of our economic actions--as well as of our products. Much of what will be said in this book is informed by this thought. And it should be obvious that all our knowledge of the toxicity of anthropogenic material flows will necessarily inform our decisions with respect to new processes, products and services. It would be naive to believe that sand is as toxic to humans as dioxins. The present book is concerned with the long-term stability of the biosphere, which has never been threatened by dioxins.

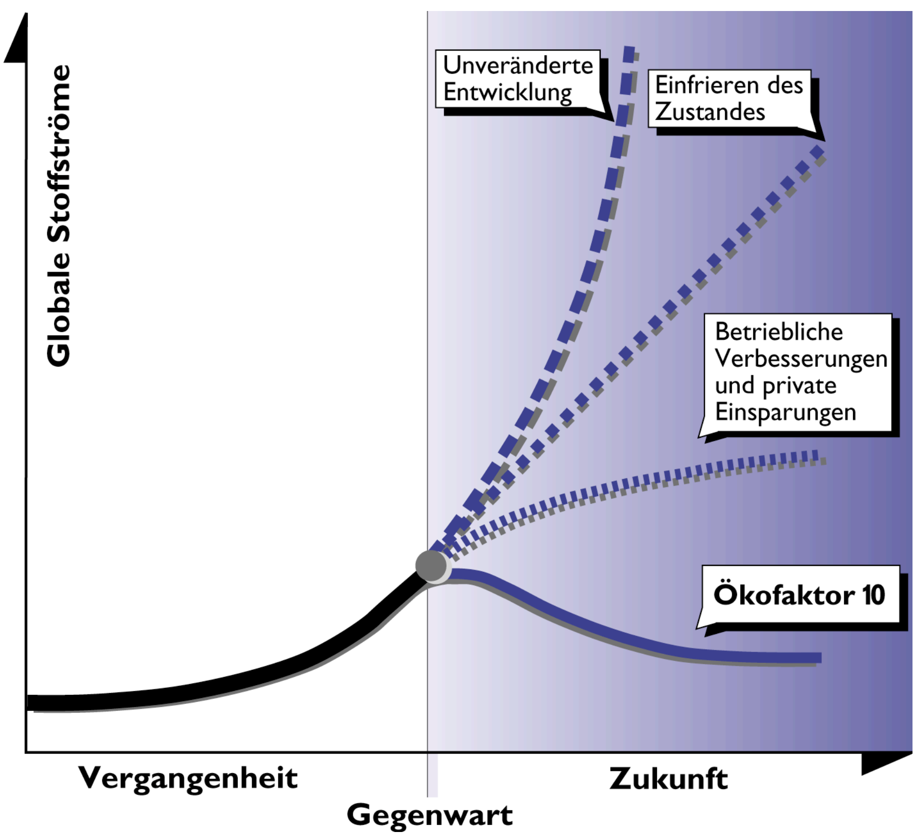
Only a simple measure can persist and be relevant in everyday decision making with respect to millions of different purchases and other economic decisions. Only a reliable and scientifically defensible measure, that--in all its simplicity--still has the ability to indicate at least the proper direction, can hope to find favor across borders and with people of diverging interests. Such a measure cannot be understood as scientific, in a restrictive sense, any more than money is a scientifically accurate measure of the value of a product or service. It will turn out to be a measure which people understand and can use without having to always review the ecological ramifications of their economic decision in all their complexity.

The material flows tied up with producing the wealth we have come to enjoy, are, especially for the people of the rich countries, a global phenomenon. It is our conclusion that our present goods, services and infrastructures are too material and energy intensive. This is calculated "from the cradle to the grave," or, as Walter Stahel[3] says, "from the cradle to the cradle," as all the materials and energy we use eventually return to the earth. We must create a dematerialized economy, supported by a completely new technology and informed by a concern for the welfare of future generations. In this book we shall also entertain the question of whether or not the demands our economy makes upon surface- or land-use are too high, and how one could possibly measure surface-use in an ecologically meaningful way.

If our present economic activity, i.e. the methods by which we generate wealth, stands a chance of ruining what is perceived to be a more or less beneficent environment, any future eco-politics, or "earth-politics," as Ernst Ulrich von Weizsäcker[4] would call it, must concern itself with the creation of an ecologically sustainable economy.

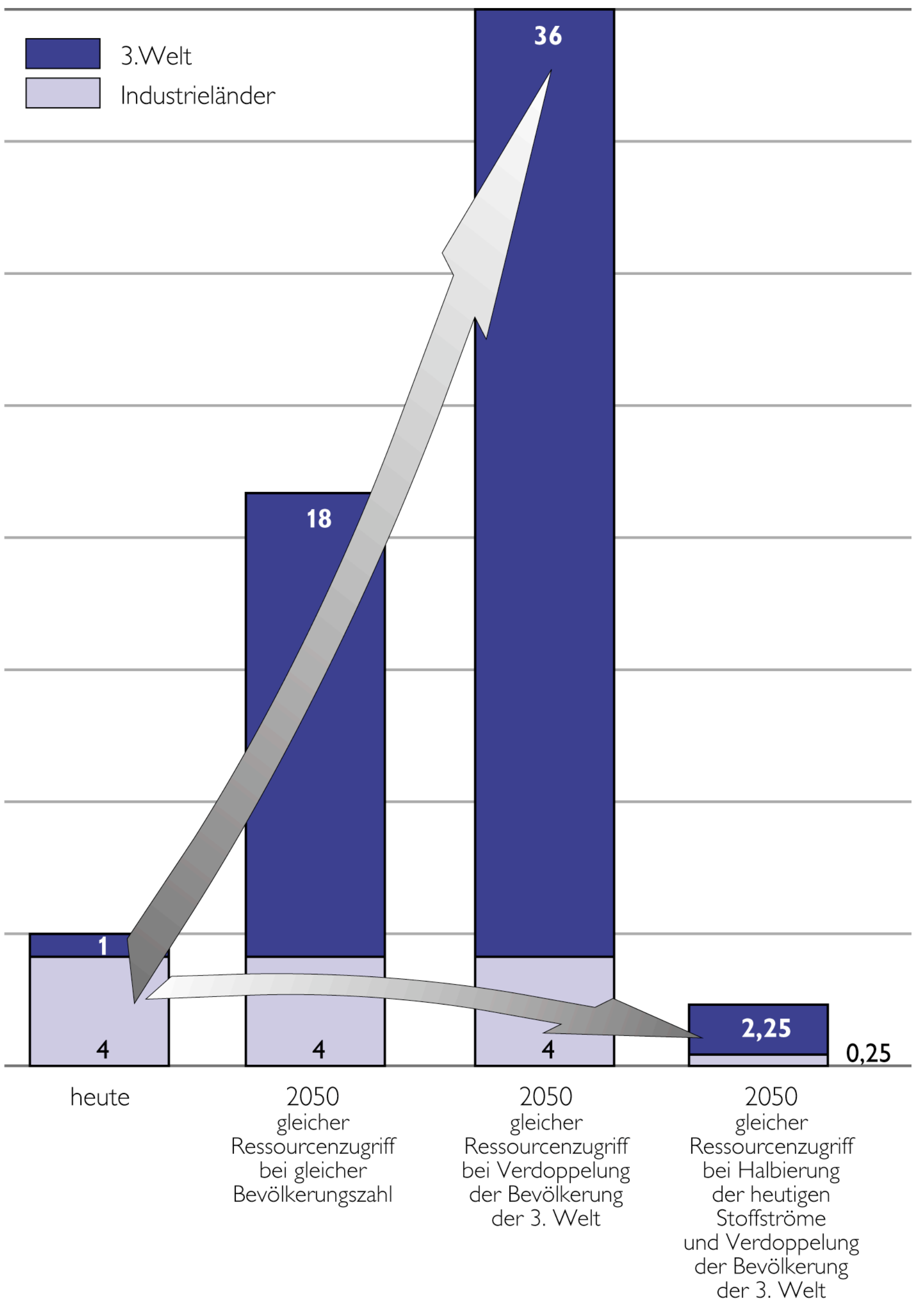
We must dematerialize our western economies by an average factor of ten or more, as well as de-energize them, if they are to be sustainable.

FIGURE 5



This emphasis on the West derives from the fact that in the industrialized North we lay claim to roughly eighty percent of the global anthropogenic material flows to create our material wealth. A more equitable distribution of access to resources would therefore require considerable reductions in the West, if we entertain the hope of merely cutting in half the global environmental burden. In the Chapter "Factor 10" we will discuss this in greater detail (Fig. 5).

FIGURE 6



It appears that such a dematerialization would also lead to a drastic reduction in the volume of solid waste, especially if sensible closed-loop options were utilized. Furthermore, entirely new means for limiting the use of toxic substances would emerge. From a technological perspective this is no utopian goal, even if the quality of goods and services remain equivalent. We shall be offering some examples of the "eco-efficiency revolution" in the pages to come (Figs. 6).

The ecological transformation of the economy is apparently one of the most crucial political tasks for the near future, nationally as well as globally. If we hope to avoid an "ecological revolution," or even an "eco-dictatorship" we would do well to begin conceptualizing ecological structural change--with an eye to bringing it about. The sooner we begin to realign our economy within its ecological guard rails, the better. As important as employment, healthcare, fiscal policies and others are; as uncomfortable as the current recession in the OECD countries may be; once we have used up or ruined our ecological capital--the foundation of our biological existence as well as that of our children--not much will remain to redistribute, let alone enjoy. Recent history has reminded us of the fact that borders of nation-states are very transient structures from a geological or ecological perspective. For this reason alone, the decision making power of national governments requires that attention be paid to the worsening condition of the biosphere and not just to the right to unlimited use of its resources. Accessing resources that lie outside sovereign territories of nation-states should only be allowed with international agreement. This applies most importantly to the oceans and to Antarctica. A symbolically important step would be for Germany to belatedly join the *Seerechtskonvention* (Maritime Convention).

Let us not forget that presently close to four billion people in the Third World, and several more billion in the decades to come, appear to have no greater goal in mind than to emulate our ecologically catastrophic economic system. They merely wish to own the things which we hold so dear. Presently we are even granting foreign aid to increase the speed of this process, for the former East Germany as well as for many other countries. With this type of foreign aid we are financing our own ecological suicide. Something is decidedly wrong here! Reflecting on this, Wolfgang Sachs of the Wuppertal Institute has seen fit to come up with an obituary for the West[5].

The eco-politics of the future consists of system-based management of material and energy flows as well as wise investment in technologies, infrastructures, goods and services.

What is of concern here is the development of an economic policy which allows us the greatest possible space within which to develop and increase our wealth, while abiding by the limits imposed by nature. This book aims to provide some preliminary practical aids and suggestions as to how we might succeed in this. What will be said here should not be misconstrued as the final word. Rather it is intended as a contribution to the discussion of the means for building a more hopeful future. We would like to move beyond the loss of a political consensus, beyond the apparent listlessness of the political decisions and beyond the visionless wasteland of our post-socialist world.

If the remaining contradictions between the traditional goal of economic growth and the requirements for maintaining global ecological stability cannot be surmounted, the loss of political credibility will continue. It will continue to erode until the legitimacy of governments and public institutions at the local, national and international levels is gone, which will bring about changes not unlike those which are still rocking the formerly socialist world. One of the victims in this development could be the market economy, another the liberal society.

In this book we attempt to get at the root causes of environmental changes, rather than trying to trim some of the branches. We believe this root to be the material flows which we set in motion--even those which permit us to use energy. To make this plausible, to draw some preliminary conclusions and to discuss these conclusions is the concern of this book.

We will introduce the foundations for the requisite ecological measure in the ***first*** **chapter** by searching for an answer to the question, What it is that continues to make our economy so un-ecological after we put so much time and effort into improving environmental technology? **Chapter *two*** illuminates several aspects of today's environmental policies in light of the inevitable ecological structural change. We shall also summarize the current methodologies for evaluating the environmental risks associated with economic goods. In this context we shall also be thinking about the necessary extent of the structural change.

What such a measure for the environmental tolerance of processes, infrastructures, goods and services should look like and how it might be introduced into the economic realm will be discussed in the ***third*** **and subsequent chapters**. The ***fourth*** **chapter** focuses on the surface area demands of human activity and in the ***fifth*** **chapter** we shall be entertaining the question of how much abuse we can expect the biosphere to swallow. We shall be asking the question how and by how much will we need to change our economic behavior in order to make it sustainable.

In **Chapter *six*** the question of what services really are will preoccupy us. We shall make some suggestions about how shopping can become more ecologically responsible. We will also comment on the limits to adjusting prices and satisfying demands by introducing technologies that are more ecologically benign. **Chapter *seven*** discusses how an ecologically optimized refrigerator was created. We wish to use this example to illustrate how the design of future products can be systematically addressed. In **Chapter *eight*** we will concern ourselves with economic questions. We especially wish to address how ecological structural change can be set in motion. In the final, ***ninth*** **chapter** we wish to show that the transition to an ecologically compatible economy will have to be an international one.

In our attempt to meet the demands of the next century, this may be the most difficult aspect.

Einleitung

[1] Rachel Carson, The Silent Spring. Boston: 1962.
[2] M.J. Molina and F.S. Rowland, "The Stratospheric sink for chlorofluoromethanes, chlorine atom catalyzed destruction of ozone. " *Nature*, 249 (1974): 810-814.
[3] Orio Giarini and Walter Stahel, The Limits to Certainty--Facing Risks in the New Service Economy. Dordrecht, 1993.
[4] Ernst Ulrich von Weizsäcker, Earth Politics. London: Zed Books, 1995.
[5] Wolfgang Sachs, The Development Dictionary: A Guide to Knowledge as Power. ed. London: Zed Books, 1992.

Chapter 1 Humans are a Part of the Biosphere

Act only on that maxim through which you can at the same time will that it should become universal law.

Immanuel Kant's Categorical Imperative

Quidquid agis, prudenter agas et respice finem[1]
(Whatever you do, act wisely and consider the end)

The blemished biosphere

Humans in the industrialized world have accomplished a feat over the course of the last two centuries that is without precedent in human history. With their determination and their machines they have succeeded in achieving an unprecedented level of material wealth. Due to these efforts the people of the industrialized nations live amidst a profusion of technical possibilities, products and services, which has--without a doubt--reduced the level of uncertainty, of risk, decisively. For hundreds of millions of people this wealth obviates the daily struggle for the provision of food, material needs and energy. If this is not "progress" in the best sense of the word, if this is not an achievement of human civilization, what then could be imagined progress, what, an achievement?

In this book we will concern ourselves with ecological themes, with the negative consequences of progress to date. To disavow progress would be to ignore the presuppositions of ones own work. The fact that we can ponder the effects of our achievements, that we can discuss them and understand ecological relationships, that we can research and write books are all direct consequences of these achievements. Perhaps it is therefore especially difficult for humanity to understand, or to merely imagine, that we are approaching limits--to understand that disastrous mistakes have been made.

The price for civilization's progress is and has always been to change the environment in which we live. These changes have acquired a new quality--for three reasons.

First of all: in order to favorably alter the environment, humans used to rely on the use of their own physical strength, the strength of their domesticated animals and on wind and water power, until the age of modern machinery--until James Watt's invention. The utility he could derive from nature, the productivity of his daily work, was limited. Since the invention of the machine this "labor productivity" has risen by a factor of thirty, forty or even fifty--in special cases up to fifty-thousand. In Germany's lignite open cast mines, one machine that is operated by five people is able to extract up to 240,000 metric tons of coal per day[2]. Machines have increased the human capacity for initiating material flows so dramatically that the unintended consequences have taken on a new set of characteristics.

Secondly: since 1800, humans have increased their numbers more than five-fold. Not only has the technical ability of humans to move material flows increased, but the number of people who use these technologies and who derive material wealth from them has grown.

Thirdly: for today's mass-produced goods, we rarely use the materials which we take from natural material fluxes in their preexisting state, as our ancestors did. The products which we produce, use and eventually throw away consist of materials which have been chemically and physically altered in numerous ways. The chemicalization of the material flows has led to a situation in which natural processes--which ordinarily break down and convert materials--are only able to affect the material flows emitted from the technosphere over exceedingly long periods of time.

The material flows which we set in motion severely disrupt natural development processes of ecosystems. The biosphere is forced to react in the following two ways:

First: The naturally occurring ratios of different materials are no longer unaffected, even on a global scale. CO_2 in one atmosphere is an example. Over the last 150 years humans have succeeded in changing its concentration in the atmosphere by about twenty percent, from about 280 ppm to more than 350 ppm (parts per million). It should not surprise us if the biogeochemical cycles of the earth do not change to accomodate this anthropogenic strain. In primitive systems such reactions can be approximated. The more complex the system becomes--and the earth's atmosphere is an unusually complex system--the more difficult such an approximation becomes. Furthermore, the long-term and indirect effects cannot be accurately predicted at all.

Second: Materials are introduced into the environment which do not naturally occur there. A spectacular example of this are the CFCs; spectacular because it illustrates the degree to which one can be ignorant of the long-term consequences of such a chemical. The group of chemicals to which the CFCs belong is chemically very unreactive, which, from the perspective of humans and of nature, means that a chemical or biological reaction with a CFC is highly unlikely. In other words, they hardly affect biological processes at all--they are especially non-toxic. For decades this was agreed upon and because of certain other technologically desirable characteristics they were used in an increasing number of applications: in refrigerators, as foaming agents for expanded plastics, in aerosol cans and for cleaning printed circuit boards in the electronics industry. But suddenly measurements indicated a growing "ozone hole" in the stratosphere. We realized that in an entirely different chemical environment than was to be found on earth, the CFCs were no longer unreactive. In any case they were reactive enough to disrupt the unstable chemical equilibrium of ozone in the stratosphere--globally. No one had anticipated this with enough precision to have drawn the necessary conclusions. Sherry Rowland alone, while researching otherwise unrelated systems, recognized that such effects were possible with CFCs[3]. Up to that point, whether for shortsighted economic reasons or simply out of ignorance, no one had considered these effects to have been a necessary *evil*.

The possible future of humanity

Humans cannot afford to be indifferent to the ways in which the environment reacts to anthropogenic material flows. The human species is a part of biological evolution of life on this planet. This development was made possible by ecological systems that were and continue to be both complex and dynamic. This planet's biosphere--the sum of all life on it as well as the sum of all physical prerequisites such as moisture, climate, and others--has created the conditions under which an organism such as the human species could emerge.

These conditions provided the conditions in which the human species could survive and develop what we refer to as civilization. If we alter these conditions--this support system--they will change from the way they were when human life became possible. It is not a question of 'if,' but rather of 'how much,' of 'what,' 'where' and--above all--of 'how fast.' Ecological changes must not necessarily and in every case be negative. They are almost always negative, though, when we force changes too quickly. This is precisely what characterizes our economic activity: time is supposedly money. As long as saving time translates into an economic profit, though, no economic system will prevail that can claim to be sustainable under "conditions of marginal ecological stability," to use a phrase of Udo Ernst Simonis.

If we dislodge the ecological systems from the state in which they made human life both possible and tolerable, whether consciously or unconsciously, we must expect that over the long term the conditions will become less favorable for our continued survival. The biological survival of the human species could become endangered. We do not mean here that human biology would change in such a way that survival cannot be guaranteed. The changes in global ecology do not threaten our survival through effects on human metabolism, but rather through negative effects on our surroundings, such as the water supply, climate conditions, or the prevalent UV radiation.

Humans live within ecological surroundings and depend on them. In this sense we are creatures like all others. But this particular creature is intelligent enough to destroy the system which enabled its emergence. The biosphere of the planet is in a very fundamental way indifferent to this fact. It will most assuredly continue to exist--in some altered form. Ecological development is never dependent on one of the many life forms it has brought forth. If humans wish to have the biosphere continue to put up with them, they must see to it that the ecological conditions under which they became a viable species prevail. And if we expect ten billion people to remain within the carrying capacity of the earth, then we must be especially concerned about returning the ecological conditions to a more stable state.

Humans are stronger than the geosphere

What about the stability of the biosphere? The basic scientific premise is that the rapidly increasing anthropogenic material translocations are changing the evolutionary balance. These translocations are already greater than those from within the geosphere,[4] and in some cases exceed them by a factor of 200. For millions of years, geological processes determined how and when the faces of the earth would change; now humans have taken on that role. In pre-industrial nature--the result of millions of years of evolution--the material flows between environmental reservoirs were more or less a balanced state of affairs. Supplies of important biological materials such as air, water, soil and sediments remained fairly constant, if one looked beyond the inter-seasonal variations. Both industrial and economic forces have now disturbed these material flows, and the reservoirs are rapidly changing their composition, when compared to the speed of geological processes (Fig. 8). At some future date, other, new equilibria may establish themselves. But these new conditions will not be advantageous to humans because they are divergences from the conditions under which humans first emerged. Forest dieback, the ozone hole and changes in our climate are premonitory examples of this development.

Humans are in the process of calling into question the livability of the only earth they have.

The livability crisis will manifest itself in different regions of the earth in different ways. In some cases the determinant factor will be the climate--in others, the availability of drinking water, the changes in vegetation, or soil fertility. Each technical attempt at "improving" the situation, insofar as it is effective and affordable, will require the mobilization of new material and energy flows, which would serve to exacerbate the situation even further. Social conflicts, wars, urban flight, and mass-migration are sure to follow. In the end there will only be losers.

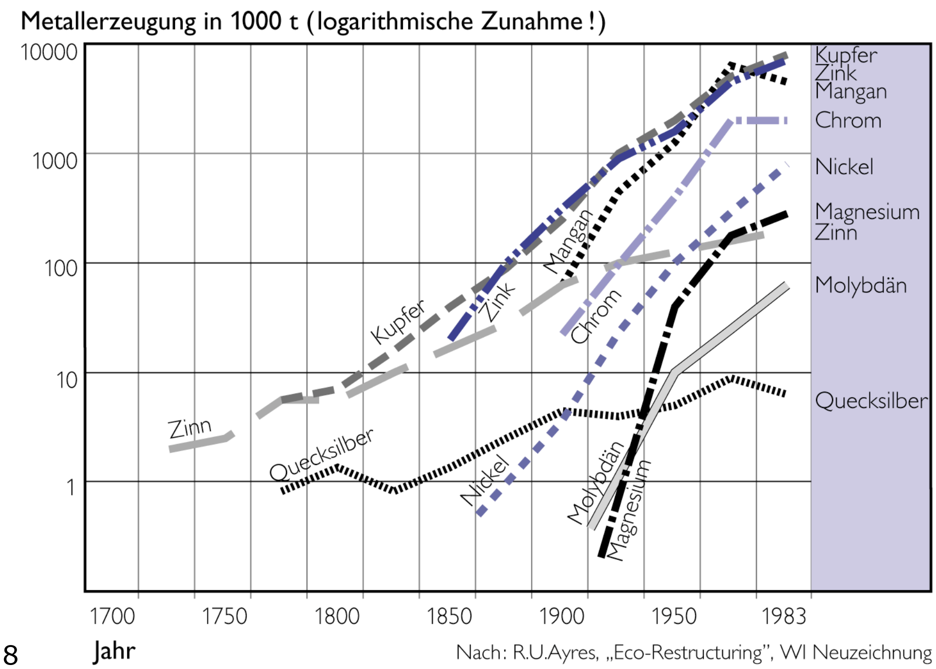


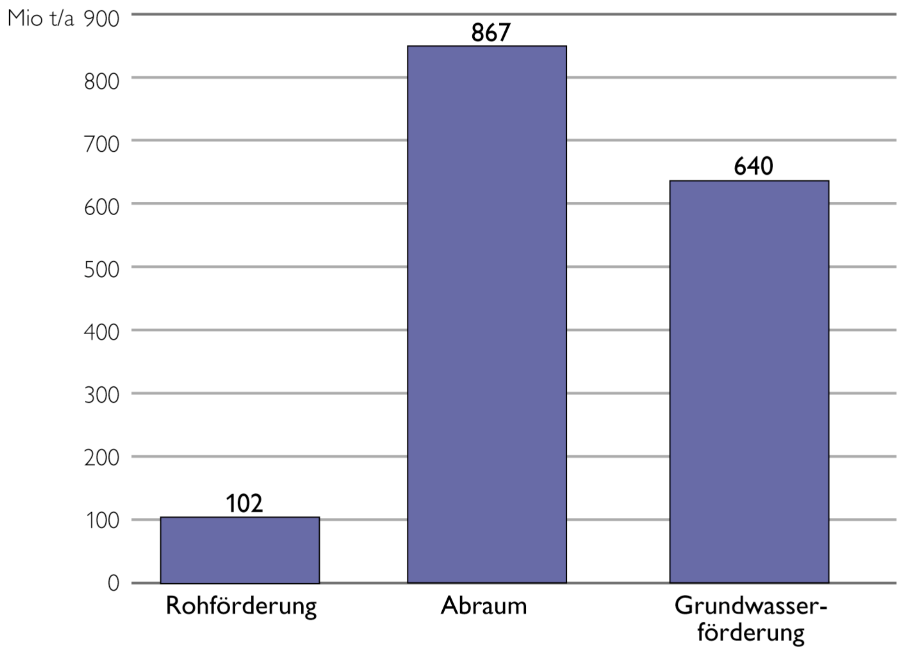
FIGURE 8

Humans against both geosphere and biosphere

Commonly the human use of energy is used as a measure of the effect of human behavior on nature[5].

In a later chapter of the book we will articulate reasons why we feel this to be an inadequate measuring stick. The indirect consequences of energy "use" through technology are really only marginal from an ecological perspective. Energy "use" does become a relevant factor via the material flows associated with it. In this category we include the large quantities of water, oil, coal, natural gas, CO_2, SO_2, and NO_x, as well as the enormous amounts of overburden which are involved in mining coal, and the frequently underestimated magnitude of groundwater that must be pumped away (Fig. 9).

FIGURE 9



In addition to these material flows, which are directly associated with energy transformation, we include all of the others we move about: plowed soil, building materials, excavation materials, sand, minerals, water (used for hydroelectric power, irrigation, industry and drinking water), as well as industrial, agricultural and forest products (including those moved about in international trade) and all emissions, effluents and "solid waste."

When we talk about material flows in this book, we do not only mean those flows which humans manipulate or chemically alter for their economic value (see Table 1)

Each movement of material, each dislocation of matter from one place to another is a material flow, with concomitant effects on ecological coherence.

These can be positive or negative effects. Material flows set in motion by nature can also be negative in the sense that functioning ecological *Lebensräume* (habitats or living spaces) are destroyed. A landslide in a mountainous area is an unequivocally negative ecological event for the landscape buried beneath it. Ecological conditions are subject to perpetual change because of the material flows which they set in motion. In the end new ecological relationships emerge. Nature is neither "gentle" nor "unchanging." Sometimes it is destructive and it is always in flux. Thus humans are not doing anything unheard of by mobilizing material flows.

But humans have not abided by the rules according to which nature plays the game. Natural ecological changes are, with a few exceptions, either slow, or they happen on a very small scale, or both. An ecological upheaval may destroy in one location, but another such upheaval may provide fertile soil for new life somewhere else. Throughout evolutionary history, ecological fluctuations have changed enormous, thriving landscapes into deserts. But nature has seen fit to change deserts into blossoming gardens in which new life emerged without the helping hand of a gardener. Overall, ecological changes have always been diverse and have brought forth diversity. Never have they favored one organism over time at the expense of all others.

With humans it is different. They change their *Lebensraum* only for their own benefit--for short term benefits-- on a large scale and with tremendous speed. The areas in which the laws of evolution, unaffected by human intervention, are still valid are increasingly being crowded out. And naturally no new ecological diversity is brought forth through these efforts. Humans would not be capable of such a feat, even were they so predisposed, as the complexity of ecological systems far exceeds our ability to manipulate them in such a way.

Humans create new sets of prevailing ecological conditions on this planet, and we do not even know if one day there will still be room for us in the new regime. What we do know is that it is becoming increasingly unlikely.

TABLE 1

Taxonomy of anthropogenic material flows

(1) Primary materials*
1. earth** (including overburden, excavation materials and altered soils
2. geologic raw and building materials** (including energy carriers, sand, gravel, minerals and ores)
3. water**
4. air**
5. biotic raw materials (from organic and other agriculture)

(2) intermediate and final goods
1. industrial secondary and intermediate goods
2. industrial final goods***
3. infrastructures (i.e. transportation systems, buildings and facilities)
4. packaging materials

(3) waste products
1. solid and liquid waste
2. airborne emissions
3. contaminations

** Some of the "primary materials" lack any economic value in and of themselves. Some of the "primary materials" only partially enter into industrial products (i.e. ores, water and air).*

*** Materials which are either not or only partially entered into closed loops/circulation.*

****Final goods which are intentionally dissipative, in other words, they are emitted into the environment in such a diluted form that they cannot be retrieved (i.e. pesticides, exterior paints)*

The barrel is full

The biosphere is no longer able to swallow the material flows which humans set in motion--as if sinks existed into which it could all just disappear without any long-term consequences. The material flows must necessarily remain within the biosphere, where they force reactions with natural systems, and where they alter the biosphere itself. For millions of years these changes were either very small or they happened so gradually that they went unnoticed. A third possibility was that because they remained local, humans were able to move out of harm's way. In the meantime, however, it appears as if the productivity of our industrial systems has reached, if not overshot, certain limits. This cannot be determined from any single occurrence, but rather from the sum total of the warning signals, and the fact that these signals are increasing in frequency.

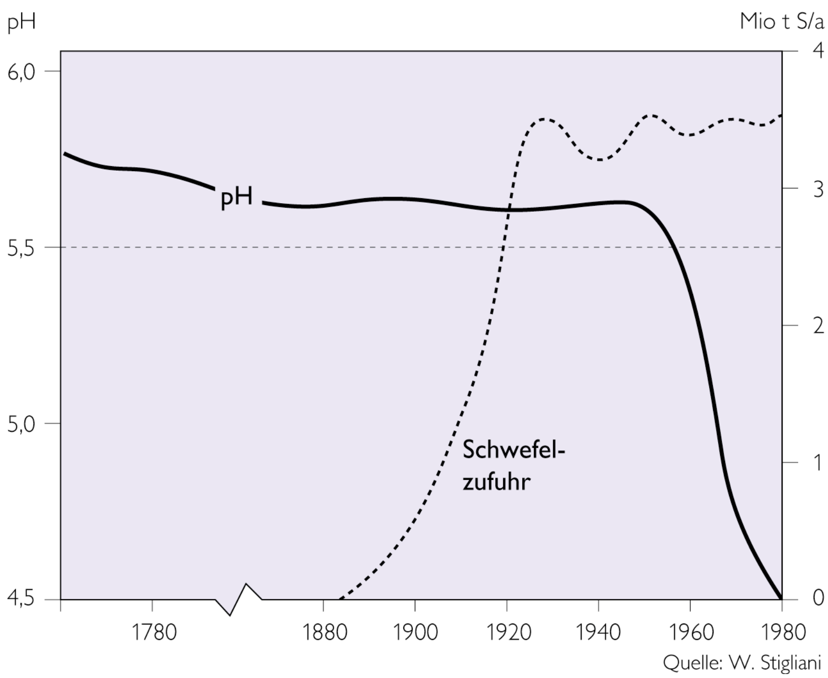
The big warning signals are *Waldsterben*_(forest dieback), soil erosion, potable water shortages, the greenhouse effect, the ozone hole, respiratory diseases, species extinctions and pollution of the world's oceans. These warning signals are sounded because toxins are discovered in areas as remote as the frozen wastes of the arctic, and the deep wells in Provence. These signals are transmitted to us by scientists and environmentalists, by doctors, fishermen and foresters, by a few politicians, and by the growing surge of environmental refugees[6, 7]. For several years now, an entire economic sector, the insurance companies, has joined the ranks of those issuing warnings[8]. Especially the large reinsurance companies, those who insure other insurance companies against devastating losses, are finding evidence for these trends in their balance sheets.

The *Münchner Rückversicherungs-Gesellschaft (MUNICH RE)*, one of Germany's most famous reinsurance companies, recently announced that the insurance industry will have to start changing the way it calculates[9]. Anticipated future trends will have to be taken into consideration as well, rather than merely extrapolating the events of the past, as has been the standard procedure. Premiums will have to rise and the deductible levels below which the policy-holder would have to pay will rise as well. The natural disasters which occurred in1992 were given as the reason for this announcement. The insurance managers argued that both the number and severity of the storms had markedly increased. In 1992 alone, 100 billion German marks worth of damage had occurred globally, of which only 40 billion had been insured. In total the insurance companies had enumerated 509 natural disasters, far more than in the preceding years. It was "surprising, that for the last six years, almost every year a record level of damage occurred."

The symptoms are there for those who wish to see them. But in many cases the symptoms are but the tip of the iceberg. Just one example to illustrate this: if the water in a well is found to have a concentration of nitrate that is unsafe for humans, this means that the nitrate has seeped through many soil strata into the groundwater, originally coming from fields that were too heavily fertilized (agricultural runoff). Some soils hold retain nitrate very well, though. So if it has made it into the groundwater, either the buffering capacity of the soils is already exceeded, or--and this is more likely--the soil structure found between the field and the groundwater does not bind nitrates very well. In both cases the nitrate concentrations in the well water are a sign that the soils in the catchment area of the well already contain high levels of nitrate. Unfortunately, these nitrate deposits can be mobilized, if, for example, the climate changes and precipitation levels increase. The groundwater can then be contaminated within very short time spans.

As frightening as some of these symptoms are, they may often indicate much more dangerous conditions that are merely latent. Many changes that occur on a small scale, or over the entire biosphere, have the dangerous characteristic of only manifesting themselves after a delay. Once the symptoms have been recognized, it may already be too late to put on the brakes. A recent international agreement provides for a drastic reduction in the use of CFCs. Yet even if all the CFC-producing and consuming nations were to abide by these provisions immediately, these chemicals will persist in attacking the ozone layer of the stratosphere for several decades. This is because it takes them decades to reach the stratosphere, where they can begin to do damage. The CFC concentrations which are doing the damage to the ozone layer--as we are able to measure it--reflect those quantities produced and released decades ago. We do not know today how much more of the ozone layer will be destroyed, and how this will affect life on earth. We have stepped on the brakes. We can do no more at this time. We can only hope that the vehicle will be able to stop in time.

FIGURE 10



For more than fifty years the Big Moon Lake (USA) buffered the sulfur immissions brought down by acid rain. Then, suddenly, the pH plummeted – the lake acidified, but after the rate of the annual sulfur additions had already leveled off. No one knows how many such time bombs are presently ticking away.

Another example: decades of air pollution appeared to have left the Great Lakes of North America untouched. No effects of acid rain on the water quality were observable. Then suddenly the buffering capacity of the huge lakes was exhausted. Within a very short time, the water acidified--the effects were undeniable. In this case nature's ability to stabilize and buffer jointly suppressed all known symptoms up until the point at which a change in course was no longer viable[10] (Fig. 10).

Systems analysts refer to this capacity of ecological systems as "overshoot"[11]. External damaging influences manifest themselves with such a delay that the buffering capacity is exceeded. Even if the source of disruption is then immediately removed, the system may already be damaged so severely that it begins to erode. It no longer has the strength to renew itself and "turns over," reaching a different equilibrium. What the characteristics of this new equilibrium will be, and whether or not there will be room for human life is very difficult to predict. Were the ozone layer to disappear completely, life might be forced back into the oceans from which it emerged millions of years ago. All terrestrial life forms would be damaged so severely, either directly or through the destruction of their nutritional base, that few animal and plant species would be likely to survive.

Even if the ecological catastrophe is not characterized by such overt destructiveness, a species as demanding as humans might have a difficult time. If humans cannot find a more ecologically benign economics, which would include their behavior as consumers, then it would seem foreordained that our economic life in the next century or two would be determined by defensive actions against ecological catastrophes, which we are initiating right now. This would literally lead to a fight for survival that only the rich would be able to carry on, those who are sitting on the necessary raw materials and who can access the necessary experience and technical aptitude. We should be wary of too readily assuming that the OECD countries will necessarily belong to the privileged side.

Some indicators seem to show that we exceed the limits of the biosphere long before the catastrophe becomes one of global ecological proportions. Well in advance of that we will experience economic and social crises, both of which are inextricably linked. Meadows, Meadows and Randers[12], in the follow-up to their report to the Club of Rome, Beyond the Limits, drew up a list of indices that signal when overshoot has occurred within the economic sphere. Those indices which are the most important in our context are the following:

Capital, resources, and labor must be diverted from final goods production to exploitation of more scarce, more distant, deeper, or more dilute resources.

In fact almost everywhere in the world coal and many other minerals are mined with increasing effort and declining yields from ever-lower quality deposits. The depth of bituminous coal mines in Germany is now a matter of kilometers. In the copper mine in Butte, Montana, the copper content of the ore has dropped from thirty percent to one-half of one percent. Where it took three tons of rock to obtain one ton of copper it now takes two hundred tons, without considering the increased requirements of energy and the increased amount of water that must be pumped off. So far this increased expenditure in industrial nations has not been a deterrent to the continued production of final goods. We still have access to high quality deposits of all the important raw materials, that can be extracted inexpensively--but often at the expense of the local populations.

Capital, resources, and labor must be diverted from final goods production to activities that compensate for what used to be free services from nature (for example, sewage treatment, air purification, flood control, pest control, restoration of soils, pollination, or the preservation of species).

Flue gas desulfurization in power plants and catalytic converters are two examples of the fact that we are well on our way to diverting extensive technical and financial resources to preserving the air we breathe in a form we do not consider downright toxic. The U.S. economist William Cline has calculated that a global climate change would likely cost the U.S. economy close to sixty billion dollars per year in decreased harvest yields, higher consumption of electricity, more difficulty maintaining water supplies, as well as in disaster relief[13]. Ernst Ulrich von Weizsäcker[14] estimates that we are losing about 3,000 metric tons of fertile topsoil every second. Lester Brown, of the Worldwatch Institute, calculated the loss of topsoil in the United States for the year 1977 at six tons of soil for every ton of grain produced[15]. In the Deccan region of India the erosion rate of topsoil lies between 40 and 100 metric tons per hectare per year, in the basin of China's Yellow River it is 100t/ha/a, and in Guatemala between 200 and 3600t/ha/a[16]. Soil conservation is still not a priority. In the places where it has been tried, the process of building up the soil has been a costly and tedious project. Yet here again, the effects are measurable in the industrialized nations, but are not felt in terms of reduced production of final goods.

Capital, resources, and labor are used to protect, defend, or gain access to resources that are increasingly concentrated in just a few remaining places.

The world has seen its first war over cheap oil--the Kuwait war of 1991. The plans to explore the potential for oil-drilling in the ecologically sensitive Arctic National Wildlife Refuge in Alaska is an unmistakable signal as well. The experiences with the exploitation of Russian oil and natural gas reserves have also been ecologically catastrophic.

So much for the signs of "overshoot." We have every reason not to wait until catastrophic ecological reactions become undeniable. The biosphere's reactions to anthropogenic material flows must not necessarily lead to collapse. The attempt to counter the prevalent trend is always worthwhile, and the sooner the better. In our case this means humans must drastically reduce their energy and material flows. We, especially those of us in the industrialized countries, must make do with significantly reduced material flows. We must dematerialize our goods and services.

Chopping away at the tree of economic prosperity

Contemporary Western industrial products and services destabilize the biosphere because they are produced, used and eventually discarded with excessively wasteful amounts of materials--over their entire product life. Every industrial product and every service carries a "rucksack" of materials around with it, which have accrued at one phase or another of the product's life. Each ton of lignite coal from the coal-producing areas along the Rhine carries with it a *"rucksack"* of eight tons of overburden. Each kilogram of platinum carries with it 300,000 kg of dislodged material with it--just from within the mine! It would generally not involve any great technical difficulties to achieve the same goal--the same "service"--with considerably less material expense. One can, for instance, make even diamonds with fairly compact machines today, instead of having to mine them.

If large material flows must be moved to produce a product, or to offer a service, then this product or service has a high "material intensity." In an analogous way, if it takes a relatively large quantity of resources to produce very little, the "resource productivity" is low. In western industrial nations the standard production process has a higher material intensity and a concomitantly lower resource productivity than would be technically possible. The same holds true for the formerly planned economies. Resources have been and continue to be used wastefully. It is not the availability of resources that is limiting economic growth. This view, associated with the publication in the early seventies of the sensational report to the Club of Rome The Limits to Growth, has retreated into the background, or rather into the future. The sum of ecological feedback due to the effects of anthropogenic material flows will threaten humans, nature and even economic growth long before we run out of resources. Hubert Markl has characterized this predicament as having three components:

1. The problem of solid waste accumulation

2. The problem of external environmental costs which one could term thoughtlessness, although a lack of foresight might be more apt

3. The problem of counter-evolution, or better nature's resistance[17]

As long as business as usual, such as we have witnessed over the last two hundred years, does not give way to new approaches, we will force the biosphere to react with ever greater force, to the point at which our lives will become increasingly shaped by defensive strategies to ward off ecological disasters of our own making.

Numerous attempts to quantify in monetary terms the costs of environmental disruption indicate that we already devote a considerable portion of our GNP not to improving the quality of life or to increasing our wealth, but to repairing the damages incurred because of our production and consumption levels. These "defensive" expenditures are estimated to be twelve percent of GNP for Germany[18]. As provisional as numbers from such research must necessarily be, they do make a fundamental point: if we destabilize the biological basis of our existence, then we will have to take on the responsibility for some of the services formerly provided by nature for free. And it will be up to us to foot the bill and to deal with the unanticipated setbacks. If we fail to eventually get the message, then it is very likely that we will one day no longer be able to foot that bill.

Ernst Ulrich von Weizsäcker has put it this way: "We are entering the century of the environment, whether we want to or not. In this century everyone who considers himself a realist will be forced to justify his behavior in light of the contribution it made toward the preservation of the environment"[19]. The sobering quality lies in the words "whether we want to or not." Either we make the next century a century of the environment, or the environment will force us to do so. Weizsäcker does not mean for us to take the "century of the environment" as a promise either. "What is meant is the cruel reality which is already manifesting itself and which will be culturally determinant if humans continue looting the planet for a decade or two to come."

The "richer" nation states, those who in the past have accumulated wealth at the expense of the biosphere, will occupy the more advantageous initial position in the fight against increasingly malevolent ecological conditions, and will be better able to actively or passively protect their citizens. They have access to more and better technology and knowledge. In these countries, infrastructures are in place with which to effectively dampen, repair or conceal the environmental disruption. They will have the opportunity to build dams, literally, as well as figuratively. They will build physical dams along the coasts against rising, or at least more stormy, seas, and figurative dams against the millions who will take any chance they get to flee to places where even poverty is preferable to the conditions they had to face at home.

We must draw the inevitable conclusion: goods and services must be dematerialized dramatically, from cradle to grave, and the industrial nations must take the first step. How dramatic the dematerialization must be we will try to estimate in the chapters ahead. We will also show how much a technology which deals with resources in a different way can achieve. The necessary change, however, is not merely a technical one, but a structural one as well. It must encompass large areas of economic life as well as cultural values.

Structural change and the immune system of human societies

After this brief outline of the conceptual starting point of the book and its goals, one note to the impatient, who find themselves wanting to give up in light of the slowness with which environmental policy progresses in a world that is so unquestionably heading for dramatic changes (if it is not already in the midst of them).

It is true that warnings of environmental disruption caused by human activity are nothing new, and it is true that these warnings have generally not had much effect in the political sphere. It is also true that science today finds itself in an entirely different situation than a century ago; its relationship to politics is closer, and its knowledge is deeper. But this justifies neither impatience nor resignation. Let us look back. How long has it been since the first large scale, or even global, changes in the biosphere became visible--visible to everyone? We have known of damage to forests for a long time, but this has generally been a phenomenon limited to industrial regions. It has been scarcely thirty years since we observed dying forests far away from industrial centers, and dying lakes in Scandinavia and the U.S., in areas that would otherwise be considered pristine. The ozone hole was discovered less than ten years ago.

This means we now know beyond a doubt that some effects of human activity do not, or no longer, dissipate and become harmless. We know that we must act, but we have not known it for very long when compared to the time frames within which societies are able to rethink.

We obviously are also dealing with ignorance, with power struggles and powerful, shortsighted economic interests. We also obviously do not know how much leeway the biosphere will grant us to experiment and drag our feet. If we want to bring about the transition to a more ecologically benign economics within the market system and in a democratic fashion, then we have no choice but to anticipate the inertia of societal learning processes and to use the democratic means at our disposal to effect change.

FACTOR 10

If we hope to avert an "ecological revolution" or even an "eco-dictatorship" we will have to begin the ecological structural change very soon.

Every society has a defense mechanism that impedes change which might overtax the whole or the individual. We could refer to this as an immune system[20]. This immune system is as necessary for society as the biological one is for the health of the individual organism. If internal or external circumstances force a society to change too many things at once, bad things can happen. One can complain about stubbornness and conservatism or even about ecological stupidity, but one should keep in mind that the necessary transformations require a broad consensus. This societal agreement will be the more difficult to achieve, the greater the internal conflicts are within a society as well as on a global level. Politics based on consensus has never beena place for simple solutions; the eco-politics of the future will be even less sympathetic to such attempts.

One must take this immune reaction of society into consideration if one intends to initiate such a fundamental structural change as would be expedient to ensure the long-term stability of the biosphere. The goal must be to set in motion developments that permit society to discover what had been foreign, and to embrace it as something positive. This would then not be a revolution, but a kind of self-help, allowing new ideas to grow. The prerequisite for achieving this goal is to initiate developments at the right point. To stay with the medical analogy, we need to apply the right stimulus at the right "acupuncture points," but we must be sure that the points are carefully selected.

We shall return to what constitute expedient "acupuncture points" in the upcoming chapters. The "acupuncture point" *par excellence* is without a doubt the *price* of using the environment. Globally, few issues are as much a matter of course as for people to make their decisions about investment and purchasing according to the prevailing market prices. If prices "speak the ecological truth" as Ernst Ulrich von Weizsäcker has put it[21], much of what would be ecologically necessary would take care of itself.

A second "acupuncture point" is the availability of *information* about the ecological relevance of one's actions. This information is indirectly contained in the prices, insofar as they reflect the ecological costs involved. If the goods and services which are ecologically "costly" have a high monetary price, stickers and certificates with purchasing suggestions are no longer as necessary. As long as the prices do not meet these criteria it will remain important to make use of symbols such as the "Blue Angel," denoting any ecologically relevant information, to augment the incomplete price.

A powerful means available within our form of politics is to show that alternatives are available and achievable. Another goal of this book will be to point out some of these alternatives.

[1] The latin translation of a phrase found in a book of the Apocrypha, Jesus Sirach, 7:40.
[2] Information from The Rheinbraun AG in Cologne.
[3] Molina, Sherwood Rowland, Stratospheric sink.
[4] Lester R. Brown, State of the World 1992. New York: W.W. Norton, 1992.
[5] We speak of energy "use", but should not forget that energy is never used up; rather it is transformed. The heat of steam is converted to the turning motion of the turbine, which in turn is turned into electricity. This then is converted to the motion of the streetcar's wheels and into the friction generated by those wheels and the brakes. In the final analysis all energy transformation processes yield waste-heat, equal in content to the energy with which we began, but in a form no longer usable. Even so, this heat warms the earth's atmosphere ever so slightly.

[6] Al Gore, Earth in the Balance: Ecology and the Human Spirit. Boston: Houghton & Mifflin, 1992.
[7] Weizsäcker, Earth Politics.
[8] Schweizer Rück, Umweltschutz--Lebensschutz. (brochure) Zürich, 1989.
[9] Frankfurter Rundschau, 23 April 1993.
[10] William Stigliani, Changes in valued "capacities" of soils and sediments as indicators of nonlinear and time-delayed environmental effects, in: International Institute for Applied Systems Analysis (IIASA), November 1988.
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Chapter 2 Environmental Policy Today

The Minister of the Environment today is still too much of an end-of-the-pipe minister, someone for ex-post environmental repairs. Others are making sectoral policy, and the Minister of the Environment adds a little filter of environmental recognition at the back. This is and remains a second-best scenario; it would be better to include the issue of environmental compatibility in the initial policies.

German Minister of the Environment,
Klaus Töpfer, in an interview with the "Frankfurter Rundschau," June 1, 1993.

Classical environmental policy: water

Frankly most ecological problems have not really been taken seriously by the majority of people--or by politicians. The reason for this is a narrowed focus. Where changed environmental conditions directly affect human well-being, they are taken very seriously and expeditious relief is made a political priority. The subtle and usually very slow changes in our biological life support systems brought about inadvertently by human activity are often the much more dangerous and insidious ones. The narrowed focus may obstruct our view of the real problem. By trying to ameliorate the perceived problem we may be unwittingly causing greater harm to the systems whose support functions we have yet to appreciate. Furthermore, we might very well commit the fallacy of viewing ourselves as apart from the biosphere rather than a part of it. But humans live within, and because of, the biosphere. As long as we allow the dying forests to remain the concern of environmentalists and foresters, we have not yet understood what is happening to our life support systems. To put it differently, our concern does not really appear to be for the well-being of humanity, but for the well-being of one generation--our own. Throughout history this has never been a contradiction, but because of the speed with which we are transforming our biosphere, it has become one.

Our relationship to water illustrates our short-winded reactions to fundamental problems. This example also illustrates an area of concern in which some issues, though far from enough of them, have taken a turn for the better.

One of the first effects of industrialization on what we now call "the environment" which caught most people's attention was the pollution of rivers and streams. The contribution made by fouled water to diseases such as cholera and dysentery are as old as the cities themselves; but this isn't our concern, because for centuries people did not understand these connections. What we are talking about are the effects everyone can see and smell. Water that is dyed with bright colors, that is choked with large amounts of foam and out of which dying fish are washed up on the banks.

The earliest disputes over the preservation of streams and rivers in the last century are chronicled in Wilhelm Raabe's novel Pfister's Mühle[1]. This first of disputes was not instigated by environmentalists who appreciated the ecosystemic integrity of the water, but by fishermen who saw their livelihood threatened. Initially the fishermen lost. Apparently their contribution to the general welfare was thought to be less important than that of the polluting industry. From an ecological perspective, many other such defeats must have been suffered since that time, as our pride over aquatic life returning to rivers as large as the Rhine and the Thames can attest.

Once freshwater fishing ceased in Western Europe, the inhibitions vanished. Karl Otto Henseling characterizes quite vividly the development of jurisdiction and of the laws governing trade and industry in the second half of the nineteenth century, in his book on the history of the chemical industry[2]. The verdict of the *Reichsgericht* (German Supreme Court until 1945) of December 22, 1897, from which Henseling quotes the following sentence, constituted a milestone in this development. "The water flowing in a public as well as in a privately held river constitutes the sluice provided by nature, not only for runoff, but for the frequently contaminated water necessitated by economic enterprise and which must be carried off, as well."

Not until after World War II was anything done about this state of affairs, and even then it was not for any ecological reasons. Foam was blown out of the streams onto the streets and disrupted traffic. Property values dropped if they were in the vicinity of flowing water, and swimming in open water was forbidden almost everywhere. Today Germany, at least the western parts, can hold its own in an international comparison. It possesses one of the densest networks of water treatment facilities using the very best technologies. According to the newest OECD statistic[3], in Germany 86% of the population (West 91%, East 62%) are connected to a public sewage system. In Great Britain it is 87%, in France, 68%, in the U.S.A., 74% and in Japan it is 39%. The OECD average is at 62%.

And yet we are still forced to prohibit swimming in an attempt to protect ourselves from most of the rivers. Even so it has still not become a public issue that cities and even many rural communities draw their water from deep wells or pipe it in with the help of aqueducts from reservoirs that often lie up to several hundred kilometers away. The reason for this situation is frequently that their own ground water is either insufficient, or too contaminated with nitrates and other pollutants. The health of Lake Constance has been threatened once already, but was saved. The motivation behind preserving it was partly due to tourism, and partly to the fact that central Europe's largest lake was in the process of being designated the future drinking water supply for several millions of people.

While the waterways are becoming "cleaner" in Germany and in other European nations, the efforts to preserve the abutting oceans, which would very definitely be in the interest of the fishing industries, have not shared in the success.

Environmental and health policies?

We still don't pay adequate attention to ecological connections. We do not care to maintain their integrity for their own sake. We act when our interests are at stake.

We have always asked: what the are effects of individual substances, and we have rarely gone beyond the toxicologist's highly specific viewfinder. Dioxins are not a problem for ecosystems, they are a problem for human health. Formaldehyde, asbestos, pentachlorophenol (PCP), lead and cadmium share a similar role.

We find ourselves asking about toxicity, about carcinogeneity and about other negative consequences to humans, to a few select plants, animals, microorganisms and communities. Environmental policy has dealt primarily with the question of whether the anthropogenic substances found in nature are harmful to humans. Surprisingly, the question is never turned around. We never ask if the things that benefit us might not harm the environment. No systematic attempt to determine the toxicity of medicines with respect to the environment is presently undertaken anywhere in the world. How fish might react to ingesting valium is still not high on anyone's list. (Klaus Töpfer, the German Minister for the Environment, has proposed that such a criterionbe applied to the testing of medicines.)

A distinction between health and eco-politics is not commonly made. In the interest of better protecting the environment , such a distinction would be very advisable. What is called environmental policy today is often a combination of the two. If the Ministry of Environment were to focus its efforts on truly environmental problems, it would have a very positive effect, in light of the limited resources at its disposal.

In this book we wish to distinguish between the terms health policy, environmental policy and eco-policy. Central to our health policy is the health of the individual person. Eco-policy, on the other hand, is concerned with the condition and stability of the biosphere. In the final analysis we do, admittedly, come back to human welfare, to their survival on this planet, to their long-term well-being, their opportunities for self-realization and their economic interests. To reach this goal, eco-politics must look beyond the individual, beyond the present generation, beyond borders and concern itself with the long-term stability of the carrier systems, which make human life possible. This is an entirely different approach than the environmental policy which targets pollutants. Pollutants and their toxicological and eco-toxicological effects are but one of several categories with which eco-politics must be concerned. Classical environmental politics concerns itself with cleaning up a lake which has been contaminated through human activity; eco-politics has as its goal the preservation of our ecological inheritance, and must therefore deal in an ecologically beneficent manner with material flows, energy and the available surface areas of the earth.

Environmental policy deals most frequently with the ends of a human activity, eco-policy deals with the beginnings.

Environmental policy can fall back on administrative law, injunctions, prohibitions, laws, conditions and other such instruments. The goal of eco-policy is to effect a profound structural change in the economy.

Returning to the example of water: pollutants in fresh water are simultaneously a health threat to humans and of concern to the environment. Protecting waterways thus remains an important goal of both health and environmental policy. The ecological problem, though, does not have to do with the small amounts of toxins suspended in the water, but with the millions of tons of soil which erosion has washed away, or even with the vast quantities of water itself which we divert into canals or use for irrigation. Water is diverted, rerouted, drained and pumped to obtain other economic goods and services such as hydroelectric power, coal, sand, highway systems, entire cities and many other things. Whether or not the biosphere will react to such interventions is rarely taken into consideration.

We do not mean to imply that humans should not use or divert naturally occuring material flows. It is just that to date, humans have done so on such a grand scale and without properly understanding the consequences--without researching the consequences. Too rarely is an ecological perspective invoked, permitting the question of whether this intervention was necessary, or whether it could have been carried out with less of an impact. Instead the narrowly economic perspective is chosen.

In Germany it is generally believed that inland navigation is especially ecologically benign. New numbers from Hartmut Stiller[4] of the Wuppertal Institute indicate that the picture is not that clear. If one includes the tons of building materials that must be moved about for the construction of canals, and if one divides these quantities by the number of tons of freight and the distance over which they are transported along these waterways, inland navigation fairs only marginally better than road or electric rail transport. The difference is on the order of ten to fifteen percent, and the amount of environment required for each ton-kilometer lies above 300 grams! As a comparison, a small diesel truck burns between sixty and eighty grams of fuel per ton-kilometer of freight. The high numbers for barges on inland waterways result from the construction requirements of the canals. In building the locks and lining the canals, enormous quantities of earth as well as cement and steel are required. Using an existing waterway is not very expensive, although in some cases the dredging procedures are considerable, and the locks are subject to significant stress, whether in rivers or canals.

Over the last decades humanity has experienced the local and global repercussions of the biosphere to anthropogenic material flows, which had previously been considered harmless (collapsing subsurface mines, the Aswan High Dam in Egypt, CFCs and CO_2). It seems that humans would do well to anticipate a biospheric reaction in the short or long-term, every time they move large material flows. Whether this will actually occur, and how, where and when can only be predicted in those cases where we have access to specific knowledge of the effects and interdependent chains of effects of these substances within the biosphere. This rather coincidental and necessarily incomplete knowledge is not a very confidence-inspiring foundation for policy-making, especially when the goal is to initiate reliable structural change with respect to the economy. What we need is an indicator or measure which can be referenced by both policymakers and economists in the cases where specific knowledge is either incomplete or nonexistent.

Pollutant of the week

"Classical" environmental policy is in a dilemma of a different kind as well: it strives to achieve something which it cannot.

Humans have so far dealt with the environment's reactions in a manner already caricaturized as "pollutant of the week." This caricature implies that we are always ready to act when the environment surprises us, or if an accident occurs which makes the headlines.

Following industrial accidents involving chemicals, the public is given the impression that no one has control of the situation. It begins with a statement by the company president that everything is more or less under control and that there is no danger. No one believes him, least of all the press. At this point the public receives a very extensive series of impressions which are exceedingly difficult to sort out. Suspicions, insufficient knowledge of the actual dangers involved in this "unprecedented" event, attempts at winning political brownie points, visual recordings of much laborious cleanup work as well as human suffering and anxiety are fused into a series of impressions that ebb and flow along with the news media's attention. An interest in the actual effects and in what we may have learned has never been the characteristic attitude of the mass media anyway. Who knows what is going on in Bhopal or Basel today? All of these accidents do in fact lead to new understandings and often to new investments and improvements in management to better avoid such events in the future.

The problem is that the next accident will most certainly occur at another location within the same or another factory, and will involve other chemicals. Then, as viewed from outside, everything seems to go out of control. For the continuation see above. . .

This book will not further illustrate the problem of the "pollutant of the week." Many publications exist on this topic[5]. It is also not our intention to add to the debate over which products are good for our society, and which constitute unacceptable luxuries or are the result of misleading advertisements. What concerns us are the excessive demands which *all* products make upon nature.

The phenomenon of the "pollutant of the week," with its recurring dismay over the "unprecedented" effects, serves to illustrate quite well the fact that our knowledge of chemicals and the increase in such knowledge over time is neither an adequate nor a very stable foundation upon which to build an ecological economics. If one considers that roughly 100,000 materials are synthesized and sold on the market today (with 20-30,000 accounting for the greatest quantity); if one considers that emissions and discharges constitute another 100-200,000 and if one realizes that nature produces millions of different materials, one must recognize the fallaciousness of imagining that we could ever explain complex environmental problems--let alone predict them--with the help of incremental and specific examinations of individual substances.

This statement obviously excludes substances which, by their very nature, are unequivocally lethal, such as concentrated hydrochloric acid, strychnine or dioxin. In responsible societies, such substances will hardly be permitted to acquire ecological significance for health reasons alone.

The inability to understand or predict these interrelationships is not only due to the sheer number of chemicals, materials and compounds humans release, but also to the complexity of those biological systems receiving them. The variety of possible reactions and the range of their possible intensities, the generally delayed reaction time of the biosphere as well as the frequent physical separation between cause and effect all bear on the issue of our limited understanding. (Who would have thought that hairspray would contribute to the destruction of the ozone layer thirty kilometers above our heads?)

We cannot condone the planning of profound international structural change of the economy on the basis of a small number of more or less randomly selected material flows recognized to be ecologically "harmful." Each year we would then be faced with having to add several new "pollutants" after necessarily exhaustive international deliberation--and our planning would have to be revised accordingly.

If such an incremental approach were to inform political decision making, the result could easily be the creation of other problems of comparable magnitude elsewhere. We will give two examples of this later on in the chapter. Furthermore, the perspective of a single discipline cannot possibly be expected to predict global ecological consequences of our actions with any political precision. From the perspective of scientific theory it seems reasonable to conclude that humans will never be able to surround all imaginable effects, all synergies and antagonisms of materials and compounds in the environment, let alone predict the working out of these relationships in time and space with enough time to effect meaningful political interference. Even if it were possible, which scientist would be willing to carry the political and economic responsibility of such predictions?

Many global environmental effects manifest themselves very gradually, over decades. Beyond a certain point it doesn't matter much if something about the technology changes. Once the reactions in the biosphere have been initiated, they can sometimes continue for decades. They cannot be stopped, and can potentially even develop in an irrevocable manner with a dynamic all their own and independent of our attempts to interfere.

It is scientifically fundamentally impossible to examine, simulate or quantify, let alone monetarize all possible chemical, physical, and biological effects on ecological systems, even for a single substance that we have introduced into the environment.

Environmental policy which suffers from these limitations is unable to do more than clean up where damage has already been done, and take precautions to prevent known problems from recurring in the future. While this is far more than is currently done in most countries, it is insufficient as a guide for structuring economic processes in such a way that they will continue within ecological boundaries over time.

Principles for environmental protection

The following three principles were formulated in the German Parliament in 1973:

1. *The precautionary principle*: environmental policy shall prevent damage, not just remove the effects.

2. *The principle of cooperation*: various sectors of society, such as the economy, the government and unions shall participate in environmental policy decisions.

3. *The polluter pays principle*: the party responsible for the damage must pay the cost.

After twenty years of experience with these principles, their effect with respect to material flows can be summarized as follows:

1. Avoiding materials that have been identified as environmentally dangerous cannot provide a basis for a precautionary policy. We have already mentioned the reasons. Nevertheless the precautionary examination of new materials prior to their introduction into the market, and continued monitoring such as required by the *Chemikaliengesetz*, is sensible because in this way, many particularly noxious effects can be avoided.

2. The principle of cooperation is sensible and has been effective wherever governmental agencies inquired and listened to the parties involved, prior to making a decision. This holds true for legal procedures as well as for voluntary agreements. The principle of cooperation has been effective more often than the public seems to believe. Nevertheless, improvements would be welcome. This also holds true for the impartial willingness to engage in dialogue on the part of industry, consumer advocacy groups and unions. The Germans' willingness to enter into discussion of these matters has not kept pace with their economic strength. Especially television, sadly enough, falls short of providing any examples worth imitating.

Eco-politics, as we propose in this book, requires a profound, and above all, international, societal change. Such change will not come about without the full participation of all social groups and individuals. People need to have access to reliable and simple information about the environmental significance of processes, goods and services so they can be participants in the formation of political objectives and are able to make sense of their role as consumers in the marketplace. Consequently we require a generally accepted method for measuring the environmental stress intensity of political and economic alternatives if we hope to succeed.

3. As sensible as the polluter pays principle is, it has remained internationally ineffective. As long as cause and effect of ecological disruption occur within the borders of a nation this principle is a practical approach, even though the implementation is far from straightforward, even under these circumstances. But in the international arena the hurdles have been too high. This derives partially from the fact that international trade

flows are so interwoven and that the question of responsibility and ownership are sometimes far from clear. It also has to do with the fact that the countries of the industrialized North have built up their wealth with resources from around the world for two hundred years. The countries of the South perceive this as two hundred years worth of accumulated environmental sins on the part of the North, and demand reparations in the international arena.

Once we have come to an international agreement on the principles according to which the environmental significance of processes, goods and services shall be measured, we will be in a position to quantify environmental damage and identify their causes. Such a procedure could even relate the respective amounts of environmental damage associated with functionally equivalent outcomes. This would be highly relevant to future GATT negotiations[6]. In this book we will be introducing such a procedure.

Alongside these three principles, we could imagine adding the following principles to the list, constituting an outline of a future eco-policy. We suggest the following areas:

1. The plausibility principle should become the basis for our economic decision making. I.e., whenever possible, the decision making process should favor alternatives (when such exist) which minimize the environmental stress potential.

2. Wasteful use of matter, energy, and space (unnecessarily lavish from a technical perspective) inevitably leads to undesired ecological effects, often across national borders.

3. Societal contracts on the national and international level are a prerequisite for a sustainable economy, as the market is incapable of internalising the ecological costs of mistakes[7].

4. Economically, technologically, and societally amenable adaptations to the conditions imposed by the ecological guard rails require decades; they presuppose long-term political reliability and stability.

5. The decision making power of national governments includes the care of the biosphere and not merely the right to unlimited use of its resources.

6. Existing facilities and products should not be replaced with ecologically preferable solutions until such a replacement would be ecologically beneficial overall.

7. The principle of convergence between South and North, East and West for the use of natural resources.

Reasons for the dilemma of environmental policy

It is important to understand fully the reasons for the dilemma of classical environmental policy if one is about to propose new concepts in their place. Six reasons are enumerated here. We will be returning to them periodically throughout the book.

1. The failure to recognize systemic mistakes in our economics. These mistakes are not inherent to the market system, but rather derive from the way in which we currently

practice economics. This economic system is oriented toward deriving the greatest possible profit from the available capital and labor. It maximizes the capital and labor productivity. By contrast the raw materials do not count for much at all when it comes to determining the final price of the goods and services. One need only look at the prices of raw materials on the international markets in a daily paper to realize this. Resource productivity is therefore not maximized. Optimization at the level of the firm leads to economically and ecologically nonsensical results today. It is profitable to sell apples from New Zealand in Central Europe, and Dutch tomatoes (consisting mostly of water) in Vienna. It is also profitable, as Stefanie Böge from the Wuppertal Institute has shown in considerable detail, to accumulate unimagined transportation distances for a glass of yogurt. (see the chapter "The travels of one glass of yogurt.")

2. The assumption that the sum of incremental political reactions to environmental problems and subsequent "measures for their amelioration" will add up to a long-term environmental policy. We have discussed this already in some detail.

3. The confusingly large number of complex, often overly specific, and internationally incompatible assumptions and data from both real and imagined experts which are brought to bear on the causes and strategies for the elimination of specific environmental problems.

4. The absence of a rugged ecological indicator with which to approximate the extent of environmental stress associated with the provision of *all* economic goods and services, and with which to make directionally stable improvements possible.

5. The absence of internationally recognized methods for Life Cycle Analyses (LCAs).

6. The deeply rooted uncertainty over the extent of the necessary structural change of both economy and society necessary to effect the long-term restabilization of the biosphere.

Humans have realized that the biosphere is no longer in balance, and a number of things are happening in the course of attempts to right past wrongs. Successful restorations are no longer the exception: the salmon returning to the Thames river, perhaps even to the Rhine in the near future, the de-linking of economic growth and energy consumption in countries of the North, the increase in total area of the nature reserves in Germany, and much more. Unfortunately we can just as easily find examples of situations that have worsened. Presently the most alarming are the signs of human-induced global climate change as well as decreasing concentrations of ozone in the stratosphere. The regional problems that are expected to command our attention next will in all likelihood be water-related.

Apparently humanity has not managed to curb the dynamics of environmental change despite all of the individual successes. We do not yet know what and how much must be done in order to curb this trend. Politically, little can be done until we have at least a rough estimate of the necessary extent. The answer will determine whether small alterations and reforms will be sufficient or if we must initiate fundamental structural changes. Without such an assessment, our eco-policies are doomed to fail. We have tried to estimate the degree to which humanity, specifically that segment residing in the industrialized North, has overdrawn its ecological account. We will introduce these estimates later in the book, along with a defense of why we believe the international community cannot circumvent the issue of fundamentally restructuring their economic systems.

We offer the following summary of the reasons why classical environmental policy faces such a dilemma:

The conceptual issue which is fundamentally missing from environmental policy that concerns itself with pollutants is the necessary focus on appropriate structural changes with which to restabilize and preserve the biosphere as the only foundation for both biotic life and human economic behavior.

In closing this section, we offer some thoughts on how an environmental policy which concerns itself with pollutants might look were it better able to fulfill its own claims. One of these claims is found in the precautionary principle: recognize and prevent environmental consequences of human activities before either humans or the environment have had to suffer from harm. This standard could be met at least in part with instruments that detect environmental damage at very early stages. Such instruments must be able to detect unanticipated environmental changes as well. The astronomers using radiotelescopes in their search for extraterrestrial lifeforms would be hard pressed if they only used frequencies or signals which we find useful on earth.

Nowhere in the world do we have an environmental observation system set up to detect a wide range of diverse and un-anticipated changes in the biosphere, that is also capable of sending reliable early warning signals.

The emphasis here is on the word "un-anticipated." Were such a network of observation points designed using the same technical sophistication which we employ in contemporary technical and scientific innovation, and in the creation of new goods and services, then we might very well have the ability to detect many of the "external effects" of our present economic endeavors. It is true that not even the most sophisticated observation system is able to detect processes which have not yet begun, so that even this system would have its limitations, but it would doubtlessly give environmental policy an additional opportunity to detect, and attempt to correct, disturbances much earlier.

An early warning system, designed to detect unanticipated biospheric reactions, must measure aggregative parameters, i.e. not single causes; and where possible, it should measure generalized, aggregated information about the observed effects. In principle, such an arrangement would not be so different from a large assortment of thermometers. The significance would simply lie in knowing with considerable certainty that something was amiss. In a limited way we already have such indices. The pH value, indicating the acidity of a body of water, is such an aggregative parameter in that it conveys something of the condition and change in the ecological makeup of the water, without carrying any explicit assumptions about the chemicals responsible for the change. The biotic oxygen demand, or BOD, is a measure of the nutrient content of a body of water.

Much remains to be done in the realm of biology, though. Our goal should be to design reliable, automated systems with the ability to indicate even the slightest changes in the rates of key biological processes. We would, in effect, be dealing with "environmental quality probes" made up of a combination of cultured organisms, cells or organelles and a recording device. Additionally, measuring arrangements could be developed further--and automated--that would respond to slight changes in the behavior of fish, water fleas, ants or any other species, while differentiating between the normal range of behavior and erratic, or statistically deviating behavior[8].

FACTOR 10

An interlude: the science - politics - news media triad

We indicated our skepticism about the potential for science to eventually provide all the politically relevant information about the complex and interrelated causes and effects of human activity within the biosphere. So as not to be misunderstood, we realize that science asks questions about the complex interrelationships in the biosphere and attempts to answer them. Svante Arrhenius, for example, asked the question about a rising level of atmospheric CO_2 100 years ago[9]. The motivation to ask such questions and any associated reservations are initially not politically driven. Scientists formulate such questions in a way that is not readily accessible to most. To the lay person, their use of complicated and exceedingly "precise" language or jargon obscures what they are doing. At the inquiring stage their questions should not--in fact cannot--be taken as serious political advice. This is not inconsequential in an age when politicians must increasingly rely on the expertise of scientists. This inability of scientists and politicians to communicate may have rather unpleasant consequences for all involved, including the watchful public.

We know the lament: Before the end of the nineteenth century, concerns about an impending greenhouse-effect due to the widespread use of coal were heard. By the turn of the century, numerous scientific papers existed on the topic of forest dieback as well as other environmental calamities. But no one heeded them. Why should the situation be so different today?

To many people who follow the reports of environmental catastrophes and global changes it remains a mystery why so little political action is taken to stabilize the biosphere, and why the action which is taken is so slow. In fact much of the evidence seems to indicate that humans have less and less time left to make up their mind to do something. Besides the fact that impatience was never a good guide, we should not to overlook one thing: the conclusion that humans are either unable or unwilling to structure their economic behavior in line with ecological requirements because they did not heed any of the warnings so far, is unwarranted. Individual scientific discoveries are by no means a societal force, and are generally not conceived as such by the scientists themselves. Scientific discoveries are initially always limited, isolated discoveries. An honest scientist will interpret even an alarming discovery first and foremost as an invitation for peer review, and not as an invitation to political crisis meetings. Not until many scientific discoveries can be assembled into a larger picture, along with more or less severe, observable damage where scientists predicted it would occur, does science find itself an actor in the political realm. In the environmental arena, Sherry Rowland's warning of the consequences of using CFCs provides a spectacular example[10].

Science has only achieved this status in a few areas. Science observes patterns of recurring local and global damages and increasingly finds itself able to decipher cause and effect complexes. In several cases, science has been able to link human acitivites with global effects with such reliability, that the remaining doubts should be considered relevant only within the scientific research communities involved.

But there are limits to certainty. Results that permit no doubts do not further the goals of science. Science would quickly become an ideology if this were permitted. If researchers were unwilling to refute the claims of their colleagues, especially in such politically charged fields as environmental and climate research, we would be in dire straits.

Unfortunately, these doubts, which are really the motivating force of science, are paralyzing political decision making. As the role which science plays in political decision making becomes ever more important in our increasingly complex world, the conflict between the internal demands of science and politics is exacerbated. Two dangers involved in this dilemma are becoming increasingly apparent; they serve neither the interests of science, politics nor the environment:

First of all, science must always remain open to doubts--exactly what politicians use as an excuse for inaction.

And secondly, we must concede that sometimes individual scientists look for the confirmation they are denied by their peers, in the public and political spheres.

When these problems occur jointly, and when scientists and politicians work hand in glove with the news media, the result is too often nothing but smoke, mirrors and derailed environmental policy. This phenomenon of scientists entering the political arena is all too frequent, and is generally considered either accursed or mildly amusing. Although the problem is a serious one, its characteristics are very much those of a caricature:

1. The story begins with either a press "leak" or with an industrial catastrophe.

2. The responsible minister is dismayed and inquires of scientists from within and outside of industry "whether this could happen *to us.*"

3. Science offers past discoveries and early warnings of the phenomenon, but counters this with the need for further research, as the available scientific results are not easily and unequivocally transferable to the present problem.

4. The press accuses the responsible parties of having ignored or even obfuscated the early scientific discoveries.

5. The minister defends himself with reference to the scientists' professed need for further research. He allocates funds to their research.

6. Science eagerly accepts the funds and scientists increase their research activity. If the initial event is succeeded by other similar events, legal action is demanded, to close factories or to intervene in some other way. Otherwise little else happens politically until the next "leak," at which point, see no. 1 above.

To get beyond this impasse, science cannot hide in its ivory tower, i.e. persist in its claim that discoveries will be interpreted according to scientific criteria exclusively, and that all futher use of the data is up to someone else. Rather the opposite is necessary. In light of the caricature above, it is becoming ever more important for scientists to contribute their own political interpretation of the results, or at least to seek a dialogue with politicians.

This exchange should not consist of the scientist attempting to convey the full complexity of his or her discovery in the hope of seeing it adopted as law--unmodified. The simple and simplified stands a much better chance of gaining a political hearing. An important task for future science will be to contribute to this simplification, to a "scientific" simplification which could include the search for aggregative, summarizing indicators that reduce complex problems to simple, measurable quantities. This is the only way that we can hope to preserve the essential elements of the scientific discovery, without running the risk of introducing any of a number of possible errors.

To many scientists this will sound like an unwarranted encouragement to participate in trivializing the results of their professional work. But this would be a misunderstanding. What is meant is a process of translation from the scientific discovery into the political praxis, from the complexity of the discussion among peers into a straightforward simplicity required for making knowledge the basis of the everyday acitivities of non-scientists. The concern of this book; to introduce an ecological measure dressed in everyday clothes, is an example of what is meant here.

Energy--the environment's number one enemy?

We cannot afford the luxury of examining one chemical after another for decades with the hope of legislating their eventual reduction. Instead we need reliable standards for ecologically beneficent economic behavior. The search for such standards is not new. In science and politics, energy has now been debated for a considerable time as a possible candidate for such a standard. Let us examine this assumption in greater detail before we deal with the specifics of environmental assessment procedures common today.

To summarize in advance:

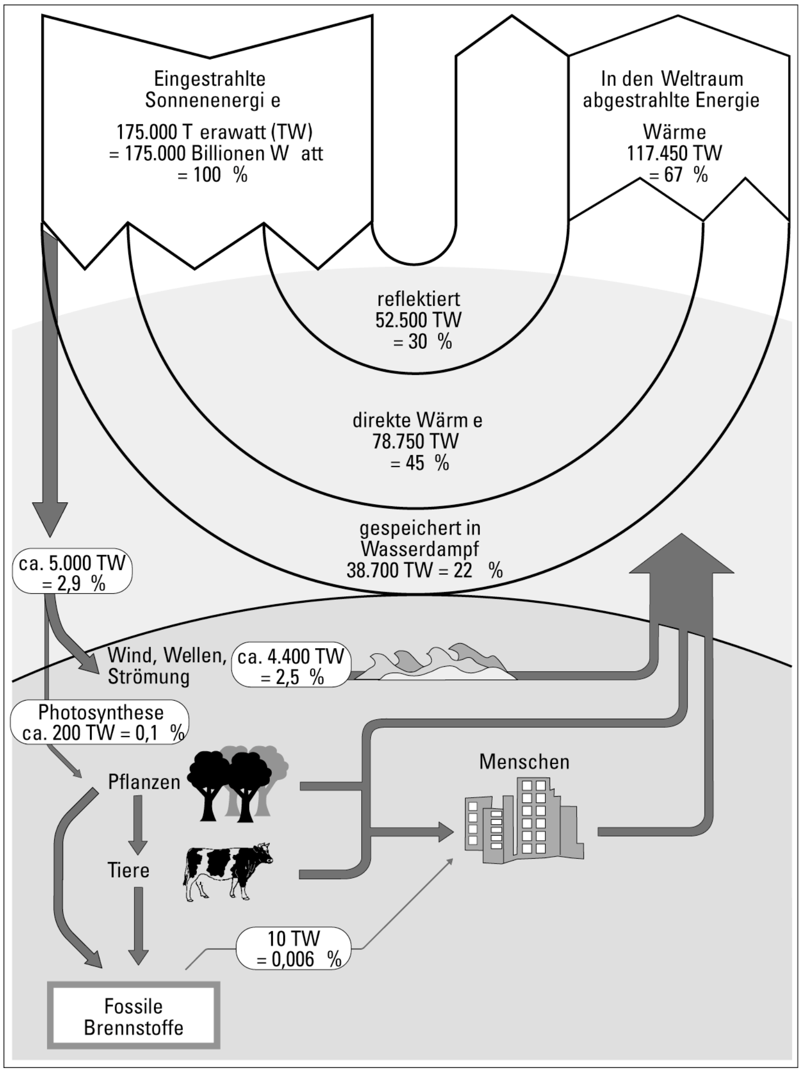
The environmental detriment of energy use does not follow from the environmental dangers of energy. The energy flows set in motion by human activity are only of marginal ecological significance. The problem stems from the material flows associated with the provision and use of the energy.

The human use of energy is only a small fraction of the sun's energy. The global energy balance is not affected in any significant way by the considerable energy demands of modern industrial and consumer societies. The amount of solar energy that is intercepted by the earth's land areas is 3,000 times the amount of energy humans used in all of 1990 (Fig 11).

Energy consumption--an indicator of environmental stress?

About a dozen gallons of diesel fuel and some primitive road-building equipment are sufficient to rid one hectare of forest, even tropical rainforest, of all its trees. This equals about 1,000 tons of timber, or perhaps twice that amount, in addition to the destruction such activity brings to the innumerable plant and animal species. It would take decades or even centuries for the trees to grow back, assuming that is possible at all. The resulting erosion can add up to a loss of between 10,000 - 50,000 tons of soil and the complete and utter destruction of any soil fertility. We can have all this for the same amount of fuel we put into the tank of our car on a family vacation without even realizing it. It seems unlikely that energy use would be a good measure of environmental stress in light of the above.

FIGURE 11



As everyone who lives in Provence knows, it only takes a box of matches and some lighter fluid to burn down entire slopes of the Les Maures mountaines. Lighting forest fires seems to be a popular sport in some Mediterranean countries, sometimes in order to gain access to otherwise protected land in order to develop it. The required energy is almost negligible. Plowing farmland with large tractors and other implements that reach far down into the ground does not require much energy. This practice has nevertheless caused so much erosion in some states in the Midwest, that only half of the original topsoil is still in place.

Simple roadbuilding equipment was used to carry off enormous quantities of overburden in the open pit coal mines in the Appalachians until the mid-1970s. As much as twenty times the amount of coal extracted was dumped into the valleys as overburden. Thousands of square kilometers of forest were destroyed in this manner. Roughly ten percent of the retrievable energy from the lignite coal was thus wasted. The problem was that wood is not of much use in a power plant. Hundreds of streams were filled in, resulting in massive flooding. More than 10,000 kilometers of streams and rivers so acidified through the oxidation of the sulfur compounds in the overburden, that the water was no longer usable.

Earlier in the book we discussed the subsidence of parts of the Ruhr area of Germany because of subsurface mining activities. Even here the energy balance was positive, at least initially.

An energy balance alone does not surround the ecological consequences of many human activities. It is even possible to draw erroneous conclusions from such an energy balance as the extreme examples show. Energy use is only a part of the ecological truth of human activity. Sometimes an important one, sometimes not. In practice, the question will often arise as to what extent it is possible to reach the goal of estimating the environmental stress intensity more quickly by drawing on simplifying assumptions. We believe that only very careful analyses of the material and energy inputs at all stages of the life of representative products and services will convey that information. We must not neglect anything until we have studied representative examples and determined the magnitude of that which we are tempted to neglect.

Renewable Energy sources

If environmental policy focusses too exclusively on any one particular problem, it runs the risk of creating new ones. A very striking example of this would be the notion that our present energy demand, (and, as some would argue, also our future demand) could be met with solar energy and hydroelectric power. Such a plan is absolutely unrealistic and incompatible with a concern for the ecological integrity of our activities. Vast areas would have to be covered with solar panels and global distribution networks would have to be built to transport an energy form, which, to date, has only generated a yield of ten to fifteen percent on any large-scale project attempted so far. Although the efficiency of such power plants is rising, we would still be forced to dam up every river and flood every valley in order to even begin to meet the demands of a society which has adjusted itself quite comfortably to the abundance of coal, oil, natural gas and nuclear energy.

Few doubts can reasonably be raised about the need for expanding our present use of renewable energy sources. Over the long haul, the non-renewable energy sources will be exhausted, as their name implies. Over the short haul, they too contribute massively to the destabilization of the biosphere through their rucksacks of material flows. Nevertheless, no advocate of renewable energy would support the above scenario. He would be suspected of contributing substantially to the ecological catastrophe which he was professedly trying to avoid. In order for a solar energy scenario to be realistic, we must provide those energy-intensive services using far less energy, which means that they will have to get by with significantly reduced material flows. Only if energy can be provided with a decisively reduced material intensity per energy unit (kilowatt-hour for instance), only when significantly less energy is needed for each unit of service, will we be on our way toward a sustainable economy. Energy policies that follow ecological principles must therefore begin with policies which change the structure of supply and consumption; solutions which focus on a single problem may therefore be justifiably suspected of merely postponing the ecological problem.

The case of CO_2

The most recent discussion concerning possible climate changes highlights an important isolated problem, probably the largest environmental problem ever to be publicly debated. From an ecological perspective it is but a partial problem, however, and we must be wary of forgetting the other problems when so much energy is suddenly devoted to the debate over CO_2 reduction. Within just a few years, CO_2 emissions became a new qualitative measure of all technologies and services. Even the battle lines between nuclear power opponents and advocates ceased to be clearly drawn.

Carbon dioxide is emitted into the atmosphere from quite a variety of anthropogenic sources, and only one of them, albeit the most important, is the burning of fossil fuels: coal, oil and natural gas. If we only include this source, the flow of carbon dioxide with which we stress the earth's atmosphere and affect the earth's climate, we are capturing only one of the many material flows which occur in the context of providing and using energy. We must therefore treat carbon dioxide as merely one aspect of the energy problematique. We must be particularly careful when attempting to curb the emission of CO_2 or even in trying to remove it from the atmosphere that we do not again mobilize terrific material and energy flows, if our efforts are not to be counterproductive.

The president of the Japanese Science Council, Professor Jero Kondo, has suggested that we solve the CO_2 problem by collecting the "surplus" carbon dioxide in the atmosphere using solar energy, before turning it into industrial chemicals. He recommends the same strategy for the CO_2 in smoke stacks. He also shows pictures of what such equipment would look like, and which chemical products could be obtained in that way[11]. This just might be the starkest example of an "end of the pipe" technology. Professor Kaya of Tokyo University, one of the highest-ranking advisors to the Japanese government, refers to the next century as the century of "decarbonization"!

As an aside, the assumption that the contribution made by CO_2 to climate change is the only possible ecological effect of the massive anthropogenic CO_2 emissions does not hold water. CO_2 is, after all, one of the most important compounds involved in plant growth. We simply do not yet have much data on the direct biological effects of increased CO_2 concentrations in the earth's atmosphere.

The discussion about climate change and CO_2 is therefore anything but superfluous. As long as it does not shift the balance in the environmental debate and political practice too much, it may serve the future of eco-politics in a very important way: if scientists from around the world concern themselves with a problem of such magnitude as global climate change and allow themselves to be scientifically fascinated by it; if conferences are held and in some--admittedly rare--cases political consequences are drawn, then we are experiencing what amounts to a first-rate example of the potential political and scientific action--the willingness to debate and to seek consensus, of which humans are capable. It is important to carry on debates about partial problems of eco-politics, if only to develop the instruments necessary for carrying on such politics at the international level. Yet it could lead to false conclusions, were we to forget that we are dealing with but a part of the problem.

Balances: how much environment does one product life cost?

It is a generally accepted fact that money is in short supply and that costs must therefore be carefully calculated. The rich and the poor do not differ much on this point. They have a more or less well defined understanding of the budget within which they can operate, and they know that in the private sector they cannot get around the limitation of only spending their money once. Terms such as incidental, or follow-up costs, belong to the everyday language of economics, because money is accepted, quite naturally, as a limited means.

Our dealings with the raw materials of this earth follow very different paths. As long as the often highly destructive efforts required for the provision of the goods and services we consume are not reflected in the price we are asked to pay, they will have no noticeable effect on our purchasing decisions. The fact that the bells and whistles with which we adorn our automobiles--from the spoiler to the low profile tires and magnesium wheels, the tuned mufflers and tinted glass--often come from halfway around the globe and were produced with enormous quantities of raw and auxiliary materials, not to mention energy, does not usually figure into our assessment. Neither does the fact that packaging materials, which instantly become waste once they cross the store counter, required high-quality raw materials for their production. Flying somewhere on vacation produces more carbon dioxide than can be granted an individual as their entire yearly CO_2 budget--if we keep in mind the protection of the earth's climate. If we go by today's prices, resources are apparently still inexhaustible and cheaply obtainable. The ecological consequences of their use change nothing in the final price--at least not yet.

The experience of the last few years has shown that in order to gauge the environmental tolerance of goods we must take into consideration all facilities, raw materials, products, packaging and transportation requirements that can be classed as inputs, and the estimation must cover all stages of the product cycle. In other words, the areas of raw material extraction, production, use, recycling and finally, disposal. The situation is analogous for the estimation of the environmental stress intensity of processes and services. The primary reason for these very high standards is that we have no way of knowing or estimating *a priori* which inputs or which phases of a product's life are associated with the greatest strains on the environment. A nuclear power plant, for example, requires the mobilization of enormous quantities of material before it is ever taken on line, whereas a coal-fired power plant necessitates the greatest throughput of material during its operation. Going by our present eco-toxicological knowledge, aluminum is a harmless material, but in its production, vast areas are laid to waste and tremendous quantities of energy are required. The material flows associated with the production of a catalytic converter are on the same level of magnitude as the weight of the finished car. This short enumeration indicates the need for large quantities of data. Furthermore it demands that a large number of very different criteria be taken into consideration if we are going to estimate the relative environmental stress of goods and services.

For several years now, individual products and even product lines have been subjected to "Life Cycle Analyses" or to one of several other related procedures. The more one restricts one's inquiry in time and space, the easier such a procedure becomes. The use of energy and water in a washing machine is relatively easy to compute for the useful life of the machine. Thus the comparison of an "environmentally friendly" washing machine with a conventional one is fairly simple. Whether or not such a comparison is warranted cannot be determined right away. The more in-depth such an analysis goes, the more difficult it becomes. It also becomes increasingly important to decide what one is looking for, what one is valuing. Is the criterionthe use of energy needed to operate the machine, in other words, the energy coming out of the wall socket? What about the energy required to explore and extract the raw materials, the production, packaging and transportation of the good? Or does the amount of waste and pollution perhaps furnish the decision making criterion? What is then to be considered a pollutant and what is not? Or are we instead more concerned with the amount of surface or land necessary to produce a product? How are we to decide how to compare differing types of land with each other?

In the ideal case, such an analysis would take all direct and indirect environmental effects of a product or service into account. But the first attempt to approach this ideal state will bring to light another problem: how is one to decide among differing damage potentials? How is, for instance, the ability to alter the genetic makeup to be compared with an observed toxicity to fish? The potential for changing the climate is difficult to assess alongside favorable characteristics of decomposition. We have no way to make such comparisons objectively, that is, no way to decide such matters independent of the interests or perspectives of the analysts or the reigning political authorities. As already noted, we presently find the CO_2 emissions associated with a product to be far and away the most important characteristic. Five years ago it was a very different picture. At this juncture we note a subjective force creeping into the analysis. This makes it contestable.

These, in brief, are the reasons why we presently do not have a useful method for comparing the environmental stress intensities of differing products, processes and services. Without such a method it remains doubtful whether we can expect to create a sustainable economy. If ecological criteria are to enter the realm of economic decisions--and they must for the economy to become sustainable--the degree to which one decision puts stress on the environment relative to another must be given much greater importance. In order to do this, the political and economic actors need reliable and transparent information about the environmental stress intensity of economically and ecologically relevant products, processes and services, calculated from the cradle to the grave, from the first cut of the spade or bite of the power shovel in extracting the resource, to the landfill or incinerator at the end of the service life. Any inaccuracy or incompleteness in this package of information can lead to mistakes that in the long-run may prevent us from meeting our ecological mark.

It is obviously true that we produce and use products which require so much more material and energy during one particular phase of their life that the other phases do not make the list; only that particular phase affects the ecological integrity in an important way. While a washing machine requires considerable material and energy for its production, the washing machine is--to put it bluntly--a machine designed to move large material flows *during* its service life. Each wash cycle requires electricity and so much water that after only a few uses, the water used would more than outweigh the machine itself. Could we therefore expect a fairly accurate picture to come from an analysis of only the service life of the washing machine? While this can be presumed, any further speculation would not be helpful. This presumption would turn out to be false if we discovered in the production of this machine, any small amount of material used that had itself necessitated the displacement of large amounts of material for its procurement, or great quantities of energy--in other words, that carried around with it a large ecological rucksack.

We must therefore always know with the greatest possible precision the material ingredients of such devices or machines. Speculations of the sort mentioned above are therefore not useful as a basis for production decisions or legislative endeavors which have ecological structural changes as their goal. Legislative attempts at revamping the tax structure can only hope to influence such a structural change with any directional stability if a reliable picture of the energy and material flows is available, and the opportunity exists to add up all the little rivulets that would otherwise go unnoticed, and which in the end add up to ecologically relevant flows.

A further reason why we cannot avoid adding up the material flows from the the cradle to the grave stems from the incredible interlinkages between the product flows on the world market. Were a small country with high import-quotas to decide to tax the use of raw materials, this measure might well have no effect whatsoever, as the greater part of the goods and services used in the country, requiring high levels of raw materials for their production were imported and thus not included. Not until it is known how and where the material flows occur, can a country make ecologically effective political decisions (and would, in the above case, have to push for international agreements).

Material flow analyses "from the cradle to the grave" or better "from the cradle to the cradle," as Walter Stahel would say, are also necessary. Thus the goal of Life Cycle Analyses and similar procedures are worthwhile, even if--as we will try to show--they are still not easily achieved. A carefully carried out Life Cycle Analysis requires two to three person-years of work today. It cannot be done under any circumstances in less than one person-year. The labor costs for one such analysis would quickly add up to five- or six-digit figures, and if one considers that millions of products are currently sold on the market and would have to be analyzed to provide a complete picture, then the endeavor already looks problematic from a financial perspective.

Internationally harmonizing the assessment of the environmental dangers of materials is a frustrating business. In twenty years the OECD managed to bring about agreement in fewer than ten cases.

Whichever way one looks at it, without a scientifically defensible yardstick permitting rough estimates that can be manipulated simply, cheaply and easily; that considers criteria that are relevant to all processes, goods and services without exception; that permits the comparison of data without complications and contradictions and that nevertheless reliably points in the right direction--without these criteria, the neccessary overview of national and global material flows will not come about. We will be introducing such a measure in the next chapter, illustrating the characteristics it should have and what it might look like. Not until we have the help of such a measure can we compile Life Cycle Analyses as screening procedures. Only in this arrangement can they be assembled in an acceptable amount of time, with an acceptable amount of effort, and on the necessary scale, i.e. for all ecologically relevant processes, products and services. Where it then becomes necessary to inquire in greater detail--because for example the initial analysis did not show one alternative to be unequivocally preferable--then other procedures should be used, also and especially with respect to the question of the possible eco-toxicological effects of the materials involved. Stefan Bringezu of the Wuppertal Institute has worked out this argument in considerable detail[12].

A plethora of methodological approaches exist with which to describe the ecological risks associated with goods and processes, and a large number of names and terms are used in this context. This diversity materialized with a certain inevitability, as innumerable attempts were made to come to terms with the effects of human activity on the biosphere at various levels. So it is quite sensible to examine the environmental relevance of a chemical with different methods than the environmental significance of a firm, and to treat differently again the metabolism of a city, region or nation with their respective environments. As diverse as the methods may be, it must still always be the goal to find decision making criteria for the protection of the biosphere. The question thus becomes what, if anything, these many approaches have in common, and if there is perhaps a kind of "principle cause" of all these environmental effects. We can answer this question affirmatively. Wherever human activity changes the biosphere, material flows are involved, including those that are displaced to make energy available. We will return to the question of how these approaches can inform our measure of environmental harm at a later point.

As some terms will reappear throughout this book, and because this book is based on the experiences gained from past attempts at recognizing environmental effects, we will deal briefly, though not exhaustively, here with some of the important and currently used instruments for the description, registration and quantification of environmental stresses. More detailed treatments are to be found in the appendix.

Life Cycle Analyses

The German *Umweltbundesamt*, the technical support of the Ministry of the Environment, has defined the term "Life Cycle Analysis" as follows:

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 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.

Product Line Analyses

The term "product line" was introduced by the Öko-Institut Freiburg[13] in Germany. It is an attempt to expand the LCA concept, which has a strong natural science-ecological emphasis, by introducing social aspects and the concept of utility. In this sense, then, the Product Line Analysis is to be located somewhere between the "Life Cycle Analysis" and the "technology assessment."

Life Cycle Analysis of spatial or geographic entities

One particular type of LCA is concerned with the effects of human activity on spatially delimited ecosystems such as the mudflats of the North Sea, or areas in the Alps, or other ecologically sensitive regions, but also of the *Ruhrgebiet*, Germany's agglomeration of industrial cities, or other urban areas. Berlin and its surrounding areas, as well as the city of Düsseldorf, have already had such analyses performed. The investigation of a product or service is not at the heart of this type of LCA. Instead an inquiry into the stresses and the theoretical carrying capacity of a region is undertaken. The goal is usually to obtain information about the long-term development of a region, with respect to industrial siting, for instance, or tourism. To restore or rehabilitate a region requires such an analysis. When managing structural change, this type of analysis can provide insight into the areas where "undisturbed" developments might still be possible, as well as how the stress is distributed. The *Umweltbundesamt* has published a series of papers on these topics.

Using the *Ruhr Area*, Helmut Schütz and Stefan Bringezu from the Wuppertal Institute have delineated how a more spatially oriented LCA might look (see the chapter on "SIPS"). These developments are of considerable significance to any future environmental statistics of Germany, or to those of any other country or geographical area.

Environmental Profiles

The results of an LCA can be highly complex. In order for these results to be useful in practice, for bestowing an *Umweltzeichen* (environmental label) for instance, they can be simplified with an assessment framework. The result is a so called environmental profile. In its simplest form it is a table, indicating which of the criteria used in the assessment matrix were met by the various products, processes and services compared, and which they failed to meet. The environmental profile simplifies considerably. It stands at the end of a series of assessment procedures, and cannot be sensibly used for further analyses or assessments without reference to the LCA and the assessment framework.

Technology Assessment

Technology Assessment belongs to the oldest procedures for assessing technology. Its reach goes well beyond the registration of effects on the environment. The term "Technology Assessment" (TA) comes from the U.S. Congress' Committee for Science, Technology and Development, which concerned itself with the "unanticipated consequences" of technology in 1966. The Committee defined TA as a type of early warning system that is intended to help detect societal, health and environmental side effects of new technologies. In order for long-term and cumulative effects not to be overlooked, it was determined that complex interacting mechanisms between social conditions, technical and scientific developments and their effects should be examined. In addition to the focus on risk analysis, a catalog of decision making aids and alternative suggestions for policymakers was agreed upon as well. As a result of the work of the Committee, the Office of Technology Assessment (OTA) was founded in 1972, which has done highly acclaimed work for over two decades now.

For many years the Germans debated the merits of having their own institution for technology assessment. A special commission of enquiry concerns itself with this topic. Since 1990, the Office of Technology Assessment of the German *Bundestag* has taken over the coordination of these matters. Because of the broad interpretation of the concept, the cooperation between different societal groups is always necessary. To consider it a purely scientific affair would be too limited a perspective.

Technology assessment has now been a rallying point of the labor unions and is understood in this context as a procedure for the assessment of social consequences of technologies in the realm of production. The area of concern is in fact with present technologies, deemed problematic for one reason or another, as well as with technical developments which are expected to generate relevant effects in the future.

Environmental labeling

Experts at a 1991 conference organized by the United Nations Environmental Program or (UNEP) decided what an environmental label was: "Programs dealing with environmental labelling are making the positive statement that a product or service that is to be used for a particular purpose is less harmful to the environment than similar products or services."[14]

In Germany the "Blaue Engel" or "Blue Angel" has been issued for 15 years now. Canada, Japan, the Scandinavian countries, Austria, the Netherlands, France, Singapore, and India have their own such labels. In 1992 the European Union decided to introduce its own label.

The Blue Angel has become a trademark and a frequently used decision making aid in Germany. In May of 1993, 3,500 individual products from 873 producers carried the label. Fourteen percent of the products and fifteen percent of the producers were from outside the country. The label is given out for seventy-one different product categories, including household chemicals, home, garden, and office equipment, building materials, water saving devices, particularly quiet devices, paper and cardboard products as well as reusable packaging. In the field of transportation they are issued for public transportation, retreated tires and car washes.

According to a private law contract with the "German Institute for Quality Control and Labeling" (RAL), the Blue Angel may be issued. It is issued by the pluralist "environmental labeling jury" on the basis of criteria set up by the German Ministry for the Environment.

Environmental compatibility tests

Since 1990, public projects must be tested for several environmental effects. This has since been written into the law concerning environmental compatibility testing. The effects which are tested are those on humans, animals, plants, soil, air, climate, landscape as well as on cultural and intrinsic value. These tests are a first attempt to systematically register and compare material flows that result from constructing facilities and businesses. The goal is to compare the different alternatives and either to throw out all variations, or to select the one which will cause the least harm to the environment. The procedure of an environmental compatibility test is roughly equivalent to a Life Cycle Inventory within an LCA, with a subsequent balance assessment.

Environmental Audits

An environmental audit has been defined by the European Union[15] as a "management instrument with which to obtain a regular, systematic, documented and objective assessment of the achievements of the organization, management and processes for the protection of the environment. It shall further serve the following goals:

1. simplifying the role of management in promoting behavior which would have an effect upon the environment;
2. assessing the corroboration with management policy on environmental matters."

Materials reports

Materials reports attempt to describe the effects of a chemical upon the environment. The toxicity to humans and the environment are described according to a differentiated conceptual framework. For several years an internationally agreed upon pattern has been used, originally developed by the OECD and later adopted by the World Health Organization (WHO).

Chapter2

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The travels of one glass of yogurt

One little glass of strawberry yogurt is an inexpensive item. It costs a few cents. One would think the producer wouldn't have all too much room for extravagant production methods. And besides, how could a little strawberry yogurt harm the environment? Milk from the nearby dairy, some fruit, a lid--albeit an aluminum one--but otherwise just a few odds and ends--one would think.

Stefanie Böge from the Wuppertal Institute has examined the few odds and ends*. With the help of the *Südmilch AG* in Stuttgart she researched just one environmental aspect of

Swabian strawberry yogurt--its transportation. She suddenly found herself on a trip across Germany and beyond.

The dairy farmers are actually from the surrounding area of Stuttgart. Even the sugar is from produced locally. But the bacteria needed for turning milk into yogurt are shipped in from Niebüll in Germany's northernmost state. The glass itself is produced in Bavaria with raw materials from North-Rhine-Westphalia, and even the aluminum lid travels from the lower Rhine area via Bavaria to Baden-Württemberg. The strawberries grow in Polish fields and are processed in Aachen, on Germany's border with France, before being shipped to Stuttgart, where they are added to the yogurt. In the packaging for shipping the glasses she discovered various and sundry ingredients from cardboard to glue and plastic wrapping from Bad Rappenau, Aalen, Cologne, Lüneburg, Varel, and Ludwigsburg, as well as from suppliers in Austria and France.

Once returned home, Stefanie Böge added up the distance: 7,857 kilometers of roads had been used, and all with trucks. When divided into one glass of yogurt weighing 150g, this means that each glass was driven 9.2 meters before it could be bought off the refrigerated shelf in Southern Germany. These nine meters are probably on the short side, as the trucks sometimes returned empty, and the trips for buying and returning the glass are not included in the calculation.

One can spend a long time arguing about whether nine meters are a great distance or not. What is certain is that several of those meters would not have had to be travelled if the transportation had been optimized according to ecological criteria. Strawberry farmers exist in the immediate vicinity of Stuttgart, and the same goes for fruit processing and packaging materials.

Even so, no processing plant demands that ingredients be shipped thousands of kilometers out of malice or complacency. Economically, such "chains of transportation means," as the traffic scientist calls them, make sense. With numerous taxes, fees and other measures we subsidize traffic. Therefore we should not be surprised when carefully calculating entrepreneurs contribute their share to it. Predictions indicated a doubling of truck traffic even before the European borders ceased to have any significance for intra-European trade.

What should one do? Stefanie Böge made some suggestions. A consumer can already contribute meaningfully by selecting locally produced products from nearby stores. Politically, the prevailing conditions must be arranged in such a way that businesses have an incentive to both avoid unnecessary transportation as well as to optimize the unavoidable tranportation, and, where it is possible and sensible, to switch to other modes of transportation such as the train or ship. If yogurt were, for example, sold in standardized reusable packaging, many of the supply and return shipments could be avoided. By raising the cost of transportation, buying ingredients locally would automatically become economical.

Her appeal to business can be understood as a general conclusion: "The more decentralized an economy organizes the structure of its production and the faster the packaging and transportation industries can harmonize their efforts (with respect to both transportation packaging as well as the packaging of individual products), the sooner we can reach the goal of reorganizing our freight transportation in more environmentally friendly ways."

* *Stefanie Böge, Die Auswirkungen des Straßengüterverkehrs auf den Raum--Die Erfassung und Bewertung von Transportvorgängen in einem Produktlebenszyklus. Diplomarbeit am Fachbereich Raumplanung der Universität Dortmund, Juni 1992.*

Chapter 3 MIPS: A New Ecological Measure

MIPS in nuclear technology: micropulse inspection and processing software
MIPS in computer science:million instructions per second
MIPS in this book:material intensity per unit of service

The requirements of a new measure

At the conclusion of the previous chapter we showed that a variety of approaches exist in science, administration and the economy to record the environmental effects of human activity in such a way as to permit comparisons as well as to illustrate alternative courses of action. The enumerated procedures differ in their methodology and in their questions, as well as in their goals. It would therefore not be fruitful to try to decide which method is "best" able to provide guidance in trying to adapt products, procedures and services to future ecological conditions. The LCA, for instance, allows the comparison of certain goods and services. The environmental compatibility test is supposed to assess businesses and facilities. The regional LCA is designed to record the material flow dynamics within a political or economic entity, and materials reports are intended to simplify the assessment of individual chemicals as well as to allow for some international commensurability.

Much has already been done, and some of that has been translated into actual political decisions. But are we on the right track? Do our present knowledge and analytical methods form a rugged basis with which to render the effects of the many ways in which humans interfere with the functionings of the environment comparable, understandable and, above all, avoidable? What is the common denominator for ozone holes, fish kills, erosion, contaminated water, climate change, forest dieback, air pollution, flooding, garbage inundations, salinization, advancing deserts and the pollution of our oceans? What is it that makes our economies so fundamentally un-ecological even though we have spent almost twenty years fiddling with apparently effective environmental technologies and have spent very large sums of money on them? Of what material is Ariadne's thread that could lead us out of the labyrinth of seemingly endless and endlessly varied environmental problems?

If it is our goal to construct a sustainable and more ecologically sound economy we should be in a position to give some immediate answers to the above questions and to search intently for other valid answers. Otherwise a systematic and confident transformation of the western economic system, which has not only been maturing for decades, but which also gives the impression of internal coherence, is unthinkable.

The much-discussed marriage of economics and ecology can only occur if both the value and the load-bearing capacity of the biosphere are understandable and accountable.

The ecological currency must be tradeable. Good heads of state rarely exhibit a thorough scientific knowledge of complex non-linear systems.

The concepts for judging the relative environmental burden we introduced in the last chapter are not yet sufficient as reliable sources of insight on how to construct a sustainable economy: the analyses generally remain on the level of the examined case study. They are not designed to provide the information necessary to generalize. A generalization would hardly be possible even if the inquiry were very limited, because examining ecological linkages and effects yields tremendous complexity. Even if this complexity were completely understood for a particular area, it is not certain that the resulting discoveries are transferable to other materials, procedures, facilities or services.

This should not be understood as an indictment of such case studies. The bottom-up approach is necessary for constructing a foundation upon which legislative decisions, i.e. restrictions and bans, can be built--especially in the event of danger. But administrative law does not in and of itself produce structural change. Even with the largest conceivable number of individual inquiries, it is unlikely that we will eventually obtain a total picture of the feedback loops between humans and the biosphere. The number of individual products, services and processes is far too great, and because of the creativity of our economic system, more are added at such a rate that time-consuming and expensive scientific assessment procedures can not keep up.

This means that humans need a foundational indicator able to represent even complex interlinkages in an aggregated form; a measure that is scientifically defensible as well as rugged, with which to measure the environmental stress in a simple way, despite the complexity of the causes. This measure must, even though it should be simple, generate rough estimates. In other words it should be able to consistently give a fairly accurate approximation of the intensity of the environmental stresses involved.

Specifically, such a measure should meet the following conditions:

1. It should be simple, yet reflect important factors influencing the environment.
2. It should be based on characteristics which are common to all processes, products and services.
3. The selected characteristics should be straightforwardly measurable and subject to quantification.
4. The use of this measure should be cost-effective.
5. The measure should permit the transparent and reproducible estimation of environmental stress potentials of all conceivable plans, processes, goods and services from the cradle to the cradle.
6. Its use should always lead to directionally stable results.
7. The measure should form a bridge to market activities.
8. It should be usable on all levels: locally, regionally and globally.

Wrinkles on the face of the earth

The basic assumption of this book is that the massive and rapidly growing human-made and human-caused material translocations are changing the evolutionary equilibrium of the earth. The stability of the biosphere is being called into question. These anthropogenic translocations of mass are--as mentioned above--already greater than those of the geosphere, and in some cases up to 200 times as large. We shall briefly remind ourselves of the growing cities, the new industrial areas as well as shopping malls, transport systems, energy supply systems, the agricultural interferences, airports, landfills, clearcuts, slash-burnings, mines for both ores and energy carriers, gravel quarries and straightened rivers.

In the physical sciences we have come close to discovering natural laws. In physics the Laws of Thermodynamics belong in this category. With these laws, we can argue that perpetual motion is impossible. With respect to our inquiry, these laws imply that the more material we set in motion, the greater the chance that some of the effects will be harmful, and that we create ever more "disorder" on the earth, the more energy we pump into our economy. Forest dieback, the ozone hole and global climate change are the first measurable signs of this development.

In simple systems, we know that adding or removing materials which stand in a reciprocal relationship to other materials, or which react with them, forces the entire system to adapt. With the help of "Guldberg and Waage's Law of Mass Action," one can even calculate the ratios that will establish themselves between the different components in such a simple system after a new equilibrium is achieved. In chemistry, such computations have both a practical and a theoretical significance. The Law of Mass Action cannot be simply transferred to the much more complex prevailing conditions in nature. Nevertheless we should state clearly that each and every human interference in the material composition of any part of the biosphere forces that part to adapt to the new circumstances. The greater the extent and the more material involved in these interferences, the more comprehensive the ecological reaction must necessarily be.

Covering an undisturbed green space with a parking lot, or "sealing it off" has a very different significance to the earth worms and the thousands of other organisms trapped below than to the user of the parking lot. Sealing off means radically altering the biological processes in the soil. Sealing off prevents all photosynthesis, which means that on that surface no more CO_2 can be fixed by plants in the form of biomass. Sealing off also changes the hydrologic balance, both below and above the sealing layer, as the rain water has to go somewhere else. Building houses, cities, parking lots, sports facilities, streets and roads, train tracks and much more--in short, all of those things that we do for our material wealth--is bought by sealing off these areas. Besides, sealing off is but one in a long list of ecological consequences associated with building houses, cities and parking lots etc. And sealing off is but one of many human activities which change the face of the earth.

If someone were to quip that the earth does not seem any worse for wear, then one should be permitted to ask whether anyone has really tried to find out?

Material intensity and service units

Most people would instinctively agree with the supposition that the material, energy and surface demands of a product have a good deal to do with its environmental tolerance: the more "environment" required for the product, the worse it appears from an ecological perspective.

Interruption

Wolfgang Sachs[1] asks: "Is not aesthetics an "early indicator" as perhaps ethics or decency might be, long before we get to the scientific demonstration? That people "instinctively" agree with our supposition has to do with this. Does our affinity for aesthetic quality not "instinctively" tell us something about ecological quality? This would be an entirely different introduction to the discussion. Schmidt-Bleek is correct, but we have to think about it very carefully first."

We realize that this cannot be all that is worth considering. If we were to take two automobiles, for instance: both require the exact same amount of "environment" for their production, both require the same amount of oil and fuel, but one of them is driven twice as many miles as the other one. The automobile which yielded more service is obviously the more "ecological" of the two products, as the other one stopped "half-way" and had to be replaced by another one.

If, on the other hand, the owner of the car which lasts longer drives twice as much as before, because he knows that he owns the ecologically better vehicle, the benefit to the environment is lost.

This is precisely the development which we have observed over the last few years; later in the book we will return to the issue of whether people should change their habits in the future.

People often remark in discussions that the automobile is really more an object of passion than a means of transportation and mobility. It is rather a status or sex symbol even. As the human urge to be noticed certainly did not begin with the automobile, the question arises what might have filled this place before? Should we take a look at old photographs? Was it uniforms, medals or ostrich feathers? In any case, we can imagine many forms of expression that would cater to the need for putting oneself on display--even some ecologically benign ones. A large field of opportunity appears here for intelligent marketing; perhaps even as an opportunity for environmentally troubled tennis stars, news anchors, ecclesiastical dignitaries and members of royal families to live out new trends.

Another interruption

Perhaps these comments do not take the malaise seriously enough: Wolfgang Sachs[2] points out that people live in worlds of meaning, and that today these meanings are tied to consumable objects. Status might not even be such an all-important element, but rather one of several manifestations. He thinks that the symbolism of consumption is the issue, rather than its use. We will have to think these issues through very *carefully if we are interested in determining the social and societal dimensions of possible ecological structural changes.*

In this book we wish to keep separate two issues. On the one hand, we will search for new standards for assessing technically verifiable processes, which can be kept within the ecological guard rails with the help of such verification; on the other hand lies the values discussion about material consumption and human well-being. We have to keep these separate or else we will never come to any resolution. Especially when it comes to the question of "service units" and the "use" that people may derive from these objects, the question will arise as to the sense or non-sense of this "use." Tea ceremonies are without a doubt ecologically more benign than hot air balloon rides. Zero-options in consumption, or the option of *non-use,* are ecologically preferable to even the most environmentally friendly technical solution.

In order to bring about a sustainable economy we must approach both: we must search for new models of prosperity and better technical solutions for the satisfaction of our machine-dependent needs and wants.

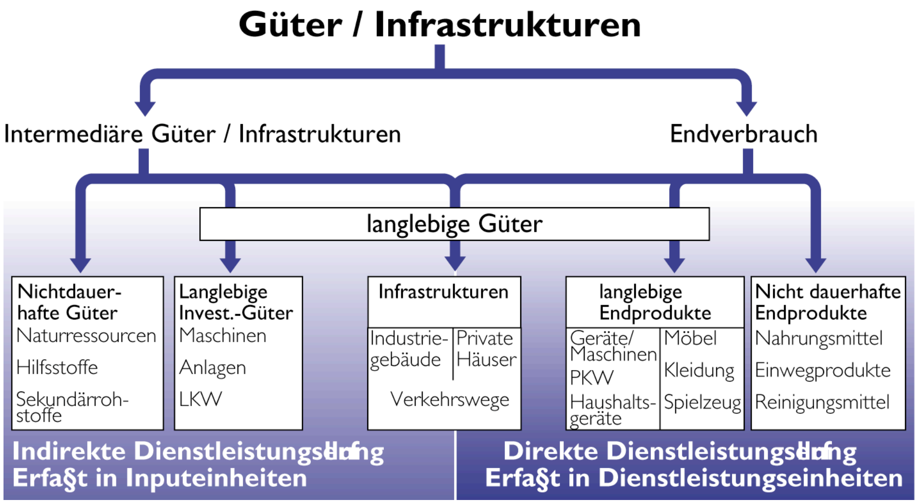
A new quality of technical efficiency must be accompanied by a newly discovered human sufficiency.

Returning to the discussion of new standards for technically verifiable processes in the context of biospherically determined guard rails: In 1992 we suggested for the first time that the total material expenditure required to make a product available, to use it for its entire service life, and to eventually dispose of it--in other words the material flows which the product necessitated from cradle to cradle inclusive of all ecological rucksacks--be used as a proxy measure for its specific environmental demands. We include in this all materials required for providing the requisite energy inputs as well.

In this procedure, the material quantities which are needed for transportation, the use of infrastructures (roads, train tracks, telephone lines, etc.), the facilities as well as packaging for the entire life of the product must be included in their proper proportions. Waste flows themselves are not considered as they are outputs and not inputs. We make the assumption that for a preliminary estimation of the environmental stress intensity of goods, a screening--a knowledge of the lifelong material intensity of the inputs--suffices.

We are finally also interested in estimating the environmental stress associated with a particular material standard of living. It appears that the sum of the "services" rendered by products reflects the material standard of living we are able to describe. Goods provide people with opportunities to function in certain ways. Often, different goods are able to offer comparable services or carry out comparable functions. Such goods or devices can be termed "functionally equivalent" or at least "comparable." In principle, the environmental burden could be lowered while maintaining the material living standard by introducing functionally equivalent goods that have reduced material intensities (dematerialized goods) onto the market. We therefore suggest measuring the material intensity of services or functions.

FIGURE 13



As shown in Figure 13, we can distinguish between intermediate goods (or infrastructures) and those which are destined for final consumption. In both categories we find goods which are very durable and those which do not last. The environmental burden associated with goods for "meeting service needs indirectly" such as steel, solvents or cement is measured in cumulative material inputs per unit good (or per unit of weight of the good). We count up how much material flowed into the production of the good, and this amount is then listed as per unit or per ton of the produced good.

The goods which "meet service needs directly" include apartments, washing machines and mouse traps. In these cases the environmental stress intensity is also indicated in cumulative material inputs, but here they would be listed with respect to the units of service delivered or performed. In the case of the washing machine the environmental stress intensity would be listed in kg material per kg dry laundry which the machine is able to wash over the course of its service life. As this total sum of services which the machine can deliver can only be known with precision after the fact, we must calculate the number using other criteria such as the guaranteed service life indicated by the manufacturer.

In the case of throwaway packaging or non-reusable products (such as newspapers), the number of deliverable service units or use-units equals one. We thank Maria Jolanta Welfens and Fritz Hinterberger of the Wuppertal Institute for the delimitations in Figure 13.

MIPS--the new measure

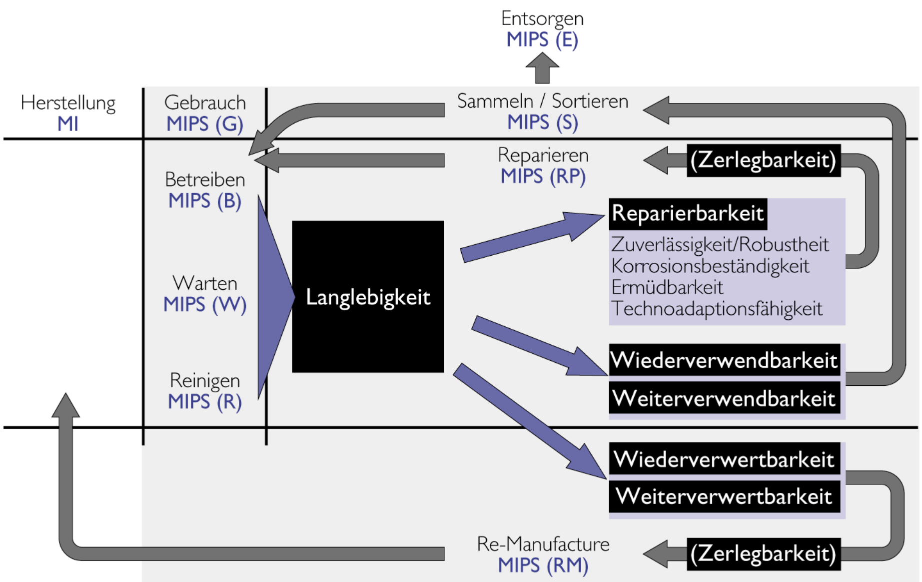
Taking all that we have said about this matter so far into account, we are now ready to define a new measure for the environmental stress intensity of any product.

The measure for the environmental stress intensity is the Material Intensity Per unit of Service with respect to the entire product life: in other words, the material consumption from the cradle to the cradle per unit service or function--MIPS.

As already indicated above, the material translocations for the energy requirements for the entire product life are taken into account as well. We will deal with the term "service" in considerable detail in a separate chapter later on.

MIPS is thereby defined for service-yielding final goods, and not for raw or auxiliary materials which enter the manufacturing process of the final good. MIPS can be used both for short-lived and for durable goods, and can in principle be derived for quite complex facilities and infrastructures. As we will show, those calculations are still quite expensive.

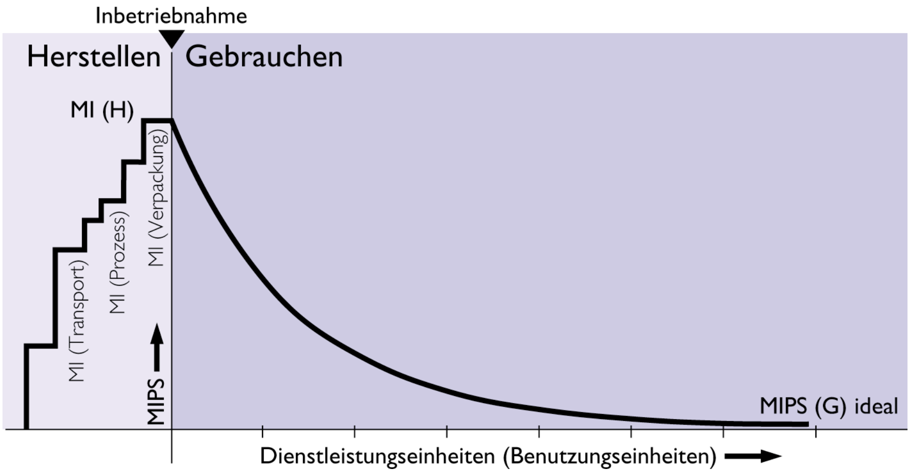
FIGURE 14



The amount of material used is measured in kilograms or tons and is set against the use which a person can obtain with the help of such a "service-delivery-machine" (the product or piece of equipment in question). In order to be the recipient of such a service, the person need not own the product outright, but need only have the right to use it.

It is now possible to show how the material requirements are divided over the various process increments of the life of a service-yielding final good. Figure 14 distinguishes between the processes of manufacturing, using (operating, maintaining, cleaning), repairing, reusing (perhaps using only component parts), collecting, sorting and disposing. Additionally, transportation enters the calculation as an almost ubiquitous link between the various steps. It is possible to compute the material and energy demands for each process. This is then related to the total number of deliverable (or, in hindsight--delivered) use-, function- or service units. In the case of non-reusable packaging material and throwaway products (which actually vanish in the landfill and are not used for other purposes), the "S" of MIPS is equal to one. MIPS in this case is equal to the aggregate amount of material for all process increments.

FIGURE 15



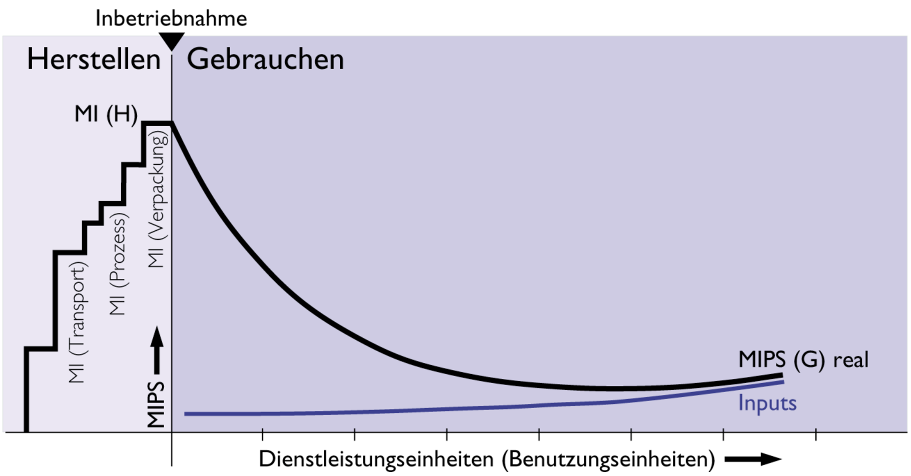
The hypothetical trajectory of the increasing material intensity of a product during the production phase. The steps indicate various processes, including transport. The material and energy inputs include their respective ecological rucksacks. Upon completion of the product, the use phase begins, and the material input per unit extracted value (MIPS) decreases with each successive use. The longer the live time of the product, the lower the average MIPS will become. This illustration is only realistic for products that need no maintenance and no inputs during use (such as a sun dial).

Figure 15 shows the decrease in MIPS as the number of service units delivered by the product rises. Each successive service unit cuts in half the value of MIPS achieved with the previous use. MIPS thus shrinks with each successive use, and the environmental compatibility of the product improves in step.

Figure 15 shows a fairly rare case. Here, neither material nor energy is required at any time during the use of the device, and it is never cleaned. The device never needs any extra material during its service life. A sundial for instance.

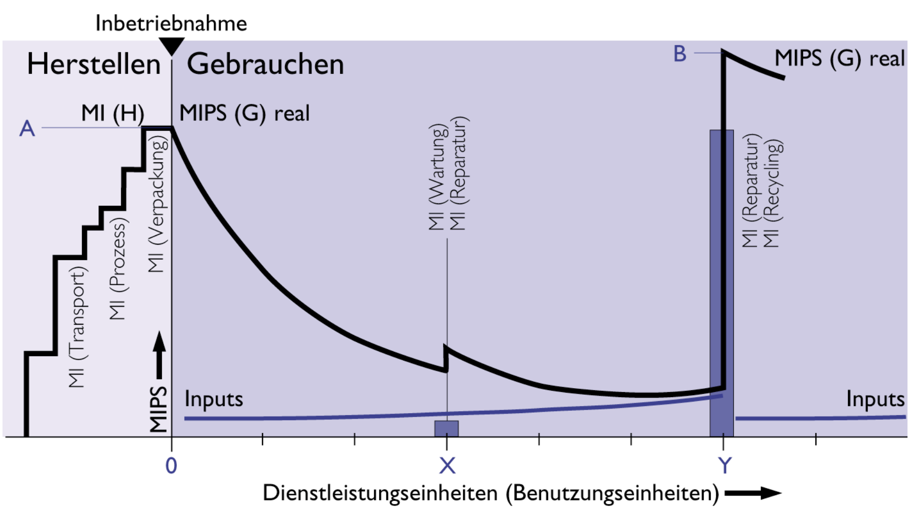
Let us look at a more typical case: a washing machine. As Figure 16 shows, the MIPS curve falls more slowly because water, energy and detergent are used in each wash cycle. If the use of water and energy rises with the age of the machine, the curve might even reach a minimum, after which it would start to rise again.

FIGURE 16



The MIPS trajectory with increasing number of uses of a product, such as a washing machine. The reduction in MIPS illustrated in Fig. 16 is less than that in the previous Fig 15 because resource inputs are required during each use of the product (water, energy, detergent). If the consumption of these inputs increases markedly as the machine gets older, the MIPS curve can reach a minimum and rise thereafter. At that point the ecological quality of the service received from the product begins to deteriorate.

FIGURE 17



The MIPS trajectory with increasing numbers of extracted utility units, such as with a washing machine. In this case, though, a small repair requiring resource inputs (energy, materials, transportation etc) was performed at point X, increasing the relative ecological rucksack of the product. At point Y, a much more substantial repair became necessary. This repair leads to an ecologically absurd result and would most likely also be a bad investment of money.

If a repair becomes necessary (Fig. 17, point X), we have a "MIPS stimulus," after which the curve begins to fall again. A repair that is very "expensive" in terms of material, energy or transportation (point Y) can lead to a situation in which the machine is operating at a higher MIPS value than when it was new. This would be an example of an ecologically absurd repair--if MI (the material intensity) for the distance X--B is greater than for O--A. (In other words, if the MI value of the repaired machine is higher than the original MI value of the new machine.) The high labor costs would probably make this an economically unwise repair as well.

The representation of an "ecologically expensive repair" could also describe the situation in which the machine is recycled by a process that involves large amounts of material, energy and transport. This might be the case if polymers were converted back to source material such as monomers, with the help of machines which themselves carry large ecological rucksacks, and which necessitate the use of high temperatures and pressure, not to mention additional materials. And this would then be only the first phase. The resulting product would still be only a building block to be used in the creation of other materials. Characteristically, though, recycling processes yield materials for which a repetition of the initial material, energy and transport requirements is not necessary. The total effort for a product that was produced with recycled materials is, in this last case, ecologically preferable to production with virgin materials.

Nevertheless, such product cycling to and from a recycling facility can involve considerable material and quality losses. In the case of paper, the fibers break each time they are recycled, and after five to seven cycles the material simply cannot be recycled again.

In the case of recycling aluminum, the required energy use is only about five percent of what is needed to obtain raw aluminum through electrolysis, according to the industry figures. Nevertheless the effort to clean, collect and transport scrap aluminum can be considerable, and several percent of the aluminum which is already in an oxidized state has to be thrown out and disposed of[3]. In Germany this amounts to no less than several tens of thousands of tons per year. This is not meant to imply that recycling is unwise, but that these considerations must always be kept in mind.

The following example illustrates the full complexity of estimating environmental stress intensity in the real world: If one ton of goods is to be transported from Hamburg to Cologne, four main transportation options exist: the train, the ship, the airplane and the truck. Each of these four transport systems must be manufactured, requiring the displacement of material flows. Each ton of steel, overburden, concrete, water, air, and other matter that is required to make the facilities, the truck, or the diesel locomotive must be divided over the total life of that means of transportation and over the total volume of freight which it can transport over the course of its life. Each vehicle needs fuel--although in different quantities; it needs transportation routes and infrastructures (gas stations, airports) that must be built--which involves moving material; and it emits pollutants and eventually becomes waste. It must also be kept in mind that each of the four modes of transportation have different payloads. That is, they can deliver different amounts of services per trip. In the case of perishable items the cost of refrigeration is a factor, especially as the length of the trip increases. If the vehicle returns empty, or only carries a partial load, the MIPS balance is negatively affected. Hartmut Stiller of the Wuppertal

Institute is in the process of computing the material intensity of different transport services for different transport systems[4].

In assessing the resource intensity of each and every process, good, and service, we will find out how large the "ecological rucksacks" are--where the large material flows are set in motion, and where it would be technically and economically most effective to attempt a dematerialization. Dematerialization does not simply mean renouncing the use of goods or services. It also does not mean that "natural" products such as wood or stone are unequivocally better than "artificial" or "chemical" products, and above all it does not mean that solar energy must always be preferable to oil or coal. It may be difficult to predict which products will fare well in a material flow analysis "from cradle to cradle," and which find themselves on the black list. This way of looking at things is new, and it is all the more exciting to try out.

We cannot carry out these analyses for all products and services in our industrial societies. To attempt this would be a frustrating experience, for reasons already mentioned. We must therefore find "indicator goods" and "indicator services," carefully analyze them "from cradle to cradle" and transfer the results to other goods and services with the appropriate corrections and margins of error. We should then begin dematerializing each good and each service, shrinking its ecological rucksack where it can be most easily realized technically or most beneficial economically. In one case this might be with the selection of raw materials, in another with the transport, in a third the best place to start might be the use-phase, and in a fourth case it might be its disposal. Initially our focus will be on material flows that can be steered or controlled on a national level. But over the long term we cannot avoid the fact that the innumerable global interconnections of goods and raw material flows will require international agreements.

MIPS and the resource productivity or the eco-efficiency

It is part of the tradition of economics that everyone makes the most with his money. One could say that everyone contributes in his own fashion toward optimizing the productivity of his capital. This has not changed for centuries.

The development of labor productivity, on the other hand, was limited as long as humans and animals provided the only muscle, and wind and water power were the only aids. James Watt and Rudolf Diesel changed all of that. Still, the first reaction of "capital" to the new technical opportunities at the beginning of the 19th century was to increase the yield accruing to capital by employing large numbers of cheap laborers on relatively simple machines. They were not intrigued by the idea of improving labor productivity in the factories. This necessarily led to child labor, long work days and to all the other unsocial appearances of early industrialization.

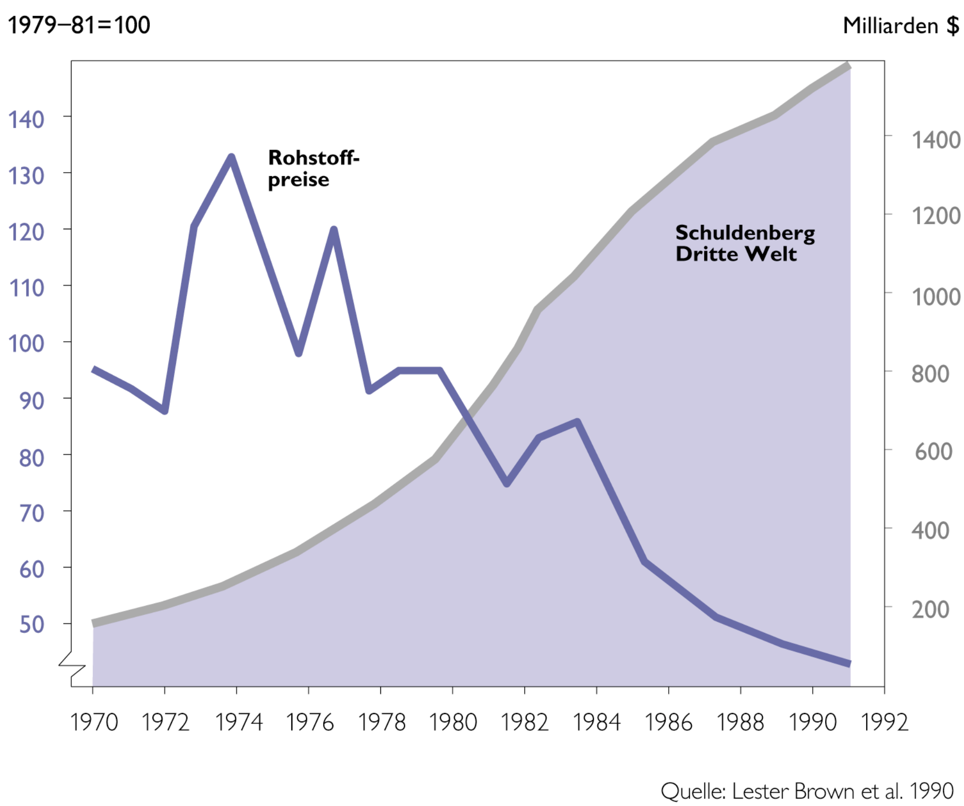
Bismarck's social welfare legislation of the 1860s, the newly awakened strength of the labor movement, and possibly also the Fordist welfare state have all contributed to a massive increase in labor costs. The necessary consequence was the development of more powerful machines, which also helped improve the quality control of the produced goods. Since that time, the labor productivity has risen twenty- to forty-fold, and in some extreme cases ten-thousand-fold and more, as in the case of surface mining of lignite (see example in Chapter 1).

It would be very informative to actually analyze the extent to which labor productivity has risen from the cradle to the market. Possibly some optical illusions remain in that area. It is not certain, for instance, that fewer people are involved in putting food on our tables today than in our agrarian past.

Apparently no one has found it necessary to worry about how much wealth could be had from one cubic meter of water or from one ton of steel. Put differently, the question of resource productivity was never asked. The question was never relevant, as resources such as air, sand, gravel, rock, soil and water were either free or available at very low prices. Even the more recent prices of wood, coal, steel and grain have fallen relative to those of investments and labor. The hourly wage of a German laborer before taxes today is equal to the price of a half a ton of grain on the world market. For the cost of disposing of one ton of refrigerator in an environmentally responsible manner, one can buy twenty tons of grain on the stock exchange today (FIG 18).

Low prices lead to careless consumption. People save only where it is rewarding to do so.

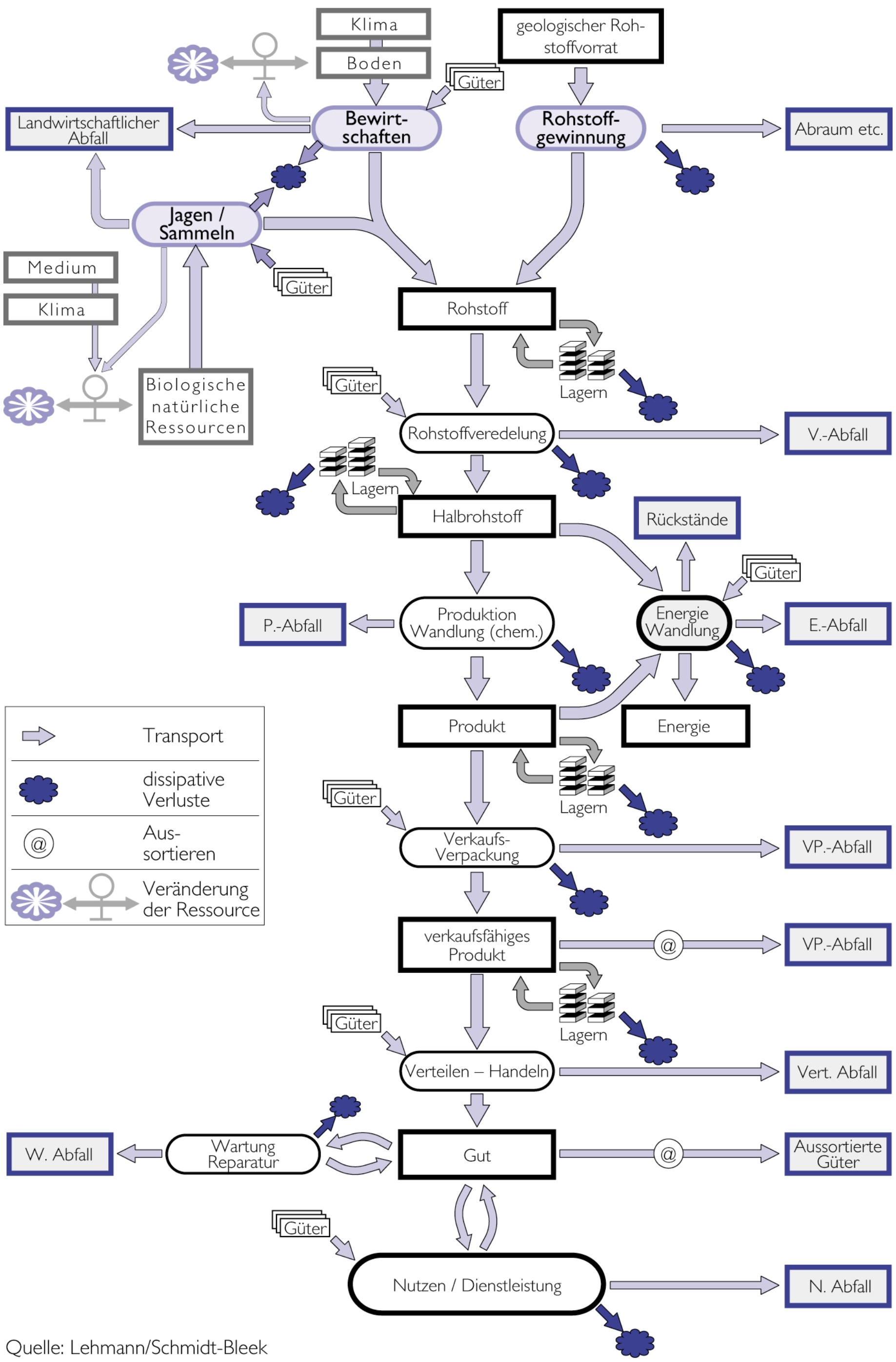
FIGURE 18



Not much can be said against wasteful consumption of material resources if the following two conditions hold: The first is that we have enough resources for all people and for all time to come. Since Thomas Robert Malthus[5] published his concerns over the increasing demand for food on the part of future generations, and more recently in the writings of the Club of Rome[6], the debate over the extent and availability of resources has gone back and forth. We will not add anything to these inquiries.

FIGURE 19

Die drei Quellen in der Ökosphäre, aus denen die Stoffströme in der Technosphäre gespeist werden, sowie der Lauf der Materialien durch die Technosphäre, einschließlich der Transporte.



Quelle: Lehmann/Schmidt-Bleek

It appears that the second condition relates to a more obvious and decisive aspect. It is at least more obvious insofar as it exposes the need for expedient and timely action. We find it difficult to condone the wasteful use of resources because, as we have seen, each use of natural resources not only serves to increase our wealth, but also affects the relationships of the biosphere. We are running the risk of suffocating from the unintended consequences of our garbage. Frequently one hears of environmental costs, external costs or externalities, which we should be concerned to include in the market prices. As Ernst Ulrich von Weizsäcker puts it, "the prices should tell the ecological truth." If prices already told the truth today, people would treat resources in an entirely different way. No one throws away gold. We will return to the question of how the trend toward higher resource productivity could be set in motion.

Right now we are concerned with the question of defining resource productivity as carefully as possible, so that it can increase its stature as a criterion for economic and technical decision making. We submit the following definition for discussion:

The resource productivity of a good is the totality of available service units, divided by the total consumption of material for the service-yielding good, as calculated from cradle to cradle, including the material flows initiated for the purpose of yielding the requisite energy. In other words, the resource productivity of a good is the inverse of its MIPS, and is measured in the unit "per kilogram."

Instead of resource productivity we could also speak of eco-efficiency.

The material wealth of a region could then be expressed in terms of the number of service units available there. If the resource productivity rises while the material consumption remains the same, material wealth increases. Put differently, dematerialized technologies can yield more service units with constant or falling material effort. Were one to increase the global resource productivity fourfold, it would be possible--under this definition--to double the number of service units and have the material inputs cut in half. Dematerializing an economy does not mean going back; it means progress, as such a development would not be possible without concomitant technical improvements. We can refer to this as a technical approach to a sustainable economy.

What MIPS can--and cannot--do

Before we continue, let us remind ourselves that MIPS is defined for service-yielding final goods, not for raw and auxiliary materials. The measure can be used both for short-lived and for durable goods, and can in principle be derived for quite complex facilities and infrastructures.

From a technical perspective, the use of the MIPS concept can have the following advantages:

1. Material and energy expenditures are measured in the same units. In so doing, contradictions in the ecological evaluation are avoided, and the evaluation becomes directionally stable.

2. The concept can be used to set up Life Cycle Analyses at the level of screening procedures. The effort involved in the analysis is hereby dramatically reduced, and the results become directionally stable. Decisions about successive analyses can follow in the form of a phased plan.

3. The concept can serve as an instrument with which to test the ecological significance of technical procedures in light of their contribution toward a sustainable economy, as well as for measuring attendant successes.

4. The MIPS approach helps in the design of industrial products, in the planning of environmentally friendly processes, facilities and infrastructures, as well as in the ecological assessment of services.

5. The concept can serve as the basis for a comprehensive ecological labelling strategy, and can be an aid in purchasing decisions and consumer counseling.

6. The MIPS approach is suitable as a tool for distinguishing ecologically sensible recycling loops and circulation systems from those which are ecologically absurd.

7. The approach can be used to establish ecological tariffs, issue licenses, set insurance premiums, assess taxes, and to make decisions about subsidies.

8. The concept is suitable for examining various codes and standards for their ecological coherence.

9. The MIPS concept can help make decisions about what kinds of research and development projects deserve financial support.

10.The MIPS approach should be well suited to assessing technical projects which are part of development aid to the Third World, and for the former socialist countries--with respect to their environmental characteristics.

11.The concept shows promise in the context of future international harmonization because of its simplicity. This would be important for the possibility of making progress toward ecological structural change on the level of the European Union or worldwide.

On a political level, the MIPS concept might have the advantage that a dematerialization of the economy could become one (by no means the only) understandable, graspable symbol of a new eco-politics. The principal techno-economic goal of such politics would involve increasing the resource productivity of the economy. Besides, this approach could easily serve to render more visible the internal consistency of environmental legislation dealing with material and energy questions.

Naturally, the concept has some disadvantages, some of which are listed below:

1. The introduced concept does not take into account the specific "surface-use" for industrial as well as for agricultural and forestry activities. This is of considerable importance as the amount of the earth's surface available for our purposes is limited. We will return to this question.

2. As already indicated, the MIPS approach does not take into account the specific environmental toxicity of material flows. The approach is not intended to supplant the quantification of eco-toxicological dangers of materials in environmental policy, but rather to supplement it by stressing the material and energy intensity of economic services.

3. The MIPS concept makes no direct reference to questions of biodiversity. It seems fair to speculate that the chances for species survival is related to the intensity of soil and resource use. Therefore we can't exclude the notion that the material intensity of a society's economy has something to do with its contribution to species extinction. The inference that some countries are not very densely populated is not helpful in this context, as the population density has no direct bearing on the material intensity of the prevailing lifestyle.

The need for differentiation

But MIPS does not always equal MIPS! For the time being we have not answered the question of whether or not we may need to differentiate between flows of differing mass--if we must actually weight them differentially. It appears so far that we should keep separate tabs on water, air, soil and technical material inputs. Additionally, we have yet to determine which type of water should be measured and how. In the case of a hydroelectric dam, should we be measuring the amount of water passing through the turbines, or the one-time volume of water dammed behind the power plant? Or, how does one take into consideration the fact that the loss of soil moisture in irrigated cotton plantations is different than under other conditions? It is quite conceivable that certain compromises will have to be made and certain conventions adopted. Asking experts about preliminary estimates of weightings for different material flows would help considerably.

In order to gain experience and practical knowledge of how to solve the above mentioned weighting problems, researchers at the Wuppertal Institute are presently examining the life cycles of selected products, as well as the material intensity of the entire life cycles of transport and energy supply systems. This research involves much effort, but the results can subsequently be used to estimate the material intensity of any product, as long as its material composition is known[7]. It would be very welcome if at this stage other institutes would concern themselves with this task as well.

We wish to mention once more that the measure which we have introduced is intended for a preliminary rough estimation of the technically describable environmental stress intensity of a highly diverse group of goods. No more, and no less. It meets the criteria listed earlier for such a measure. As we will show in the following, many opportunities exist with which to make MIPS more complete. Analyses of the relative environmental compatibility that go beyond MIPS are certainly appropriate. And once more we wish to emphasize that for every environmentally relevant decision, the question of the presence and avoidability of dangerous pollutants must be answered.

Material flows from a systematic perspective, or: the issue of the precautionary principle

From a theoretical perspective as well as in the practical aspects of Life Cycle Analyses it is not at all clear when materials are considered inputs into the technosphere (the part of the world influenced by our use of technology), and when they are expelled again. We would like to add a few thoughts to this question[8],[9].

Each human-induced material flow, transport process, and energy and land use precipitates changes in the biosphere. It is not possible to predict the quality, the intensity, the place or the temporal extent of these changes. In this context we cannot even point to a limit below which changes could be considered risk-free. To remain on the safe side, natural systems should be altered by human activity as little and as slowly as possible. Therein lies the notion of the precautionary principle.

If material flows are systematically reduced, this necessarily reduces the demand for, and use of, energy, transportion and land area, as it also produces less garbage. This implies a connection between maintaining the stability of the biosphere and reducing the material effort of human activities. From a technical perspective it is possible to reduce the specific material requirements by a factor of ten or more over several decades. We will be returning to this point again.

Technology will always offer several options of how to move toward a sustainable economy. To compare the ecological efficiency of these options we need reliable, easily grasped and practical measuring conventions. MIPS is well suited to this need.

A prerequisite for measuring such things is to clearly define the border between biosphere and technosphere (or anthroposphere), between naturally occurring and human induced material flows. The technosphere encompasses all human activities. It is a subsystem of the biosphere. Let us view this subsystem as a kind of machine: it requires inputs from the biosphere, it processes material, consumes energy, sets material flows in motion within its own boundaries (produces transportation services), and returns material output to the biosphere (waste and dissipative losses). We have chosen the system boundaries in such a way that all anthropogenic material flows are included within the technosphere. The inputs for the technosphere subsystem originated in the following places in the biosphere:

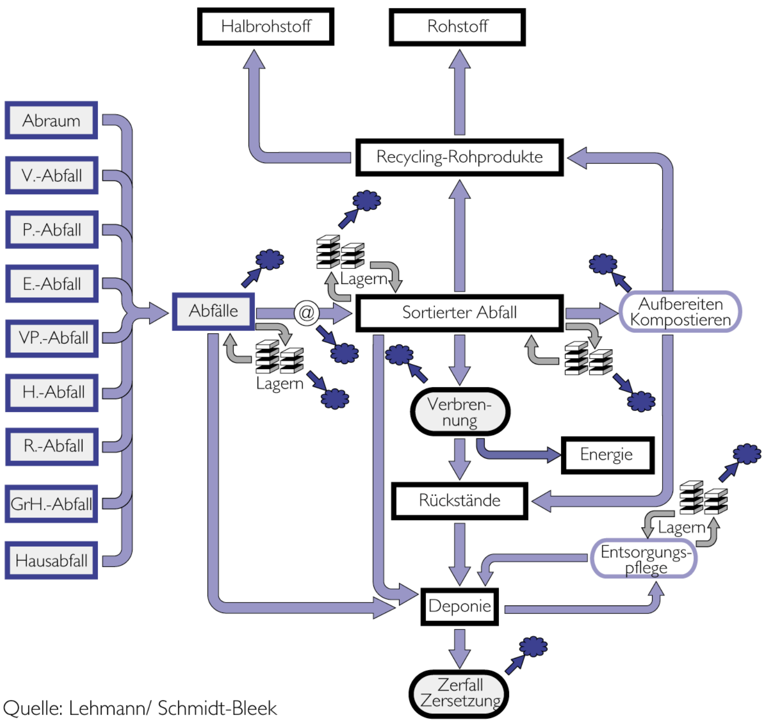
1. biological resources from undisturbed regions (hunting and gathering);

2. agricultural, fisheries and forest products from cultivated regions and

3. geological raw and construction materials as well as air and water (see also Table 1).

A few examples may clarify the systematics of material flows. In the case of mining, all materials (including air and water) belong to the technosphere as soon as they come in contact with humans or machines. In agriculture, forestry and fisheries, the harvest renders the products a part of the technosphere, and all harvest techniques as well as access roads also belong in that category. All water which people move in agriculture, forestry and fisheries, as well as the introduced pesticides and fertilizers, are included in the technosphere. Erosion caused by soil manipulation is also counted.

FIGURE 20



Quelle: Lehmann/ Schmidt-Bleek

Cultivated areas differ from those left undisturbed in the level of control exercised by humans over the distribution of species. This control extends even to those cases in which production begins centuries before the harvest commences! Therefore most European forests belong in the category of cultivated areas.

On the output side, the technosphere's borders are reached as soon as the economic interests in the material flows cease. They continue, returning as waste or dissipative losses, to the "cradle," to the sinks, to the biosphere. In principle we can distinguish between three different sinks, just as we can distinguish between three different sources: the litho- or pedosphere (soil), the hydrosphere (water) and the atmosphere (air). The output loci, the border crossings from the technosphere to the biosphere, are very diffused and spread out all across the technosphere. Figures 20 and 21 illustrate the situation.

Here, too, a few examples may help to clarify the situation. Gases and smoke, once they leave the smokestack, become a part of the biosphere. Materials that are thrown away, or forgotten, that may no longer come into contact with people (a car tire in the woods, for instance), have become part of the biosphere.

Within the technosphere, the material flows are chemically or physically altered with the help of energy according to the already mentioned "processes." A process consists of inputs, which are transformed and processed using energy, and output production. Inputs can be goods coming from the sources of the biosphere, or they may consist of parts assembled within the technosphere such as intermediate goods, infrastructures or auxiliary materials. Processes are linked by "transport." An important characteristic of transport or transportation is that it is a function of a certain distance. Even if two associated processes occur at the same location, they are treated as if they were connected by a transport linkage. The distance travelled in this transport module is then zero. Transports themselves require inputs, i.e. fuel, electricity, vehicles and infrastructures. Transports also produce outputs that end up in sinks.

The two terms "transport" and "process" describe operators within systems analysis. With these two operators, all activities within the technosphere can be represented and analyzed. If one views technosphere and biosphere together with all exchange processes as a system, no differences remain between flows of material, of money, of labor or of products as inputs into a process. The commensurability of material flows and area demands is also accounted for. Money alone has no sources in the biosphere. Harry Lehmann, who is one of the minds behind the development of this system, and Ulrike Brüggemann of the Wuppertal Institute have worked out what they call a **C**omputer **A**ided **M**aterial Flow **A**nalysis, or CAMA, on the basis of the above findings[10].

As we have noted, MIPS is only of interest with respect to final goods that can yield services (see Fig. 13). The MIPS are derived according to the following method: to begin with, all inputs, including energy and transport, are added up from "above" and "below" the good in question--in other words, from before and after the service-life phase. The inputs for repairs, recycling and disposal, as well as the proportional inputs of every involved tributary--including infrastructures--are enumerated as well. For a good that is transported by truck, for example, we must include a portion of the material requirements for building the road.

The result is a sum, measured in kilograms or tons of material. It indicates the total quantity of materials involved in the life cycle of the product in question. This is the material input, or MI. Dividing this by the sum of the receivable or received service units (or functional units) of the good, we get MIPS. Again, the energy flows are accounted for, not in kilowatt-hours, but in the units of weight of the material flows that had to be displaced to obtain the energy. The service units are either computed after the fact, if it is known for how long and how much the object was used, or in advance by calculation or estimation--on the basis of past experience or from manufacturer's warranty information.

MI can be determined for a region, if exports and imports are taken into account and a time frame is agreed upon (in statistics, normally one year). MI then shows the total material input for the region over the course of one year. If one divides this regional MI figure by a measure of wealth, say the GDP, one obtains the material productivity of the region. As the ecological rucksacks of the involved and exported materials, intermediate products, goods etc. are not yet included in the statistics of the private and public sectors, such an effort would be quite an undertaking. This is especially true because raw materials must be tracked all the way back to their sources in the biosphere, which often lie in other countries.

The difference between material inputs and material outputs of a region per unit time, including product exports, is the amount of material invested in durable goods for this time period. To put it differently: it is the "amount of environment that is locked up or frozen."

If this number grows while the measured wealth stays the same, the material productivity of the region drops.

Helmut Schütz and Stefan Bringezu of the Wuppertal Institute have published some preliminary numbers for material flows in Germany[11]. According to these numbers, the amount of material processed per capita for the year 1989 was 800 tons. Of that 770 tons were water and air. Roughly 660 million tons of material were "locked up" during this period, most of which was rock, sand and gravel, fixed in the form of buildings and facilities. The number rose by about 2% in 1990.

It is worth considering whether we should perhaps track regional, national or even supra-national MI as well as MI-increases in the production, service and transport sectors in our future official environmental statistics ("MI increase-books").

In the future, goods should preferably be dematerialized already in the design phase. Such design begins with a description of the service needs which are to be met, as well as with a comparison of the material intensities of the unfinished and intermediate products that are technically suitable (aluminum, steel, concrete, plastics, etc.). To do this, the rucksacks of these unfinished- and intermediate products must be readily available for the entire range from source to intermediate product. Prior to a selection of the best design, the expected service life as well as the necessary inputs for operation, maintenance, cleaning, repair, recycling and disposal should be estimated with as much precision as possible. It should be fairly obvious that every design should attempt to avoid the use of any known pollutant or toxins--and this applies to the potential for these substances to appear during the service life of the product as well. We will be speaking of ecological design again.

The ecological rucksack of the automobile

How is one to compute the ecological rucksack of a consumer good? We will take the car as an example. Figure 21 shows a general overview of the relationahip between economy and ecology. Nature possesses the resources which humans gather for the purpose of creating material wealth. Minerals, water, air and biomass are examples. In addition to the resources that enter the production process themselves, large amounts of material are translocated in the environment in order to reach the desired resources. Overburden, water that is pumped away, and other similar inconvenient substances are examples. Table 1 provides information about this.

FIGURE 22

$$\sum(M_i \bullet MIM_i) = MI = MIPS \bullet S$$

eingesetzte Materialien (z.B. Stahl, Glas)	Material-intensität der Materialien (Rucksäcke)	Gesamt-material-input	Material-inputs per Service-einheit	Service-einheit

$M_1 \bullet MIM_1$ … z.B. Stahl plus Rucksack

$+ M_2 \bullet MIM_2$ … z.B. Glas plus Rucksack

$+ M_3 \bullet MIM_3$ … z.B. PVC plus Rucksack

etc.

→ **Endprodukt (1 Einheit)** … z.B. ein Auto

→ **Service (Anzahl der Dienstleistungen: S)**

… bei Konsumprodukten: **n** = 1

… bei langlebigen Gütern: **n** = Anzahl der Benutzungen

oder **n** = andere Mengen (Zeitraum oder Fläche)

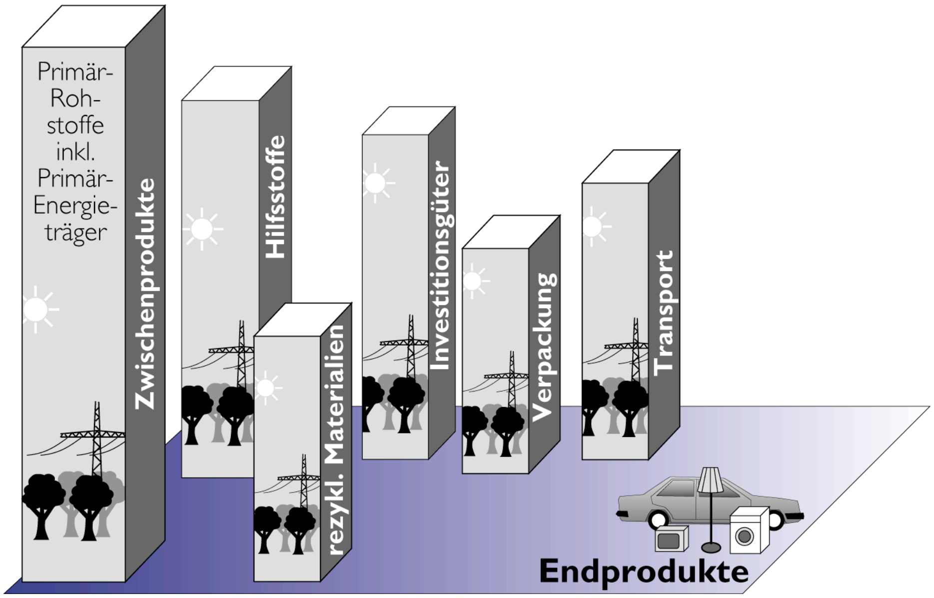
$$S = n \bullet p$$

(**p** ist die Anzahl der Personen, die das Produkt gleichzeitig benutzen)

Beispiele: Glas Orangensaft (**S** = **1**)
Fahrradkilometer (**S** = **n**)
Personenkilometer im Schienenverkehr (**S** = **n** · **p**)
p Personen leben in einer Wohnung für **n** Jahre (**S** = **n** · **p**)

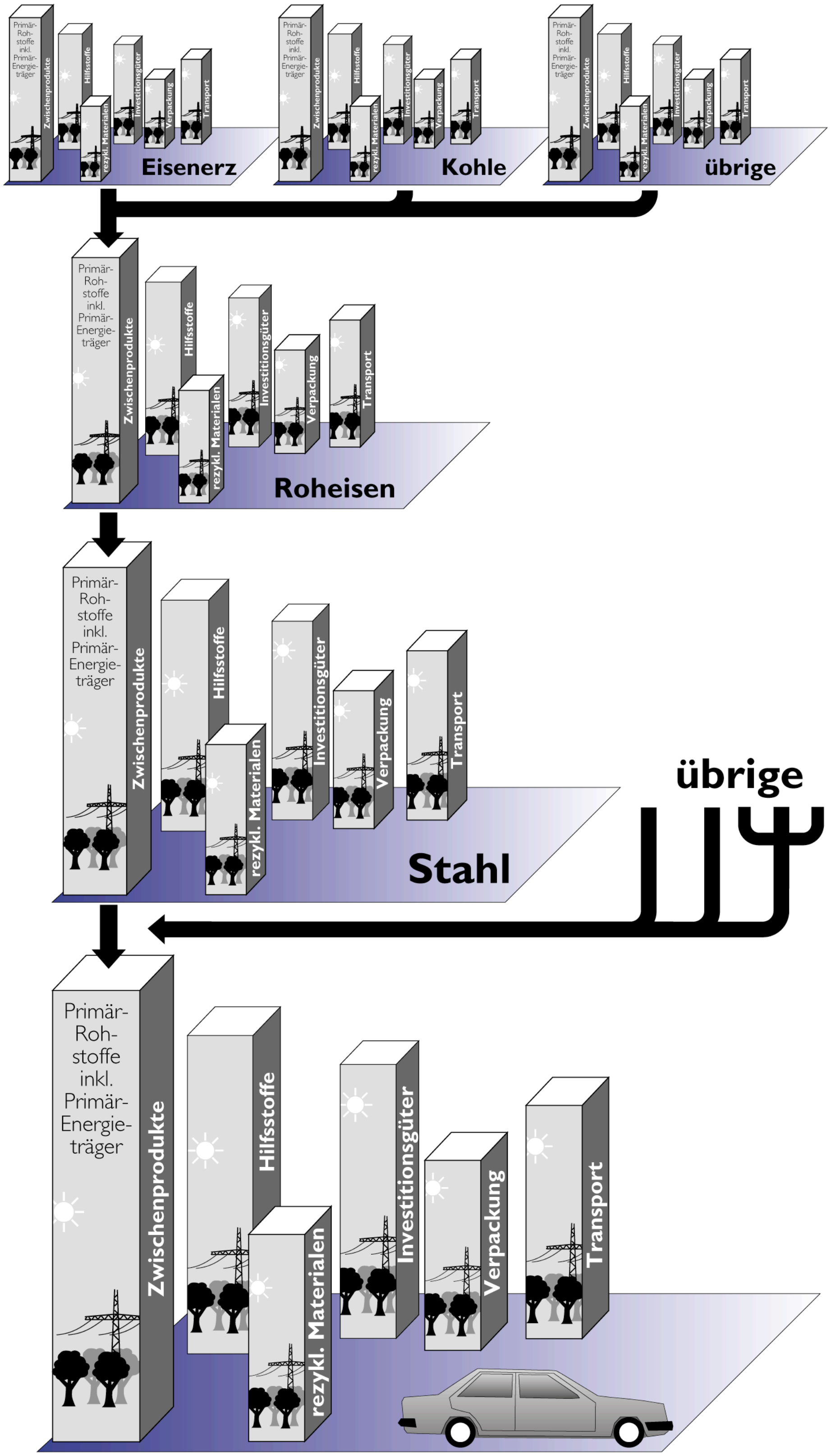
Quelle: Welfens/Hinterberger

FIGURE 23



Figs 23 and 24 are graphic illustrations of the process by which the ecological rucksack of an automobile is determined.

FIGURE 24


Eisenerz
Kohle
übrige
Roheisen
Stahl
übrige
Primär-Roh-stoffe inkl. Primär-Energie-träger
Zwischenprodukte
Hilfsstoffe
rezykl. Materialen
Investitionsgüter
Verpackung
Transport

In order to obtain the material intensity of the automobile, the first step involves listing all materials out of which the vehicle is made, as well as their contribution to its overall weight. Material 1 we will call M_1, material 2, M_2 and so on; the i-th material we will call M_i. Then we determine how much material and how much energy, converted into material flows, was required to provide each of the requisite materials in the necessary quantities. Thus we have the material intensity of the materials used--the ecological rucksacks of the individual materials (MIM_i). The sum total of all rucksacks of the automobile, each multiplied by the appropriate M_i, equals the total material consumption for producing the automobile. Figure 22 shows how we obtain the MIPS for the automobile and other consumer goods. Figures 23 and 24 illustrate the sequential steps for determining the rucksacks for the whole automobile.

The ecological rucksack of chemicals

It is really self-evident, but should nevertheless be brought to our attention, that non-natural compounds of the chemical industry must still be examined very carefully for their potential dangers before they are released on the market. This is especially true for those which, because of their particular biological activity (medicines), or their ability to destroy life (pesticides), were *synthesized* or produced according to some other like process. MIPS data should be available for all chemical products. Pesticides for instance are unusually energy intensive products; they have a bioavailability of less than ten percent, which means that more than ninety percent of their applications could be avoided, if they could be brought into more direct contact with the pests they are supposed to attack. Various methods exist for increasing this ratio: technical aides, careful timing and other procedures Fertilizers, detergents, medicines, and most other human-made chemicals fare similarly.

Chemicals and compounds as understood in the *Chemikaliengesetz* are covered in a very extensive literature. It is rare that a day goes by without some mention in the news media of a chemical, often in the context of an accident in industry or in traffic. Viewed more closely, these cases are generally or exclusively important as health issues, and not because they threaten ecological equilibria.

In this book we have tried to make clear from the beginning that politics which deals with material flows must transcend the realm of chemical compounds if it is to be ecologically relevant. Nevertheless it is appropriate to deal briefly with these materials that are either human creations, or are so concentrated by humans before they are sold on the market that they also command our attention (CO_2 in pressure tanks and hops concentrate). This is for the following reasons:

First of all, Germany is among the largest producers of chemicals in the world. In its economic importance, the chemical industry is second only to the automobile industry. Its potential for innovation is one of the highest anywhere. Roughly thirteen percent of all exports are chemicals.

Secondly, chemicals are to a large extent made from oil, gas and coal, which are derived from imported fossil energy carriers. In Germany about six percent of the imported energy is not used for producing energy, but for producing chemicals.

Thirdly, producing chemicals is very material and energy intensive. Chemicals carry large ecological rucksacks.

And lastly, from an ecological perspective, synthetic materials which nature does not produce play an especially important role.

The example of CFCs taught us the lesson that synthetic materials were able to wreak havoc on the physical and chemical composition of the upper atmosphere when they reached it. They simply destroyed the ozone.

We are dealing with a fairly universal phenomenon. Wherever nature is confronted with something it did not invent itself, (or purposely bypassed?) it must learn how to physically, chemically and biologically respond. These processes may be rapid, or they may take years to unfold. The acidification of the lakes in the Midwest and the destruction of the ozone layer are examples. These changes may take so long that we refer to them as happening on a geologic time scale, making them virtually unimaginable to humans living today or at any other time. The general rule holds that it takes far less of a synthetic substance to initiate ecological changes than it does if humans move about "natural" materials such as sand, water or CO_2.

If humans then introduce foreign substances into the environment, whose reactivity is deliberately very high for the purpose of exterminating some part of nature, one could term this "deliberate ecological clearcutting." Herbicides, fungicides and all other biologically active materials belong in this category. Even here there are differences, however. More recent biological weapons against "pests" are much more selective in their effects than their predecessors. They do not as easily harm the organisms in close proximity to the targeted species.

Chemical pesticides have a place in our modern world. They are vitally important for guaranteeing the food supply as well as for preserving people's health in certain parts of the world. Nevertheless their use could be organized in a more ecologically benign fashion. Numbers published by the UN indicate that every year close to 20,000 people die from pesticide poisoning.

These materials exemplify the continued importance of eco-toxicological discoveries, even if, as we describe in this book, policies based on such knowledge don't easily lead to structural changes and thus won't help to initiate a sustainable economy. When chemicals are introduced on the market, especially chemicals that have either never been sold before, or that only exist in very small quantities--if at all--in nature, great care is in order. That is why in Germany we have the *Chemikaliengesetz*. With respect to chemicals, all we are really advocating is that, along with other product qualities such as child and worker safety, the danger of explosion, or other health threats, the protection of the biosphere be added to the list. It should be self-evident that prior to introducing chemicals onto the market these questions have to be answered in order to determine whether the advantages or disadvantages are more important to us.

Presently, many of the ecologically relevant questions are not being asked of these newly introduced materials. From the lawmaker's point of view, the ecological potency of some chemicals does not even seem to be worth considering (with medicines and explosives, for instance).

Let us look at this issue a bit more closely. From an historical perspective--that is, from a human-toxicological perspective--what has been examined in newly created compounds is the ability of the compound to effect biological changes, to be toxic to rats or fish, to cause cancer or to alter the genetic makeup of organisms. Indications of how long such compounds remain in the soil, air or water, how they disperse, and their tendency to bioaccumulate are researched and catalogued. The list of requirements which follow from the *Chemikaliengesetz* is very long. Because they are so extensive and the information can only be obtained in laboratories, large amounts of money are necessary.

As we have argued, it is scientifically impossible to derive a comprehensive picture of the ecological consequences of introducing even a single chemical compound onto the market (the consequences for human health are not fully ascertainable either). Future surprises can never be ruled out. From an ecological perspective, though, something else is far more important: although members of both industry and politics have endorsed it, we are still a long way from making the "from cradle to grave" principle the basis for our analysis of the dangers inherent in marketing chemicals.

FIGURE 25

Only some of the ecologically relevant questions are being asked. First and foremost we note the absence of any questions about the "ecological rucksacks" which have been filled during the process of synthesizing the chemicals. In addition, the necessary information about packaging, storage and transport intensities is insufficient, as is the information concerning the reusability or serviceability of the chemicals after their initial use. It should be obvious that this information would be very useful in the case of all those compounds which were introduced prior to the passing of the *Chemikaliengesetz*, but have never been examined according to its mandates. Without such a thorough inquiry, we stand a slim chance of assessing their ecological rucksacks.

FIGURE 26

Figure 26 illustrates some of the ways in which the potential ecological effects, with respect to both the intended and imaginable applications of these chemicals, can be taken into consideration at the design stage. It is only possible to indicate a portion of the spectrum of future applications in the industrial nations as well as globally. Dissipative applications here refer to the use of chemicals in which any retrieval for further economic purposes is impossible once they have been used in accordance with the requirements of the law. Paints and agrochemicals are examples in this category.

It is of considerable ecological importance to optimize the amount or the dosage of the chemical being used--to find out how to use the least amount possible while achieving the desired effect. The injunction to minimize MIPS is as valid here as elsewhere. As already mentioned, using technically superior application methods while observing the weather and growth conditions, it is frequently possible to increase the bioavailability of pesticides by a factor of ten or more, reducing the demand for such pesticides accordingly. We cannot avoid examining the total material and energy intensities of the pest-combatting services, i.e. the chemicals themselves and their methods of application. The Swedish government has recently reduced the upper limits of pesticide use by fifty percent over five years, and reports that the harvest yields have risen slightly over the same time period.

Bob Ayres[12] has suggested an option which is interesting from an ecological perspective. Because the daily handling of chemicals is anything but trivial, and special knowledge is often required in order to avoid risks to health and to ecological processes, he suggests a new approach: creating the new profession of a "crop doctor." Using his own equipment and supplies, this professional would provide all necessary applications of fertilizer and pesticides, and would be paid by the farmer for the agreed-upon service. Perhaps the chemical industry could incorporate this service business. It is worth postulating that their interest in maximizing *sales* might thereby be reduced. Their ability to turn a profit need not necessarily be diminished in such an arrangement.

Dow Chemical seems to be moving in this direction. The company has recently started to "lend" chemicals. This means that their charge is a function of the amount and quality of the returned portion of the chemical. This is an interesting and very exemplary contribution to a "recycling economy."

It is inconceivable that we could develop the necessary technology for a dematerialized economy without the decisive collaboration of the chemical industry. This is also one of the main reasons why the creation of new dematerialized infrastructures, goods and services can be provided by highly industrialized nations. Germany stands out among these countries because of its innovation potential and the capabilities of its chemical industry.

Chapter 3
1 personal communication
2 personal communication
3 Aluminum-Zentrale, Düsseldorf, und Verband deutscher Schmelzhütten, informational brochure and personal Communication.
4 Hartmut Stiller, Material Consumption.
5 Thomas Robert Malthus, An Essay on the Principle of Population. London: Johnson, 1798.
6 Donella H. Meadows et al., The Limits to Growth, New York: Universe Books, 1972.
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8 Harry Lehmann, Material flows from a systematical point of view, and Stefan Bringezu, Where does the cradle really stand? both in: *Fresenius Environmental Bulletin*, 2(8), August 1993.
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12 Bob Ayres, Why Eco-Restructuring? Contribution to the Sandoz Colloquium, Paris, December 7 1992.

"They search for gold like swine"

Why do we need gold? The metal has certain technical qualities that make it interesting to industry, especially the electronics industry. Dental fillings are made with it, although other substitute materials exist. But all of this does not add up to any great quantity. Industry only uses about fifteen percent of the amount of gold introduced into circulation each year. The rest is investment, jewelry, myth.

The Aztecs were forced to experience the power of this myth, as the Spanish Conquistadores under Cortéz fell upon them. Bernhardino de Sahagún, a Franciscan monk, collected their impressions of the usurpation. "They grabbed the gold like monkeys. Because they are hungry for the gold," the Aztecs told him, "they search for gold like swine."

The banks, governments, businesses and private investors behave much more elegantly than the Conquistadores or the fortune hunters of today. They belong to an even older tradition that views gold as a durable and internationally accepted store of wealth. Gold is considered the most reliable safeguard of the future. It is a bitter irony that precisely this is not true: the search for gold destroys what the discovered gold could not assure--the future. The Aztecs did not know it, but they were correct in a figurative sense: only very few ecological "*Schweinereien*" (abominations) can compete with gold mining.

Gold is either found in veins running through mountains, or in rivers that flow from or below such veins. The search for gold often begins in rivers. The high value of gold is due, to a considerable extent, to its rarity: only five thousandths of a gram are found in an average ton of earth. Those who want to find gold must therefore--literally--move mountains. The average weight of such a mountain of rock and waste from which one kg of gold is won is 250,000 kg, and that does not include the water required to flush it all out. Each gram of gold carries an ecological rucksack around with it weighing 250 kg or more.

John E. Young of the Worldwatch Institute has pointed out that, despite all efforts to de-link international currency relations from gold, the demand for gold has not fallen, but risen! World production of gold rose by seventy-eight percent from 1980 to 1992, from 1,240 tons to 2,200 tons per year. The continued improvement in the development of techniques for obtaining the metal have helped this trend considerably. The labor productivity in gold mining has risen dramatically, especially since the 1970s.

The best-known example of how humans and the environment have been damaged through gold mining is the contamination of rivers with mercury in the Amazon region. The miners there dig up the river mud and mix mercury into it. The two metals bind together through amalgamation. Subsequently the mercury is removed through distillation and the gold is left. Another common method is to use water pressure: powerful water cannons are used to wash entire hillsides into ditches, where the metal can then be collected.

In 1896, G. Bödlönder published a description of the cyanide process, or "heap leach mining," in the Journal of Chemistry. It has been in use for decades and has been continuously improved. The crushed gold ore is transported to enormous containers where a diluted cyanide alkaline solution is poured over it. A 0.015 to 0.25% sodium cyanide solution is sufficient to leach out the gold.

The decisive step forward was made in the 1970s; since then they have skipped the large containers and the transportation altogether. Now the ore is simply dumped in large piles and given the cyanide treatment several times in place. This way, ore with a mere one-half gram of gold per ton can be "economically" processed.

The consequence is that gold, which used to be mined in subsurface conditions, is now extracted in open cast mines. The amount of overburden and excavated material increased tremendously. In the U.S.A., three million(!) kilograms of earth and rock are now displaced for one kilogram of gold. Large amounts of cyanide-contaminated mud accrue.

If it is collected in open pits, the cyanide can enter the groundwater. About one third of the cyanide escapes as hydrocyanic acid into the air. Hydrocyanic acid is a strong respiratory poison. Sodium cyanide itself is classed with the most toxic substances in Germany. Only a few milligrams per kilogram bodyweight are lethal within a very short time period.

Such mines, processing hundreds of tons of ore per day, use one and a half tons of water per ton of ore (although sometimes recycling it) and half a kilogram of sodium cyanide per ton of ore. Mines of this description have been scheduled recently, even in Europe, although plans in Austria and Greece have recently fallen through.

Chapter 4 FIPS: A Measure for Land Use *

It took Britain half the resources of the planet
to achieve its prosperity; how many planets will a country like India require?

Mahatma Ghandi

in response to the question whether India
will achieve the British standard of living after independence[1].

** F stands for **F**läche, the German word for surface areA*

Surface area, solar energy and coffee beans

In MIPS the criteria mass and energy are taken into account. We have argued that this permits a preliminary and rugged--but certainly still rough--estimate of the environmental compatibility of all processes, goods, infrastructures and services. We have also indicated that the consumption--or demand for--areas for civilizational and economic activities has undeniable ecological ramifications. After all, the earth's surface is all that humans have to live on. The absolutely minute amount of land that has so far been reclaimed from the oceans with the help of enormous amounts of material and energy (under "high MIPS" conditions) does not amount to much on a global scale. The Dutch obviously, and rightfully, see this a bit differently.

In the first part of this chapter we will try to develop a feeling for the importance of surface area as a resource for humans. We will introduce a few examples to illustrate this.

The two nuclear power plants in Neckarwestheim in Southern Germany take up about fifty hectares, including all the supply facilities, but excluding the waste disposal. On this surface they generate 2,200 Megawatts (million watts) of electrical power, day and night, assuming they are not switched off. Were one to have solar panels set up on the same area, about 50 MW of power could be generated, assuming the sun is shining. This is about one fourtieth, or 2.3%, of the first figure.

From an ecological perspective many good reasons speak for using the sun's energy directly, and few can be found for nuclear energy. But this is not our issue at the moment. This example is supposed to illustrate the tremendous difference in surface demands between the two forms of generating electricity. Most renewable energy sources have more or less the same disadvantage: their energy flows slowly, and not always when we want it to. Regardless of how much electricity an ecologically transformed society of the future might still demand, it will require a fair amount of surface area to generate a kilowatt if it is to be done exclusively with solar energy. We also know that parts of Northern Germany are not ecologically equivalent to parts of the Sahara. Therefore, geographically independent comparisons are of little use. This is the difference between the surface-use intensity of a service and its material and energy intensity. Material and energy intensity are independent of the location at which they are measured.

On the other hand, Germany has vast roof surfaces which are unused, and which could be used for generating electricity or hot water; or they could be planted with a "roof" cover. Table 2 indicates that the area taken by buildings in former West Germany adds up to to 15,000 square kilometers. Nitsch and Luther[2] have determined that 2,850 square kilometers of that is roof area. As only roof area with a southward exposure is useful for solar energy capture, they figure that 650 square kilometers are left which could be covered with solar hot water collectors or photovoltaic arrangements. With further careful qualifications, they come to the conclusion that the solar heating from rooftop collectors alone could save ten to thirteen million SKE, (or anthracite units) of primary energy (oil, coal and gas). This is equivalent to between seven and ten percent of all the primary energy which Germany's electrical utilities require per year.

The value of this number game is not to show that Germany can get pretty far with solar energy. These numbers are instead supposed to point out alternatives that may become relevant in the future, especially in light of the need--and the technical possibility, as we will argue later on-- for Germany to achieve a dematerialization of about ninety percent over the course of the next century. The familiar injunction that solar energy is presently not economical is of little ecological relevance as long as we do not have access to an objective comparison of the environmental burden of all technically feasible energy supply systems over their entire life, including all rucksacks of the requisite materials. Especially in the field of energy, the prices fail to reflect the "ecological truth." One of the main goals of this book is to advance our ability to assess the environmental compatibility of systems.

Our initial comparison of energy facilities is therefore absolutely inadequate. The surface demands of the finished power plant per kilowatt cannot be the sole criterion for deciding for or against solar energy. A MIPS comparison should precede any such assessments. One thing was made clear by this imperfect example, however: surface demand is an environmentally relevant factor that must be taken into account along with material and energy intensity, toxicity, and possibly others, if ecological mistakes are to be avoided.

Large areas of densely populated countries like Germany are already "sealed off" (see Table 2). While one may not consider the entire built up area (the areas taken up by highways, buildings and commercial use) to be sealed off, the numbers for the Ruhrgebiet show that roughly two-thirds of this number is *in fact* sealed off.

TABLE 2

Surface use, West Germany (without former DDR) – approx. numbers

	Area km^2	%
Transportation	12 400	5

Buildings	15 400	6.
Enterprises	1 500	0.6
Agriculture	135 000	54
Forests	74 100	30
Water	4 500	2
Other	6 000	2.4

It is fairly intuitive that the surface area is limited, and cannot be increased in any measurable way. Statistically speaking, each person requires a certain amount of land for his or her food production, for living, working, transportation, recreation and other things. For food production alone, sources indicate a per capita requirement of between 0.19 hectare (subsistence) and 0.38 hectare[4]. At 0.3 ha per capita in West Germany, the area needed to grow enough food would be 180,000 km^2. This is roughly equivalent to seventy percent of the area of former West Germany. Table 2 indicates that only 135,000 km^2 are available for agricultural purposes, apparently not enough for self-sufficiency at today's standard of consumption.

In an international comparison, West Germans demand considerably more than the average. Sascha Kranendonk of the Wuppertal Institute has calculated that to meet the Germans' demand for orange juice, the entire agricultural area of one of Germany's states (Saarland) would have to be planted in orange trees (see example at the end of this chapter). To grow enough coffee to supply the German market, 12,000 km^2 are needed in the tropics, an area equal to the total surface taken up by German highways, also equal to ninety percent of the area taken up by buildings in former West Germany. Drive your car or drink coffee? For climatic reasons neither oranges nor coffee can be grown in Germany, so the Germans occupy large parts of the Third World--in exchange for cash payments. This is also true for the supply of soybeans (which the Germans feed to their hogs), geologic raw materials and innumerable other things. Altogether one can assume that satisfying the Germans' material demands requires roughly twice the area of their country[5].

Germany would have to be several times larger than it is to produce all of the things which the Germans consume. As it is, they simply occupy the land of other countries.

As the world population grows, the pressure on the available areas will continue to rise. The pressure will rise especially in those situations where the rich countries today are occupying large areas in other countries for their own consumption. Because it seems fair to assume that we cannot, and do not, wish to deny the rest of humanity access to material resources comparable to our own, our material consumption cannot continue in its present form, either in terms of its quantity or at such low prices.

In market economies the price of land is a function of the economic use to which one can put it. But the same injunction is true for the price of land that we mentioned earlier in the context of raw material prices: they do not tell the ecological truth.

Ecologically intact nature has no market price, at least none that would give it a chance in competition for use as industial or residential areas.

Therefore society must step in and protect nature by removing it from such competition--which is in fact happening through the many forms of nature conservation laws and regulations. The success of such procedures always remain limited, however. The

Germans occupy twice the amount of area for growing coffee worldwide as they afford themselves in national parks. (The national parks total 5,700 km^2. Nature preserves add another 4,600 km^2, and conservation areas are equal to one quarter of the area of former West Germany). This form of conservation is apparently a kind of "luxury" that a rich nature-loving society can afford. From an ecological perspective something can be said for this type of "luxury," though, as the national parks and nature preserves are the only areas in which the original species diversity is still (more or less) present. If the economy turns sour, or if a conflict can be resolved by renouncing our interests in such a tract of land, then the luxury items become bargaining chips. And luxuries of this sort are not afforded at all in poor countries, especially not when area is in as catastrophically short supply as it is, for example, in Bangladesh.

In Bangladesh each person is statistically associated with 1,200 square meters. About fifteen percent of this surface would suffice to grow the coffee West Germans consume. Statistically speaking, a family of six is entitled to the equivalent of one soccer field. This area must afford all the necessary services for these six people: housing, food production, energy provision, the production of industrial goods, the private sector, transportation, and the removal of all waste. This is obviously not possible. Bangladesh imports food, just as Germany does. It should not surprise us, though, that in such a country even the most ecologically sensitive areas are "used" in some way. The rate of population increase in Bangladesh is exacerbating this situation in an unparalleled manner.

Each of the roughly eighty million Germans has about one half a soccer field (4,470 m^2) to himself--so, considerably more, even though virtually every nook and cranny is already being used in some way. We have already seen that this is not enough for the Germans. Each Frenchman and woman has about twice that amount, and each citizen of the U.S. has as much as four soccer fields, or 36,500 square meters.

The value that is placed on surface-use intensity in a national Life Cycle Analysis depends to a considerable extent on the prevailing conditions of that country. The fact that national borders change from time to time has been brought to our attention quite vividly in the very recent past. Besides, in the interest of the biosphere, it is not wise to adjust the value of a particular area according to the population density. Rather the consumption of resources should be keyed to the individual. Much political rhetoric is also directed toward the idea that all humans should be permitted equal access to resources.

At the start of the book we noted the contradictions inherent in the traditional economic policy focus of increasing national wealth alongside an awareness of the conditions necessary for preserving global ecological stability. We argued that the global loss of political credibility and the likelihood of sudden changes in the sociopolitical landscape will rise if this conflict is not dealt with. Bangladesh is among those countries that will in all probability suffer most from the climatic changes induced--for the most part--by the behavior of members of the OECD countries (to which it does not belong). We do not have that much time to solve this dilemma, and it is up to the rich to take the lead.

FIPS

In order to estimate the environmental stress intensity of goods and services, we related the associated material and energy flows to the service rendered. We will proceed in similar fashion with surface area. The reasons are again the same: it is necessary to define ecological indicators in such a way that economic activity and ecological necessity can be linked.

We are defining the surface-related environmental indicator, for the time being very generally, as Surface Input Per Service unit, or FIPS.

Once an area has been allotted to a particular use or activity, this generally excludes the possibility of simultaneously using it for another economic purpose. In economic parlance the "sealing off" or use of natural areas for civilizational or economic purposes translates into an opportunity cost for the biosphere. This means that through such human appropriation the biosphere loses evolutionary balance and stability. This loss can be partially compensated through planting such areas with grass, shrubs or trees.

Our task is to find simple, scientifically defensible and easily measurable indicators that are able to reflect the complex ecological changes (losses) due to this appropriation of surface area. The same conditions apply in this case as were mentioned in Chapter 3:

1. Although these indicators should be simple, they should reflect significant influences on the environment.
2. They should be based on characteristics that are common to all processes, goods and services.
3. The chosen characteristics must be easily measurable and subject to quantification.
4. Their application should be cost-effective.
5. The measures should permit the transparent and reproducible estimation of environmental stress potentials of all conceivable plans, processes, goods and services from the cradle to the cradle.
6. Their use should always lead to directionally stable results.
7. The measures should form a bridge to market activities.
8. They should be usable on all levels: locally, regionally and globally.

What we are going to suggest in the following paragraphs is of a provisional nature and is intended to stimulate further contemplations. These are thought fragments--no more--but they might be part of a future solution.

Surface area analysis of an economic trading area

Surface area is limited in the same way that matter is. The use of an area cannot be solely understood as a value-neutral "occupation," but must also be appreciated as a "using-up or wearing out" of the area. The soil erosion that follows in the wake of intensive agricultural practices found on the cocoa plantations of the Ivory Coast, for instance, or the changes in soil composition such as salinization following prolonged irrigation characterize such qualitative changes.

In order for an economic trading area to flourish, a certain minimum area seems to be necessary. Among other aspects, production facility requirements, consumption habits and recreational behavior all shape the extent of such an area. It therefore seems fair to relate the demand for surface area to the prevailing needs and expectations. As no presently available statistics permit such a relationship, we must rely on sufficiently detailed land-use data with which to compile our own statistics. We wish to show this in an exemplary way for the *Ruhrgebiet.* We thank Helmut Schütz of the Wuppertal Institute for the data.

Seventeen percent of the total available area of 4,433 square kilometers is used for housing. Included in this figure are not only residential structures, but also public installations such as post offices, hospitals, administrative buildings etc. Almost one-third of the area is used for the production of food. A further eighteen percent are maintained for forest products. Traffic installations, highways, streets, parking lots and car lots take up ten percent, or about 450 square kilometers. Two percent or 90 km^2 are used for recreational facilities such as miniature golf, horseback riding and amusement parks.

Altogether almost nine-tenths of the area are subject to some technical use, of which about one third is "sealed". Only about ten percent of the area even begins to look natural or undisturbed: forests, wetlands and other such areas. From an ecological perspective these "natural" areas can be appreciated in light of their ability to counterbalance the environmental pollutants emitted from the other ninety percent of the area (their ability to absorb CO_2 and other "more noxious" substances).

Each citizen of the Ruhrgebiet has only 190 square meters with which to meet his or her nutritional needs. Although this part of Germany should not be seen in isolation from the rest of the country without qualifications, we can nevertheless point out that these residents of the Ruhrgebiet appropriate 200 square meters per capita in other countries for the consumption of soybeans which they then feed to their hogs. Another 150 square meters go for growing the coffee they drink, and 82 square meters to grow the chocolate they consume. In total, these areas, which all lie outside the borders of the Ruhrgebiet and Germany, add up to more than 1,400 m^2 per capita, or seven times what is available within the borders of the Ruhrgebiet.

We have so far not included in these calculations the effects these consumption patterns have on the exporting countries--in other words, with how much soil erosion, fertilizers, pesticides, water and CO_2 the ecological rucksacks are filled. It would also be pertinent to ask what effects such trade flows have on the people involved--especially the producers themselves. Let us recall the collapse of the international *Coffee Agreements* that brought us reduced prices and increased consumption, but that also ruined many a small producer in the Third World. Perhaps we should think about the fact that the greater part of the Ivory Coast's agricultural area was lost in order to provide us with our chocolate desserts, and that the rising population of that country is now encountering shortages of food. In light of rising population and sinking agricultural yields world-wide, the question of a more just distribution of area, as well as of matter, as preconditions for a sustainable development will not go away. The results of the "Green Revolution" should have made it clear that the problem has no technical solution.

The ecological ramifications of banking on renewable resources as replacements for, say, fossil fuels or other mineral raw materials are not at all certain.

Chapter 4

[1] *quoted in Robert Goodland, The case that the world has reached limits. In R. Goodland et al. (eds.): Environmentally Sustainable Economic Development: Building on Brundtland, UNESCO, 1991.*

[2] *Joachim Nitsch and Joachim Luther, Energieversorgung der Zukunft. Berlin, Heidelberg, New York, 1990.*

[4] *"Sustainable Netherlands," Friends of the Earth discussion papers, 2 September 1993; and Meadows et al., Beyond the Limits; and Norman Myers, ed., GAIA-An Atlas of Planet Management. London: GAIA Books Ltd., 1984.*

[5] *M. Buitenkamp, H. Venner and T. Wams, Actieplan Nederland Duurzaam. Amsterdam, April 1992.*

[*] *Sascha Kranendonk and Stefan Bringezu, Major material flows associated with orange juice consumption in Germany. in: Fresenius Environmental Bulletin, 2(8), August 1993.*

The price of quenching the Germans' thirst

With respect to drinking orange juice, which here includes the categories of 'drink,' 'juice,' and 'nectar,' the Germans are world champions. Twenty-one liters of orange juice per person per year is an astounding number for a country that contributes so little to growing oranges.

Sascha Kranendonk of the Wuppertal Institute has taken a closer look at the environmental consequences of this thirst for vitamins*. Her work helps answer the questions of how material intensive and how surface intensive the average German lives. Could the whole world afford the same?

Eighty percent of the orange juice which the Europeans drink is grown in Brazil, mostly around São Paolo. After being harvested, the juice is concentrated, frozen and subsequently transported 12,000 km to Europe, almost a third of the way around the globe.

How much material has been translocated before the glass of juice appears on the breakfast table? How large is the ecological rucksack of orange juice? It turns out that each kilogram of orange juice, or every liter, requires 25 kg of "environment." Just the amount of water necessary is staggering. By the time the oranges have been washed, concentrated to eight percent of their original mass using steam, and then diluted with water again in Germany, twenty-two glasses of water have been used for one glass of juice. Additionally, almost one-tenth of a liter of fuel has been burned in the agricultural machinery for just one liter of juice.

But this rucksack is light when compared with the rucksack for the same product in the United States: in Brazil, orange orchards are only rarely irrigated; the orchards do not need to be heated if a frost threatens and are generally not harvested with machinery, but by hand. In Florida things are very different: there, two liters of fuel are burned for each liter of juice, twenty times the amount in Brazil; and the amount of water used is not twenty, but 1,000 liters for a single liter of orange juice. The ecological rucksack in Florida is thus forty times as heavy as it is in Brazil. This comparison illustrates very vividly how much environmental protection can be achieved just through more adaptive agricultural practices, which should include the notion of growing things where conditions are favorable. (Here too, the transport effort must still be taken into consideration.)

The surface-use is also enormous. To quench a single German's thirst for juice, twenty-four square meters of land must be planted in orange trees. This may not sound like very much, but it adds up to 150,000 hectares--three times the total arable land in the eastern part of Germany.

CHAPTER 5 Factor 10

"The available evidence leaves no doubt that the world--including this nation--faces enormous, urgent, and complex problems in the decades immediately ahead. Prompt and vigorous changes in public policy around the world are needed to avoid or minimize these problems before they become unmanageable. Long lead times are required for effective action. If decisions are delayed until the problems become worse, options for effective action will be severely reduced."

The Global 2000 Report to the US President, 1980

We have time for structural change, but we have no time to lose.

Ernst Ulrich von Weizsäcker

Recycling and closed loops

Much of the environmental discussion of the past years has concerned itself with quantifying "pollution sinks," with the "absorptive capacity" of nature and with the "carrying capacity" of the earth. In the process, ever more complex interrelationships were discovered: not every pollution sink is a sink for any quantity and for all time. The network of ecological processes never remains untouched where nature's ability to absorb is taken advantage of.

Self-purification is a term that was initially used in the context of water quality in rivers below places where effluents were introduced. It had been observed that rivers became "cleaner" the farther downstream one went--but obviously only until one came to the next place where pollutants were discharged into the river. It is true that certain substances such as heavy metals settle to the bottom, besides the fact that other compounds react with bacteria, dissolved oxygen and with the water itself. By these means, the rivers appeared to become "cleaner" downstream. For several decades, however, the loads we have come to expect the rivers to handle have grown at a rapid rate. Furthermore, they began to contain "persistent" chemicals. The ability to self-clean broke down more and more frequently. And, as we have already emphasized, matter doesn't vanish. The stuff has to go somewhere. In the best scenario the poisonous loads are "detoxified." Erosional loads hardly change at all, and neither do dissolved salts and many other categories of pollution.

Thus the ability to "self-clean" turns out to be more dream than reality. To be precise, in a closed system such as the biosphere, "sinks" and "self-cleaning-ability" are fictitous--everything remains within the same system. Strictly speaking each attempt at "self-cleaning" is but nature's reaction to a disruption that is answered by further shifts in ecological equilibria.

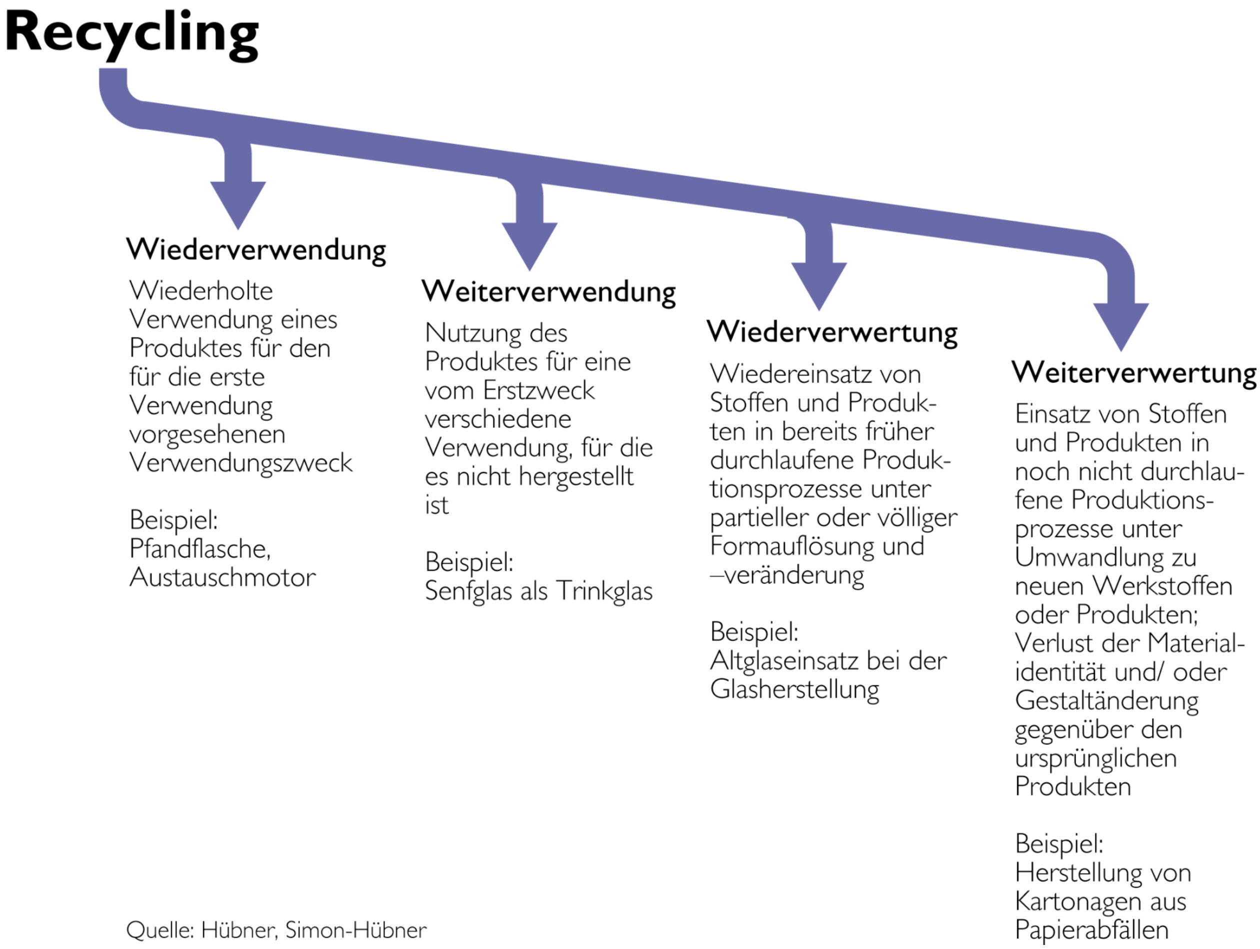
Years ago it was realized that natural "sinks" and the ability to "self clean" were no longer sufficient to deal with the rapidly increasing quantities of every conceivable kind of garbage generated by a growing world population. A new realization took hold: limited resources might not be what was hindering economic progress so much as the problem of getting rid of the garbage.

The next logical step was to consider the creation of "artificial sinks" and "artificial purification processes." The idea of recycling or reusing was a first approach to complement nature's self-cleaning ability with our own technology. Benevolently put, the idea of recycling could be understood as a first step toward conceiving of humans as a part of nature, and their technology and new forms of ecologically optimized design as an extension of nature's "self-purifying ability" (Fig. 27).

But recycling has its limits too. The public discussion about plastics illustrates this quite well. Recycling plastics is only possible under certain conditions, and the capacities are still very limited. Plastics recycling is a form of down-cycling in which the quality of the raw material drops each time it is recycled. It is a form of deferral. The inevitable end in the landfill or incinerator is merely postponed.

The situation is similar for other recycled materials, albeit less obviously. Broken glass can only be reprocessed into white glass if no colored glass is involved. High quality sheet metal from junked cars is generally not recycled as sheet metal. Because of the copper content in automobiles, it is turned into lower quality wrought iron. Paper recycling is made significantly more difficult by the inks involved, the fact that the fibers break, and that innumerable little metal staples contaminate the raw material.

FIGURE 27



It is not just the quality of the recycling products that limits the scope of recycling. It is still sometimes too expensive. Processing the material costs more than can be brought in from the sale of the finished material. We will be discussing the future need to significantly raise the prices of raw materials, so that they might disclose more of the ecological truth than they do at present. In so doing, the chances for secondary raw materials to gain a foothold in the market would increase noticeably. Recycling would become much more financially rewarding than it is now.

FIGURE 28

One can approach the issue from a different angle and ask whether a recycling project is worthwhile from an ecological perspective. We encountered this question once already in the course of introducing MIPS as an ecological measure. We saw that each and every process, each handling of material and each associated consumption of energy generated effects relevant to the environment. It is possible to relate a certain energy and material consumption to each of these steps. Figure 28 illustrates this.

Figure 28 also shows a case in which the ecological costs of recycling are higher than in the initial production. From a MIPS standpoint, a recycling facility is a machine designed to reduce a material flow (the waste flow) by redirecting a part of this flow back into the production cycle so that the flow of virgin resources into the technosphere can be reduced.

In order for this to occur, more than just the waste has to enter the recycling process. Generally it includes energy, machines, transport and possibly other auxiliary materials. The facility requires additional material flows. These material flows contribute to the material intensity of the secondary product and the secondary raw materials that the facility generates. Such an operation is only ecologically sensible if it requires *less* material than would be needed *without* the recycling facility. It should permit materials that were taken from the biosphere in the past to repeatedly circulate through the technosphere. If we find out after the fact that the recycled metal or the recycled plastic is carrying around a heavier rucksack of material flows than the virgin material, then the recycling was nonsensical.

We should obviously try to avoid this. Several possibilites for getting around the dilemma exist. The recycling procedure can be improved. Plastics can be de-polymerized; new catalytic converters can reduce the energy requirements for producing heat and pressure. One can minimize transport distances and limit the number of times the material is sorted. Furthermore, with an appropriate design, parts of "service delivery machines" (devices, appliances, machines, facilities etc.) or the complete product can be reused, possibly after a repair, but without chemically altering the product. This could be implemented in the case of car bumpers or for retail store interiors.

Nevertheless, some anthropogenic material flows cannot be surrounded with recycling. Erosion is an example, as are the materials used in building railroad embankments. Pollution of every description--among others, CFCs which attack the ozone layer and add to the greenhouse effect, or CO_2--cannot be recaptured with any justifiable means, once they have been released into the atmosphere. Roughly half of the masses set in motion by humans in the attempt to create more wealth are not recyclable.

Generally speaking, each and every dilution and mixing hinders the recycling to a greater or lesser degree; this is true for solids as well. Each time a product is made, a part of that resource is so mixed up with others, that it must be expelled from the recycling process. One hundred percent recycling is not possible. One could think of this as a "Fourth Law of Thermodynamics," or the entropy law of matter. Thermodynamics has concerned itself for about a century with the Second Law, which says that each time energy is transformed some of it is lost as heat--forever. Everyone who uses energy renders a part of that energy unusable for all time, and heats up the universe by an infinitesimally small amount. The entropy of the system increases. The nonexistent field of "material dynamics" has been provided with such a law by the late Nicholas Georgescu-Roegen.

The end to all entropic increase is the "heat death" of the universe, or, from a material perspective, the homogenous mixing of all matter into a soup that would resist any attempts at deriving utility from it. But this is a very slow process, one not measurable in human terms. So we have no reason to conclude from the laws of thermodynamics that the apocalypse is imminent. Long before the raw materials, products, facilities and with them nature and humans have dissolved in the soup, the earth will have become inhospitable to human habitation. But at the rate at which we are moving the earth's materials around, this stage is not that far off anymore.

This is no less true if we successfully shift to a greater reliance on renewable resources. In an ecological sense, these are not to be had for free either. When compared with the unmodified earth, each square meter of plowed earth contains a vastly different set of circumstances. Water and nutrients transportation, the number of species and the erosion rates are all modified. Each and every planting, tending, harvesting, transporting and processing requires material and energy, not to mention the effort required to store and distribute the products.

The conclusion to be drawn from these realizations is really quite simple: as everything we do involves the use of energy and materials, we should try to minimize MIPS (increase the resource productivity) every chance we get. This necessarily implies that we keep the material input *into* the technosphere as small as possible, and obtain as much wealth from that amount as possible. We have to be wary of the conclusion that once we achieve these goals, consumption will thereby become transformed into an ecologically benign activity. Alongside the technologically achievable eco-efficiency we must work on the consumption sufficiency. We will discuss this further at a later point.

The rich will have to make do with one-tenth

We have to reduce our material throughput. This does not have to be a one hundred percent reduction--nature moves material too. Nature was even able to cope with the small-scale translocation of human-induced material flows for millenia. We must merely reduce the material flows to a level that permits a restabilization of the biosphere and a sustainable use of its wealth. How do we find such a level? Where must we reduce and by how much?

First, with respect to the second question: it has become fashionable to hold the "North" or the "First" and "Second World" responsible for using up the resources and the "South" or "Third World" for the population increase. Both, so it is commonly articulated, must approach one another and deal each with his own problem, but work toward a common goal. Some refer to this as the "convergence of systems." We should take a closer look at this argument.

The fact of the matter is that every human being taxes the environment in some way. The degree to which a person in an OECD country stresses the environment is roughly fifteen to thirty times that of a person in some parts of the Third World[1]. And while we are on the subject of ecological stress inflicted by humans, we should point out that longevity, height and body weight are factors as much as the total number of people living on this earth. And, as an aside, a Formula 1 race car driver with his energy and material-devouring toy, his technical backup and support team can, harm the environment as much as hundreds or even thousands of pygmies.

The formerly socialist countries also organized their economies in a very energy and material intensive way. By comparison with the West, they were just not as clever at deriving as much material wealth from the energy and material. That seems to simply be a characteristic of centralized planning.

Thoughts on the *"convergence of action"* and on the access to resources of the South and North, of East and West, should be approached with a little more differentiation in the future--also especially because the differences in the use of resources between countries within these "blocs" are rather large, and even larger within countries. However one may decide the issue, environmental deterioration is not going to wait. We must succeed in bringing about the first signs of ecological structural change as soon as possible.

And now for the other of the two questions we asked above: By how much do we have to reduce our material throughput? Where is an ecologically acceptable level? In discussing climate change, an international team of scientists tried to answer the question with some numbers. Their question was: By how much must the anthropogenic CO_2 and other emissions be reduced in order for the biosphere to come away unharmed and with no significant rises in temperature? Their answer, formulated already at the end of the 1980s, was that by the middle of the twenty-first century the amount of CO_2 emitted would have to be cut in half, and that of other pollutants by even more.

As we do not yet know what environmental changes the anthropogenic material flows might bring about over the short and long-term; as we already have evidence of measurable regional and global biospheric reactions, a reduction of these flows by one-half might be a wise step toward restabilizing the biosphere as well.

What does this mean for the *"convergence of action and the access to resources"?* Presently about eighty percent of the world-wide material flows are displaced for the material wealth of the people in the industrialized countries, including the formerly socialist countries, the Asiatic "Tigers" and several of the oil-exporting countries (roughly twenty percent of the current world population). Assuming we can agree that, in principal, all people should enjoy the same right of access to natural resources, and assuming furthermore that we would not wish to interfere with the economic development of the majority of the world's inhabitants:

Then the economies of the countries in which, or for which, most of the material flows are presently moved would have to dematerialize by an average factor of ten in order to allow for a reduction in global material flows by fifty percent.

FIGURE 29

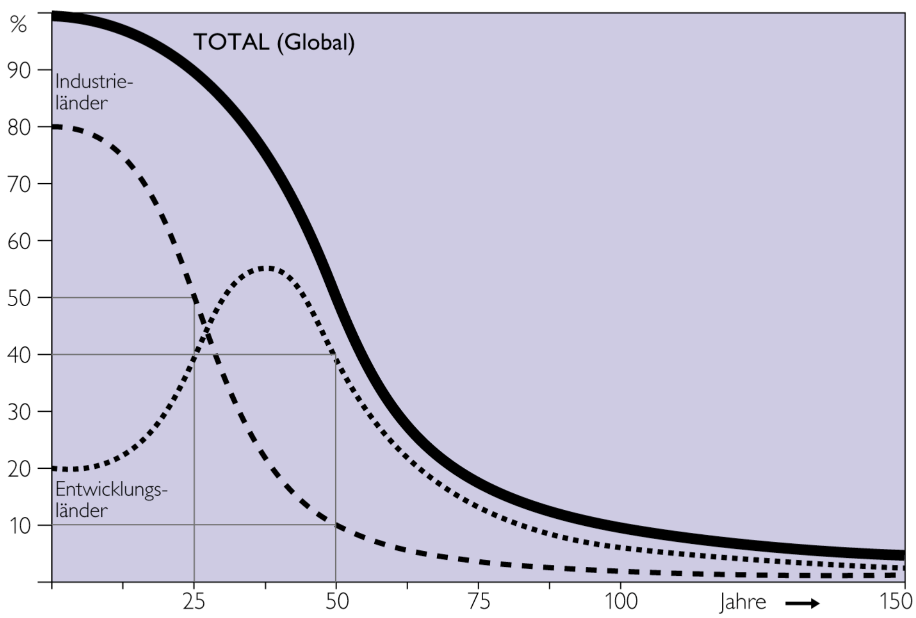


Figure 29 illustrates this situation, where the goal of a fifty percent reduction in global material flows was arbitrarily set fifty years hence. As can be seen, the decreasing material input into the industrialized countries (the "rich" twenty percent of humanity) can be organized in such a way that a temporary increase and subsequent drop for the countries in the "South" becomes possible within the overall material flow reduction scheme. This is probably also a realistic assumption for development policy. It must be emphasized again, however, that the various countries within the blocs exhibit enormous variation. Furthermore we are talking about an average dematerialization, that can begin at virtually any point, depending on the technical and financial conditions. Such a strategy is relevant to all life stages of infrastructures and goods.

One alternative would be to reduce the per-capita amount of goods and services to ten percent or less. This would be the "ascetic" model, a perhaps morally desirable, but politically unrealistic approach. Another method would be to substantially reduce the size of the human body with the help of genetic engineering, thereby reversing a trend, particularly noticeable in the industrialized countries.

The estimate that the "ecological safety factor" should lie in the same order of magnitude as ten is by no means unique to our argument. The example of the climate researchers has already been mentioned. The Dutch National Institute of Public Health and Environmental Protection (RIVM) came up with results that support our estimate already in 1988[2]. In a 1992 study on the necessary steps in environmental policy for the next twenty years, scientists reached the conclusion that the long-term stability of the environment could only be brought about if environmental pollution were reduced by eighty to ninety percent relative to the levels of 1992. Using a different approach, Hans Opschoor reached the conclusion that the eco-efficiency of new technologies, necessary to realize the goal of a sustainable economy, would have to be increased by a factor of five to thirty and more, in the very likely event that the population will continue to rise[3]. A further indicator comes from the botanical world. The annual growth rings in trees have changed markedly since the 1950s. Since then, air pollution has increased roughly ten-fold[4].

All of these papers support the idea of an ecological safety factor of about ten. The absolute number is not as important in this context as the order of magnitude. If the order of magnitude is correct, then national plans and international agreements for the reduction of individual, selected pollutants by twenty or twenty-five percent are insufficient. The goal of the politically very important "twenty percent clubs" would turn out to be shortsighted, as they would be unable to deflect the continued destabilization of the biosphere. Perhaps a few "Factor 10 Clubs" would be more timely.

The central demand in this context is to increase resource productivity. The question of how much the resource productivity must be improved, or the dematerialization must be advanced on average in order for a restabilization of the biosphere to be imaginable, is an "*ecological safety factor of ten*." It is important to point out at this juncture that this rather indeterminate value is derived from a sound basis, estimated in relation to present global material throughput. If population continues to rise as it has for the last few decades, and if the increase in resource consumption in the industrialized nations continues to rise as well, then the factor will have to be adjusted upward accordingly. The per capita material throughput would have to be eventually reduced even more in order for the absolute value to remain the same.

It is not sensible to dematerialize products only to turn around and sell more of them. If the owner of an ecologically superior automobile drives more than he used to, because the product is now more environmentally friendly, then the advantage for the environment is lost. The technically feasible increase in resource productivity must be complemented by a conception of sufficiency with respect to the use of material objects. This last point must increasingly become a matter of course.

Lazing in the sun or feeding fish is always ecologically preferable to riding a motorcycle. Meditation and contemplation don't require any fossil energy.

The factor ten is based on an absolute limit for dematerializing Western technology, an absolute limit of tolerance. Global material flows must be cut in half. A factor of ten is not to be reached simply by improving existing technologies. Little machines perched atop dinosaurs that ingest the smoke will not make the difference. Entirely new processes and facilities, entirely new products and forms of service provisioning must be developed; conceptualized with a minimization of material flows in mind. We will talk about ecological design at great length in the pages to come. An "eco-efficiency revolution" must be initiated. Or should we speak of a "resource productivity revolution"? What a dreadful word! While the word efficiency is normally used in reference to the capability of an existing facility or procedure, the term productivity can include entirely new processes and products that make available the same or even better services. The productivity of those raw materials entering the production process must rise significantly. Regardless of the technologies or facilities, we must discover how to obtain more wealth from a given amount of material. The term "productivity revolution" implies a link between raw material consumption and our general--not just materia--well-being.

One of the most pressing questions for the technicians is whether they are aware of any fundamental barriers to making service delivery machines able to meet the current demand for services with only ten percent of the material "required" today. Such savings (or resource productivity increases) could start at any point of the product life cycle. Wherever a gain in productivity is most easily realized, be it in business organization or at a particular stage of the production process, or even at some other point of its use or disposal, it should be pursued. We have repeatedly discussed this question with engineers from many different sectors of the economy. We have discussed it with first-rate designers and have searched the literature. The answers are unequivocal:

From a technical perspective, an average dematerialization by a factor of ten is realizable in many cases.

If service needs can be met with one-tenth the energy and material intensity at constant quality, why are they not already on the market? We have mentioned the false signals sent by the market: the prices of energy and materials are much too low when compared to those for capital and labor. Nevertheless, the question still remains why entire economies are working with energy efficiences of between two and four percent, as Bob Ayres calculated a few years back[5]. Is the market economy failing us? Is the necessary innovation too expensive for small businesses? Do we still lack enough information about ecological rucksacks? Are the industries in the North just plain too lazy and unimaginative? Is advertising heading us in another direction? Are the consumption patterns too inflexible? As we know, the immune system in every society powerfully resists any change. It is up to us to find acupunture methods that open the doors for ecological structural change. In the chapter "The Market and its Signals" we will be giving some answers on how such ecological structural change might be brought about.

Because fundamental technical changes require ten to twenty years for their development and diffusion, we must figure that a significant dematerialization across the board would take several decades. And as peaceful social changes require at least a generation, if not longer, a realistic time frame for the establishment of sustainable economic development would be about forty to fifty years.

Over the last five decades the prevailing technical conditions in Japan, Europe and much of the rest of the world have changed radically. The way people today have children and raise them, go on vacation, live, eat, work and enjoy their leisure time is hardly comparable to the way our parents and grandparents did those things. Only very few owned cars. Computers, tape recorders, televisions, stereos and fax machines had not yet conquered the markets, or even been invented. Travelling around the world took weeks and the Balearic Islands lay peacefully in the sun.

There is no reason why the social and technical developments of the next fifty years should be any less exciting than those of the last fifty. If we wisely and carefully steer them, if we promote the ecologically beneficent things, then we will be well on our way toward restoring the biosphere.

Chapter 5

[1] *Raimund Bleischwitz and Helmut Schütz, Unser trügerischer Wohlstand--Ein Beitrag zu einer deutschen Ökobilanz. Wuppertal Institut, 1993.*

[2] *RIVM, Zorgen voor Morgen. Nationale Milieuverkenning 1985-2010. Alphen aan de Rijn: Samsom H.D. Tjeenk Willink.*

[3] *R.A.P.M. Weterings and J.B. Opschoor, The ecosphere as a challenge to technological development (Report to the Dutch advisory council for research on nature and environment.) Riijswijk, April 1992.*

[4] *Beirat für Waldschadensforschung des Österreichischen Bundesministeriums für Wissenschaft und Forschung vom 28. Oktober 1985, in, Forschungsinitiative gegen das Waldsterben. Österreichisches Bundesministerium für Wissenschaft und Forschung, Oktober 1986.*

[5] *Robert U. Ayres, Energy inefficiency in the US economy--a new case for conservation. RR-89-12, IIASA, 1989.*

One hundred pounds of environment for breakfast

How much environment does it cost to provide us with our paper? In order to find out the ecological costs of newspaper and magazine production, weighing the morning's paper on the kitchen scales won't suffice. From an ecological perspective, the daily paper consists of far more than just a pound or two.

Each gram of paper that is run through the printing presses carries an ecological rucksack with it. In this rucksack are all the materials necessary for its production: wood--obviously, water, numerous chemicals, and an increasing amount of recycled paper. Christa Liedtke has rummaged around in this rucksack; we thank her for the following data[*].

According to her research, the ecological rucksack of one kilogram of average newsprint and magazines weighs almost 100 kilograms. Just the water used for the production of this kilogram of paper, polluted with chemicals and returned to the environment fills more than a fifteen-gallon bucket, weighing sixty kilograms.

To be more precise: the production of one ton of paper and cardboard in Western Europe requires 100 tons of material. Sixty-five tons of water, thirty tons of air and three tons of wood and auxiliary chemicals.

The ecological significance of this is illustrated by another number: each and every citizen in the former West Germany, from toddler to octogenarian, used 216 kilograms of paper and cardboard in 1990, according to the statistics of the paper industry. And the number is rising. That being so, the Germans are among the top paper users in the world. In the same year, each citizen of the world "only" used 45 kilograms of paper and cardboard. In some Third World countries the use of paper is rising rapidly. Even in this regard, the West is commanding imitation.

It is technically possible, in principle, to reduce the use of water by ninety percent through a largely closed-loop circulation system. The use of air can also be reduced substantially. While this may require more energy, it would unequivocally bring about a significant dematerialization. On the other hand the option to not consume, or to use fewer newspapers, would relieve some of the ecological pressure as well.

As a European, it is still possible to convince oneself that water is not scarce. It is cheap and seemingly available in unlimited quantities. But this is already untrue. In many regions, even in Germany, drinking water must be piped in from great distances. Deriving potable water from the Rhine or from Lake Constance also requires facilities which are virtually indistinguishable from factories. In drier regions of the world, in the catchment area of the Nile, for instance, the water is already scarce and expensive and the first transnational conflicts over drinking water are already behind us. Estimates of the ratio of water supply and human water demand indicate that water scarcity will become one of *the* big problems of the future.

Chapter 6 Services and Consumption

"The archetypical over-consumer is the North American. He consumes his own weight every day: eighteen kilograms of petroleum and coal, thirteen kilograms of other minerals, twelve kilograms of agricultural products and nine kilograms of other products (. . .). At the other end of the scale we find the Marginalen at 1.5 kilograms per capita (. . .). This means that the North American is equivalent to thirty-four Bangladeshis. (. . .) In that case the United States has a population of seven billion Bangladeshis and Bangladesh has about five million North Americans. Where is the over-population?"

Manfred A. Max-Neef,
Universidad Bolivariana/Development Alternatives Center CEPAUR,
Santiago de Chile
(from a tape transcription at the Protestant Akademie Bad Boll in Germany)

Interlude: of electric drills, lawn mowers and service provision

Industrial products are really only needed when they are also used. To use means to derive utility or to obtain a service. In this light, we could perhaps argue that people do not buy products so much as they acquire service delivery machines. This is true for the shower, as it is for the automobile, the washing machine, packaging, the electric drill or the refrigerator.

In order to obtain a service, one needn't own the product outright. Most people do not buy an airplane to go on their next vacation. But many people wish for an electric drill for Christmas, even though they rarely use it either. If one out of every fifteen people in Germany owns such a drill, then more than 10,000 tons of the highest quality material was "locked up," not to mention twenty times that amount in consumed environment that was transformed, before the product could be bought in the store. If the belief in never-ending material growth turns out to be true, then many people probably will own private planes in the near future--if enough room remains in the skies, and the biosphere has not already begun to eliminate the great inventor by that time.

Now let us take a look at the lawn mower. This machine costs somewhere between $100 and $2,500 new. When purchasing such a tool, one has an immense selection: with a gas engine, an electrical engine, with no engine, a push mower, a lawn mower tractor and with or without various other frills. The name of the machine goes a long way toward helping us understand what it is good for: you can cut off the top part of the grass with it. Sophisticated models even collect what was cut off. In most latitudes it is used anywhere from five to twenty times a year. After a while, we go out and buy a new mower. This happens maybe five to ten times over the course of a lifetime.

One could approach the situation differently, though. We could begin with the question as to what we are trying to achieve, how much of it and why? Which service need are we satisfying? In the case of the lawn mower that should be pretty simple, no? Maybe not.

Do we want a lawn as smooth as a rug because we like to practice our golf there? Because we don't like weeds; because that is the way our parents did it, or because we think the neighbors expect it? Is physical exercise important or is it perhaps because we really want to impress the Jones's next door with our new tractor? Which service delivery machine would be the most appropriate?

Or should we perhaps not buy one at all? Perhaps it would be cheaper and better for the grass if we paid a contractor to do it for us. A call is all it would take. The repair, maintenance, storage and insurance would all be included in the price. But maybe the "zero-option" is the best after all: letting the grass grow, because wildflowers are pretty too--at least into the fall?

You might think this is not an example from which to generalize. Well, what else would we have a hard time parting with? The car? The refrigerator, washing machine, computer, VCR, electrical kitchen knife, detergent, having a car telephone or a private fax machine? What about the house?

What about trying it out? Before we buy the next object, let's ask ourselves exactly what service we want/need, how much of it, when and for what purpose? Let us compare, for the sake of the argument, our present service delivery machine automobile with the actual transport and mobility needs of the family. How great is the difference between what the machine can do and what we need, or for that matter, what is possible in traffic? When was the last time we actually drove ninety-five miles an hour to work, to get groceries, or to the dentist? The speed limits in residential areas and in the city are between twenty-five and forty-five mph, and the average speed is actually a lot lower, sometimes under twenty miles per hour. How often are five people in the car? How many hours a day does the car do what it was built to do, provide transportation? The insurance, the liability, the expense of having a garage are costs spread over all twenty-four hours of the day. And if we park on the street then we are subsidizing ourselves through our taxes--streets are extremely expensive. What does it cost per mile--the out-of-pocket expenses? Fifty cents, a dollar? In any case it is about 400 grams of environment that we use for each kilometer we drive--from cradle to cradle.

Should we perhaps not own a car at all, but rather rent or lease one? Maybe a one or two-seated City-car for the week and a bigger one for weekend travelling and vacations? If we were to drive only half as much as we do today, a taxi would be cheaper--assuming we haven't bought the car on credit. Because in that case the taxi becomes even cheaper! Is something sold on the market today that meets these needs? Probably not, at least not for an appropriate price. But why? The market economy should be able to handle that, no?

We hear much talk about necessary structural changes, and well we should, if our great-grandchildren, as well as those who today still live in abject poverty, are ever to enjoy meaningful, not to mention necessary things. Ecological structural change will not occur unless we ask ourselves daily what it is that we really want, what we really need, for what purpose and why.

Aside from a few basic needs, humans only need services. The fact that these are generally met with machines, equipment and facilities may simply be due to a lack of imagination.

We have to stop wanting to buy the car, the toys, the kitsch on vacation, the house, or the appliance simply because they exist, because it is "in," or because we believe that we can meet our service needs only with these things. They are all developed and produced without the slightest regard for the prevailing ecological conditions. We have to get used to re-thinking our desires every time we are tempted to buy a piece of equipment or a product, or want to enjoy a service, especially if we can easily afford it. In almost every case they use up more environment than would be necessary to fulfill our needs.

To use and use up less than we have been is in every respect an ecological plus. This is also true for energy. Industry has a long and exciting time ahead of it in which to come up with products that meet our service and product needs in a more ecologically cautious way than has so far been the case. This is the foreign trade market of the future! We need to think about some other things in this context. For instance, whether objects like cars must necessarily be understood as private property (most belong to the banks anyway); what an ecological measure might look like with which to actually compare similar goods and services; whether we can skirt the issue of market prices speaking the ecological truth.

What are services?

Most people think of the work done by a janitorial crew or in a garage, in public transportation, in insurance and business consulting, the work of a nurse or a hairdresser. In short, they think of the services performed by some people for other people. Services would thereby include all work that is concerned not with the production or manufacture of a tangible object, but with helping, consulting or organization. We begin to notice that services are rendered by machines as well, when we get upset with the ticket machines for the subway, because they function differently in every city. We can even get money out of our bank account at midnight--from a machine.

The term "service" is also used in the context of products, for instance in connection with energy. The environmental movement popularized the demand that energy suppliers or public utilities become energy service providers. Here the term is expanded in a way we wish to adopt for the term MIPS as well. Products such as electricity, cars, kitchen appliances or a mouse trap provide services; they meet our needs. They are in every respect "service delivery machines." We in fact buy most products solely because we expect a service from them. We don't really need electricity, rather we need a means for keeping our groceries cool, a way to cook, or to read after dark. We don't need a car, but transport or "mobility" (whatever that means); we don't need a mousetrap--we want to catch mice. In short, we don't need a product, but the service it can provide. Exceptions exist: jewelry and art prints are bought for the enjoyment of beauty and as investments. Clothes, perfumes and sometimes even cars are bought for their status value. But even products that elevate our social status thereby perform a service.

At first glance it appears as if we had merely replaced the conventional terms "good" and "product" with "service," but it is not quite that simple. For one, the way we are using the term "service" permits a comparison between goods and services by referencing the service capabilities of a good. This way it becomes possible to compare the service "subway ride" with the good "automobile." This is important for the second reason, that it leads the environmental discussion out of the pointless debate over "buying- or doing without." Environmentally benign behavior in the personal realm, and environmentally benign economics in the social realm may demand that we do without a product. But the renunciation becomes easier, it even becomes politically feasible, if the appropriate service can be obtained in some other, alternative way.

From this expansion of the term "service" it is only a small step to its use in a definition of the ecological significance of products and actions as we do with MIPS. There it manifests itself as the key to a better understanding of an environmentally benign economic system. Let us take a look at some examples.

Is an "eco-washing machine" better than one that does not carry this label? The manufacturer claims that the "eco-washing machine" uses less water, less electricity, and perhaps even less detergent. This is positive, and gives it an advantage. But if the "eco-washing machine" is heavier than competing models, if more electronics (themselves produced with great material effort) are hidden within, if ecologically valuable materials were used materials (requiring the displacement of large amounts of material and energy for their extraction), or if the machine wears out more quickly, all of this would register negatively in the eco-machine's Life Cycle Analysis. What is even worse, is that such heavy, material intensive machines, whether eco- or not, are purchased and lugged into every household, even though they may only be used there once a week.

Other appliances and products fare similarly. The "eco-car" may use less fuel than a "normal" car. But the question is whether we want to use less fuel or whether we want take care of our transportation needs while minimizing the strain on the environment. Because in that case, the approach of the "eco-car" may be too short-sighted. Do we need a more efficient refrigerator or do we want to keep perishable groceries fresh? If one asks different questions, different answers suddenly become possible. We will be returning to ecological cooling at the end of Chapter 7.

The MIPS concept does not require arbitrary limitations on consumption because such consumption might be material intensive. It is a positive approach. Its mission is to encourage the search for possibilities of providing services which people demand, with alternative approaches that use less material.

If MIPS were to be accepted as a scale against which to compare environmental burdens, this would mean that any planned exchange of fossil fuels, automobiles, throw-away packaging, apartments, production methods, etc. for other solutions would only be ecologically more benign if less material were displaced in the process than today, calculated from cradle to grave.

To return to the examples from the beginning of the chapter: dematerialization means asking how five kilograms of dry laundry (the capacity of a normal washing machine) can be washed in the most ecologically sound manner. In this case, MIPS would be measured according to the scale "kg material flow per kg clean, dry laundry." In looking for an answer, one would have to consider the communal washing machine in the basement of an apartment building, the laundromat down the street, easily repaired machines as well as very durable ones. Dematerialization means cooling twenty cubic feet with as little ecological impact as possible, and keeping it at that temperature. Does this space have to be a portable refrigerator that can be put in a moving van? Dematerialization does not mean having to give up driving, even though certain limits on driving could very easily be a part of an ecological transformation, but rather looking for less ecologically damaging and more task-specific forms of transport. This could even be fun, to creatively find solutions. Cities could invite competition and award prizes. The comparative measure would be "tons of material flows per ton-kilometer transport service."

We repeat that reusing and servicing is not under all circumstances the most environmentally friendly option. Neither is a "zero-emissions vehicle" (which, by the way, does not exist and never will) or a modernized power plant always beneficial. It always requires additional material flows to reduce the emissions of a car or power plant, and sometimes the amounts are staggering. Besides, the fuel consumption (miles per gallon) is not necessarily a good or even an essential measure for the environmental burden associated with automobiles. The requisite MIPS can very easily be affected more by the material flows generated in the production and disposal of automobiles than those associated with their use.

All services require some hardware, but many services are necessary if hardware itself is to be of any use[1].

According to the classical definition, services are immaterial goods. It is apparent, though, that these immaterial goods can only really exist, that we can only derive some use from them, if equipment and machines exist that produce the services. A vacation trip is only possible if an airplane or a dogsled are available. Money can be had at the bank only if the bank has a place to keep the money out of the rain. Services always depend on real-life service delivery machines and always cost energy. Without an energy supply, without infrastructures, buildings and a list of other machines and devices we would not have a service sector.

From the ecological perspective, we must ask about the material and energy content that is hidden within a particular service, without which this service would not exist. This means that we must add up all material and energy effort from cradle to cradle. A day in a hospital for instance costs the following:

- the material and energy requirements for the construction, the operation, maintenance, upkeep and dismantling of the hospital including all ecological rucksacks, divided by all person-days "provided" by the hospital over the course of its operation;

- the total proportional material and energy requirements for the education, training and maintenance of the hospital personnel;

- the part of the consumption of medicines, equipment, lodging and energy, including all ecological rucksacks, that are necessary for treatment and care of a patient--per day.

It is well known that the financial costs of operating a hospital vary considerably between and within countries. The ecological costs are not known because no one ever bothered to add them up. But they are certain to vary somewhat as well.

The ecological costs of services can be altered from two sides: from the supply or from the demand side. As a vacationing individual, one can choose to stay at a nearby farm rather than flying to another continent, or, if one is bent on flying, one can stay there a little longer. On the supply side, the travel agencies could use the most energy-efficient equipment and facilities, both in their businesses as well as for the customer on his or her vacation. The hospital business could offer on-site treatment instead of residence.

Choosing the ecologically preferable

How is the man on the street to know how ecologically expensive or affordable a service delivery machine is? Information based on the MIPS concept is not available yet and the existing labelling is, as we have seen, not truly helpful. It will be difficult in any case, if not actually impossible, to make ecologically sensible purchasing or use decisions. Nevertheless we will try to put together a list of questions that might be helpful in discovering the ecologically preferable options. We have encountered some of these questions long ago, and others we have been using, whether consciously or unconsciously, for a long time. As already emphasized, one should first know what one is looking for. One should do a little soul-searching as to one's true needs, besides asking when, how much and why one wants the object in question. The term "good" in the following list can mean anything tangible or anything that one can put to use, from a mousetrap to a house.

- How much material does the good require during its use? This can be fuel, detergent, lubricants, cleaning agents, water or other such substances.
- How much energy does it use during operation?
- How large is the good? Are smaller versions available?
- How much surface area does it require?
- How far and with what mode of transportation was the good brought here prior to my purchase?
- Is the packaging appropriate?
- Are parts of the good recyclable?
- How much does it weigh and what is it made of? This is one of the most important and also one of the most difficult questions to answer. Neither the seller nor the buyer usually knows the material composition of the good, and the ecological rucksacks are all but inestimable. How much recycled material or renewable resources are contained within the good? As functionally equivalent products are often put together similarly, the weight of two cars or two sewing machines can furnish a first approximation. One should not rely on this too much, however.
- Does the good regulate the flow of energy, detergent, or other substances electronically or by some other optimization process?
- Can the good be used for different purposes; is it multi-functional?
- Can it be used for other purposes or by other people once I have no more use for it?
- Can I lend it or rent it to others for their use?

- How durable is the good? How long is the warranty? A knowledge of the following characteristics helps in estimating the product durability:
  - -- surface qualities (potential for wear, easy to clean);
  - -- corrosion resistance;
  - -- likelihood of material fatigue;
  - -- reparability;
  - -- partibility/separability (for maintenance and repair);
  - -- ruggedness and reliability;
  - -- adaptability to technical progress. Products should be put together in such a way that individual parts can be exchanged for newer, improved ones (car

engines or refrigeration units). This holds true not only for durable goods, but also for goods that can change very quickly such as computers.

This list is obviously much too long to be any fun, and your dealer will only know some of the answers. A MIPS-tip would perhaps be a lot easier, but if enough people persist in asking these questions things might begin to change for the better. In a market economy the customer is always supposed to be right, after all? In the next chapter we will discuss how these and many more questions can be incorporated into product design.

We should seriously consider the possibility of the following information appearing on all final goods: country of origin or production, the ecological rucksack (measured in material input, MI), the energy intensity, MIPS (based on experience with the product or on extrapolations of the manufacturer's warranty), as well as the known pollutants that are found in the product or that can accrue during its use.

Growth, consumption and the future

By economic growth we usually mean statistically averaged growth in material objects which citizens can access and manipulate. More wealth means increased access to material goods in step with an increased amount of available cash. We don't need to go into the reasons why economic growth will necessarily lead to an ecological catastrophe.

Even if the world economy succeeded in a dematerialization through technical optimization of products and through maximizing resource productivity, this conception of wealth would foil all attempts to reduce global material flows by fifty percent of present levels. What is the use of having a City-car become the standard--a super-light vehicle, requiring low energy and material inputs in its production, while getting 250 mpg--if every family then goes out and buys as many of them as they wish? This would be merely a continuation of the present material intensive lifestyle, with the one difference being that everyone would have a clear ecological conscience. How should we deal with this rebound effect?

As long as economic growth and material wealth are equated in popular belief and behavior, an ecological economy will not be possible.

But is this link imperative? People in Western cultures seem to still need something like growth. They seek the feeling that life around them is progressing, that the world is not standing still. Does growth have to be material growth? As long as people are struggling for their daily bread, for protection from the rain and the cold, and for relief from sickness, the desire for more material comforts is an appropriate instinct. The majority of humanity today has not yet succeeded in transcending this state. But how and where does growth for the sake of safety and satisfaction turn into the Poverty of Affluence[2], as Paul Wachtel has called it? We keep coming back to the same premise: the rich will have to make do with one-tenth, and the rest of the world with one-half. Otherwise the system will collapse under its own weight and suffocate beneath its own trash.

The goal:
Dematerialization without a loss in the quality of consumption.

Must growth be sin? After all, this book is calling for a kind of growth, growth of ecologically optimized technology, growth in knowledge of the highly complex response mechanisms of nature to human intervention, growth of economic systems and consumption institutions that mesh better with the biospheric parameters. This list should already make clear that growth can exist which is not to be equated with monetarized appropriation of material resources and goods. The world can continue on its path without the need for an inevitable increase in the raw material throughput. If progress and growth advance in the ways we advocate in this book, then a reduction in the material intensity of our lives will necessarily follow. Why, then, should an economy not grow in all sorts of ways, except in its appropriation of material goods? We are not prepared to put forth a concept for how such an economy should look.

Dematerialization alone will not suffice to make the economy sustainable. The eco-efficiency revolution remains inadequate and one-eyed if not accompanied by a sufficiency revolution. The zero-options must become more a matter of course. We must find better definitions of "use." All of this should become part and parcel of the political debate over ecological structural change. We need a new, a dematerialized conception of meeting needs. We will no longer be able to afford material goods in the future simply because we are able to pay for and produce them, not even if it costs us the "American Dream."

In light of this we should also scrutinize the different approaches to realizing ecological structural change. It is possible for productivity gains to be undercut by long-standing tax incentives encouraging the substitution of resources for other inputs. Raising taxes on the use of resources must be accompanied by a drop in income taxes, to pick up the inevitably resulting slack in employers cost-calculations. In countries where people are not struggling to meet their daily needs, the concept of consumption must shift away from material to immaterial things. Surely this development will only come about if children are raised differently than they presently are. This will have to start with the youngest children, who, although they have never seen a live chicken, cannot see out of their bedrooms for all their violent plastic toys, Nintendo games and Barbie dolls. This continues in the schools, in the tendency for curricula to emphasize quantitative subjects. Why should a nation benefit from teaching math, chemistry and economics over philosophy, music and painting? Listening to Beethoven or Tina Turner, visiting art galleries, playing ball or enjoying garden parties can be accomplished with much less harm to the environment than keeping millions of over-sized cars on the roads or organizing nationally televised car races[3].

Chapter 6

[1] *Orio Giarini and Walter Stahel, The Limits to Certainty--Facing Risks in the New Service Economy. Dordrecht, 1993.*

[2] *Paul Wachtel, The Poverty of Affluence. New Society Publishers: Philadelphia, PA, U.S.A., 1983.*

[3] *Considerable thought has already been devoted to parts of these issues: for example, see Reinhard Heinzel and Monika Zimmermann, Handbuch umweltschonende Großveranstaltungen--Leitfaden für Planung und Durchführung unterschiedlicher Veranstaltungstypen. Publication commissioned by the Umweltbundesamt in Berlin, 1990.*

Chapter 7 Design: From Reparing things to a new start

Designs for meeting service needs

If a sustainable economy is to manifest itself in ways outlined in the preceding chapters, we will need fundamentally new products on the market. If we do not succeed in effecting important changes in product design and in the qualities of these products, then in a few decades, five billion *more* people will be surrounded by infrastructures and products resembling those we have today. We must therefore conceptualize other ways of organizing goods and services in order to bring about the necessary productivity revolution. We must consider their design.

Design determines the ecologically relevant characteristics of products at all stages, from production all the way to landfilling. A product which has been designed according to ecological principles from the beginning will always have less of an impact on the environment than a technology which is concerned with an ex-post removal of pollution. An automobile which uses significantly less environment than one produced today is ecologically superior to one that carries a catalytic converter. A consumer good which is built according to ecological design criteria consists of selected materials. It is laid out for separability, reparability, and other criteria which we will examine in detail.

Products designed and produced today, if they are optimized according to ecological principles, are much too frequently optimized for energy use or emission control during the use-phase, or according to other criteria that are important only during the product's service life. As long as ecological design has not yet gained a foothold, this shouldn't be a surprise. Even design is a reaction to the presently debated issues of environmental and health risks, and to the "pollutant of the week." Designers have to create products that have a market. Therefore it makes sense to develop products that have advantages the customer can see and experience.

Many other qualities are ecologically relevant, however. To take them all into consideration in the design could become very complicated and confusing, unless one were to come up with superordinate assessment criteria. Dematerialization certainly is one such criteria. A logically consistent reduction of the material and energy intensity of products, facilities and services automatically reduces the waste flows, including the flows of toxic and eco-toxic emissions. Virtually all ecologically relevant qualities of products are captured by MIPS in one way or another. We wish to illustrate this with the help of a list of ecologically relevant product characteristics. The list is divided into three parts: production, use and the phase after the first use has occurred, in accordance with the manufacturer's intent; i.e. the phase manifesting any of the following: garbage, recycling, reuse of parts, or second use. All qualities that relate in any way to material intensity are marked with a *.

Ecologically relevant product characteristics

Manufacture

•*Material intensity of raw materials, processes, structures, facilities.
•*Energy intensity of raw materials, processes, structures, facilities.
•*Use of renewable materials. This is advisable only if the total material intensity is lower than if the materials were non-renewable.

•*Amount of useful products produced. This includes linked products, as, for example, in the chemical industry: those chemicals that are by-products, but that can be used anyway.
•*Waste intensity. Emissions into the air and water are included here.
•*Scrapping rate. This is determined by the quality control as well as by process management.
•*Transport intensity.
•*Packaging intensity.
• Dangerous materials (either materials entering the product itself or as waste materials; see section on "use").
• Surface appropriation.

Use
•*Material throughput, i.e. the amount of detergent required by the operation of the washing machine, fuels, cleaning agents or lubricants.
•*Energy input.
•*Energy output (in the case of facilities, those that yield energy in a useable form, such as power plants and waste incinerators).
•*Weight. This can be an important decision making criteria for the purchaser, as it is one (albeit a rough) estimate of the amount of material that is contained within a product (see also the chapter on "Market Signals").
•*Self-regulation and self-optimization. This category would include the electronic regulation of the flow of consumables (energy, detergent, ...), the "intelligent house" or the "screen saver" option on computers.
•*Multifunctionality. A touring bicycle that can be used both for recreation and commuting is preferred to a highly specialized (racing) bicycle, in an ecological sense. Buildings, for instance, can be constructed in such a way that different use-patterns can be accomodated.
•*Second-hand option. Second-hand clothing stores do an excellent job of organizing this concern, as do all other second-hand retailers.
•*Option of joint use. All products that are used only rarely could qualify here. Electric drills, washing machines and other household appliances, video cameras, lawn mowers or even yachts.
• Size and surface appropriation. This would include the requisite access roads and parking lots.

•*Durability. This is a collective term for a list of characteristics. These include:

-- timeless design, or a design that remains outside the world of fashion and obsolescence--retaining its appeal over time;
-- corrosion resistance;
-- likelihood of material fatigue (especially in the case of plastics);
-- reparability;
-- partibility/separability (for maintenance and repair);
-- resilience and reliability;
-- adaptability to technical progress. Products should be put together in such a way that individual parts can be exchanged for newer, improved ones (car engines or refrigeration units). This holds true not only for durable goods, but also for goods that can change very quickly such as computers.

After the end of the first intended use

•*Durability is also a relevant criterion in this phase of the product. Included in this list are:
-- Material composition and complexity. This determines how easily the product can be reused, or parted out.
-- All forms of continued use; reusability of parts for the same purpose or for other purposes; reuse of raw materials for the same purpose and for new and different purposes.
-- The option of collecting, sorting and transporting the product after its initial use without great material effort.
•*Flammability, or the ability to capture some of the energy content through burning the product.
• Compostability.
• Effects on the environment after the final storage or dispersion into air, soil or water

* = covered bt MIPS

The contribution of design to ecological transformation

What does a designer do? In what ways can he or she affect the ecological quality of goods? Conversations with renowned industrial and communications designers have convinced us that the design profession can contribute to a more ecologically benign product palette, albeit within certain limits.

It is the job of the industrial designer to design products. In so doing, he does not only pay attention to functionality, but also to aesthetic qualities. The design of a product in industrial practice always has two goals: to make the product usable as well as to improve its chances of selling. A designer's success is measured in the profits of her employer. This has generally meant that more products had to be sold. But this does not have to be this way. It could instead mean that the product simply becomes more expensive, either because it was made from expensive materials, or because it has been endowed with particular aesthetic qualities (as with name brand products). The customer is willing to pay more for a "designer chair," perhaps because he thinks it more comfortable, but probably first and foremost because he is willing to pay for an immaterial value: the quality of the design. Particularly ecological or healthful qualities could provide the rationale for a product that costs a bit more than the competition.

Whether a product is produced at all is generally not the responsibility of the industrial designer (this is true for employed as well as self-employed designers), and in the choice of materials he is often tied to the employer's product spectrum. But he can take an advising role and point out more ecologically sound alternatives.

The job of a communications designer is somewhat different. Her "product" is either advertising or consulting. In an advertisement she can emphasize ecologically preferable products, assuming her employer is open to such emphasis. In consulting for an ad campaign, for instance, she can alert the customer to ecologically harmful qualities. This can affect the design of the product, especially if it is somehow linked to either health or the environment. In both cases, she needs to have access to reliable information about the ecological quality of products and materials--information that is not readily available to date.

A further difference is also important. The work of a communications designer does not in all cases result in the production of a product. The result of consulting could, in principle, be a decision to do without a product, or to change the way the product that is supposed to render the service is produced.

While the designer can design a product that is durable, easily maintained and energy conserving, he cannot normally influence the consumer's attitude toward its use. The consumer may not want it at all, or may buy it because it is fashionable and then throw it away. The exception to this are products which are designed in such a way that they can be used over and over again, possibly even for different purposes. An example would be the interior of a store--the counters--which can be reused as the furnishing for a student's apartment, or for storage in the basement. For this to work, the designer must consider the issue of separability and transportability.

Once the designer has succeeded in dematerializing the product, arranged it so that fewer materials or materials obtained by less ecologically damaging means are used, he may inadvertently achieve a side-effect that can undermine all gains: the new, optimized design may lower the production costs. The product sells better, which is a definite advantage as far as the client is concerned. But ecologically, the result is not necessarily positive. Although the individual product is made with less material, so many more are produced and sold than before, that the total material flows increase. This is called the rebound effect. Dematerializing a product in its design can apparently produce ecologically undesirable consequences along with the desirable ones.

Laser printers for computers are one such example. A few years ago they were big and heavy. They incorporated much more material than other computer printers, and their material intensity was very high. (Disparities still exist) But these machines cost several thousand dollars, and were only sold in small quantities. In the meantime, they have joined the general boom in computer hardware, and are sold alongside all other printers in large quantities. Their design was optimized (while employing some very ecologically problematic materials). The result has been that the smaller, lighter laser printers of today are so cheap that in some areas they have almost completely displaced other printing techniques. Computers, thanks to their drop in prices, are also rapidly taking over, becoming as essential to an office as the desk and chair. Every employee is now often entitled to his or her own computer, and the groups jointly using one printer are growing smaller and smaller. The result is that, these days, more laser printers are sold in a few weeks than were sold over the course of several years a while back.
Copy machines have fared simila

rly. When Xerox introduced a dry copier in 1959, their business consultant estimated the U.S. market to be at roughly 5,000. Approximately twenty-five years later, in 1986, businesses bought 200,000 copying machines in the U.S. alone, in one year![1]

How can we deal with the rebound effect?

FIGURE 30

These examples are not chosen randomly. The market for office equipment, especially with respect to computers and their accessories, belongs to one of the fastest growing segments of the economy. Such markets are particularly vulnerable to these effects: every little effort to save material is subsequently swamped by the quantitative expansion. The chances for success are quite different for products in areas that have already reached capacity. The market for refrigerators, for instance, as well as for several other appliances, is pretty well saturated--each household has at least one. The car market is almost to that point in the industrialized world. If these products were dematerialized, it would have a positive effect overall, as the purchases would be replacement purchases, rather than additions to the pool.

The second reason for rapid product or model turnover is that we only have very few examples of timeless design. This means that a design becomes "obsolete"; new products are desired only because a different design is considered more pleasing. Clothing furnishes the best example of that. Fashion dictates when and what to throw out. (Although sometimes it is worth keeping them around for a while and they come back in style). Other products like cars also become obsolete, aesthetically, but the used-car market deals quite ably with that phenomenon. A third category of products does not become aesthetically obsolete at all; tools such as hammers and screwdrivers are in this camp. No, or very few, aesthetic demands are made of these products, and they are generally not even dealt with by designers.

As timeless design is so rare, the aspirations for constructing modular goods that are easily repaired and reused are necessarily limited. Products exist that can be used virtually forever, if one replaces the parts that wear out, but this concept, as ecologically promising as it may be, is not necessarily easily transferred to other types of products. Examples of exceptionally durable goods are some investment goods, like street cars, bicycles (as long as they do not succumb to fashion trends), or the vehicles used by parcel services that are often built for long service lives.

A sensitivity to ecological pros and cons is not foreign to industry. If a designer can show with reasonable certainty that a particular material is ecologically preferable to others, he stands a good chance of getting the material accepted. These days, however, such information is noticeably absent. This book is concerned with precisely this deficiency, and it is also one of the major issues the people at the Wuppertal Institute are working on. No definitive criteria exist, according to which materials could be judged. Instead, a multitude of perspectives are discussed, often contradicting each other. It is thus very difficult, if not impossible, to invoke the ecology-card, to argue for the ecologically benign characteristics of a product, if one does not want to become embroiled in an ideological battle.

Criteria for ecological design

It is highly unlikely that an independent category of ecological design will emerge if one limits oneself to "ecologizing" current products, because these products were created, optimized and used under "un ecological" conditions. Design should therefore not try to "ecologize," but should bring forth new ecologically optimized concepts. A deliberate strategy in this direction could proceed according to the following steps:

Step 1: detailed description of the service needs

The first step toward dematerialized products, systems and services of the future must be a clear definition of what is needed or desired. At this stage, the question should absolutely *not* be how to technically improve existing systems according to ecological criteria, as this often leads to the invention of "outboard motors for dinosaurs," such as filters, catalytic converters and devices which automatically turn off the car engine while waiting at stoplights or railroad crossings. Besides obscuring the actual goal, such mechanical wizardry requires additional material displacement.

Step 2: the search for the most dematerialized solutions--concept, planning, draft

Here we are looking for ways to meet those service needs. New and unconventional ideas are what we are seeking. What must be kept in mind is that while people buy goods because they are under the impression that doing so will meet their service needs, they might also have very different reasons. Aesthetics and status considerations figure in to the purchase of many an object.

Step 3: First evaluation of the results

In the first round, unrealistic suggestions are thrown out. In this phase the first test takes place. Can these ideas that emerged during the brainstorming phase as environmentally friendly actually be turned into environmentally friendly products? Mass production must be possible, for instance, and the production costs should remain within a realistic range.

Step 4: Detailed inspection of the selected options

In this step the remaining suggestions are assessed with the help of the above list of criteria for ecological design--step by step. At the conclusion it should be clear how each suggestion fares with respect to all criteria.

Step 5: Assessment of the remaining suggestions

In a further assessment procedure, the prototypes are compared with the above list of criteria, the goal being to find which entrant has met the terms best and with the least impact on the environment. The first criteria are the MIPS, and, as far as they are known, the human- and eco-toxicity. Additionally, traditional design criteria are brought into the picture at this stage, such as safety, healthfulness, and, last but not least, aesthetics.

Step 6: Implementation of the selected optimal solution--or a return to step 2

If a winner emerges, the solution is now implemented; the draft process is completed and the product is produced. If no winner emerges, the option of returning to step two, to the brainstorming, exists. If that is neither desired nor sensible, other criteria within the existing list must be emphasized more heavily.

If no solution was found, it could mean that no ecologically appropriate good exists for the job. The result might be to stick with existing products, or to do without the service provision entirely. A business that is subject to innovation pressures and competition will in all likelihood find doing without to be a difficult step.

Without a doubt, the price has to play an important role in the assessment of the chosen solution. But as long as prices refuse to "tell the ecological truth," this criterion can lead to ecologically devastating results.

The procedure just introduced for selecting an ecological design is not just stodgy theory. Ursula Tischner of the Wuppertal Institute has followed this path in her Master's Thesis, working on a new concept for the service "keeping produce cool in the household." We introduce her results under the heading "Does a refrigerator have to travel?" Precisely this question was the key that opened the door in step two to a new solution in line with our goal of dematerialization as it is demanded in this book.

Chapter 7
[1] *Robert Herman, Siamek A. Ardekani and Jesse H. Ausubel, Dematerialization. in: Technology and Environment. Washington D.C., 1989.*

Does a refrigerator have to travel?

How does one find a material-saving alternative to a conventional product? The designer Ursula Tischner worked this out in a concrete example*. She implemented the rules for ecological design outlined in this book for the refrigerator. What she came up with is not simply a new refrigerator, but a new concept for storing temperature-sensitive groceries in a household. She calls the first refrigerator in the world designed according to MIPS criteria "Fria."

The fact that she chose a refrigerator is not entirely coincidental. The type of appliance we commonly find in kitchens and college dorm rooms contributes in no small manner to the waste flow and to changes in the earth's atmosphere. Somewhere between 20,000 and 30,000 tons of CFCs leak out of refrigeration and freezer equipment into the atmosphere each year. They contribute to the destruction of the ozone layer and exacerbate the greenhouse effect. Roughly three percent of all CFCs are built into household refrigerators, some as coolant and some as insulating foam.

Besides that, numerous other materials are used: steel, aluminum, plastics, glass, rubber, formica, and more. Recycling has so far extended to the metal and not much further. All told, a 160-liter refrigerator weighs about 35 kilograms.

Such a refrigerator uses about 0.85 kilowatt hours of energy, which is 310.25 kWh per year. That's not much when compared to central heating and hot water heaters, but if we disregard those two for a moment, the refrigerator uses an average thirty percent of all the rest of the energy used in households. According to the producers, such a refrigerator is in use for about fifteen years. But they often seem to show up at the landfill after a mere five to eight years.

In the Western part of Germany, 34 million refrigerators are in use. That means 1.44 for each of the 23.5 million households. Nine percent, or three million refrigerators, are thrown on the scrap heap each year. That adds up to 105,000 tons of refrigerator, or three to five million tons of requisite "environment" each year. While ninety percent of all refrigerators are now being collected separate from other garbage, estimates indicate that the CFCs are removed from only about three percent of refrigerators before they are shredded. Most recently, and only in a few facilities, up to ninety-nine percent of the CFCs in the insulation foam and in the compressor oil are being removed.

The first step in the planning, "description of the service needs," indicates an area where new solutions are to be found. The question: "what could a more ecologically benign refrigerator look like?" is already the wrong question, as this asks about the appliance and not the service needs. Some of the services provided by a refrigerator are the following: produce or groceries should be kept cool and dark so that they will not spoil; the storage space should be located in immediate proximity to where food is prepared; it should be hygienic, able to accomodate the usual containers, as well as meet the reigning aesthetic standards, and it should be easily accessible.

The last point is not well addressed in contemporary refrigerators, as one is forced to squat to get anything in or out of them. Furthermore, they have a characteristic they do not really need. They possess a sturdy exterior box that permits them to be taken along when one moves. Why? Do we take along the bathtub when we move? Hardly. Why then the refrigerator?

The fundamental service requirement of a refrigerator is ecologically sensible. Storage in a cool dark space permits shopping in bulk, and prevents produce from spoiling quickly.

The critique of the conventional concept well illustrates our point: why should a refrigerator not be a part of the house similar to our grandmother's root cellar or pantry? If it were integrated into the outside wall of the house--preferably at a convenient height--then the appliance could shut itself off in winter and suck in cold air from outside--fully automated, no different than our central heating works today. We could do away with CFC foams as insulating material, replacing them with scraps from cork production or recycled paper. The doors, seals, control technology, as well as the separately incorporated refrigeration unit, should be exchangeable. It might even be preferable not to purchase the thing at all, but to pay a regular fee to have either the whole structure, or just the refrigeration unit, regularly maintained by a service company, who would then have every interest in keeping the device in the best operating condition and at the cutting edge of technology so as to minimize its maintenance costs. Regular and diligent maintenance will be required in any case, if the appliance is to last as long as the house.

How then should the built-in refrigerator look? Ursula Tischner has thought through the idea and built a model. She planned a cold-storage room with a variable volume of between 110 and 220 liters, built into a corner abutting an exterior wall of the kitchen. The cold-store does not have just one door as most conventional refrigerators do, but several, so that the loss of cold air through opening the door is minimized. Each drawer is cooled to a different temperature. The freezer compartment is cooled to zero degrees Fahrenheit, the "cold-store" compartment to between thirty-four and forty-four degrees, and the "basement" compartment to between fifty and sixty degrees. All materials used in the construction are high quality, to ensure durability. As few plastics as possible are used, and no composite materials, as they are difficult to recycle. The metals used are rust-proof, and cork, solid foams and gas-aerated concrete sheets were used for insulation.

The cold-storage idea is preferable in many respects. Durability and the fact that the appliance is not transported, but produced on the spot (by the installing craftspeople), reduces the material demands enormously. As the cold-storage room is to be used for the life of the house, the wearing parts must be easily exchanged, another plus for the environment.

The most important question to be put to the final draft is, How high is the material intensity per unit of service, the MIPS? First with respect to energy consumption: The cold-store, as Ursula Tischner has developed it, can be run on 0.4 kWh per day with its connected load of 110 watts. Conventional refrigerators with the same performance require 0.85 kWh, or more than twice as much. Let us assume that the electricity is produced entirely in a lignite power plant. To produce one Megawatt hour, (1,000 kWh) of electricity requires about 1.2 tons of lignite coal. To obtain this much, 9.5 tons of overburden must be displaced. As the 0.4 kWh per day for the cold-store add up to 146 kWh over the course of one year, the material flows associated with the energy requirements are already 1.5 tons per year. (This, incidentally, does not include the amount of ground water pumped off). An equivalent number for a conventional refrigerator would be 3.3 tons per annum. The above calculations also do not include the fact that an optimally installed cold-store is supplied with cold air from outside for several weeks out of the year, saving more energy.

The balance of material flows for the production looks very different, though. The box or housing of the appliance is virtually eliminated, and only few plastics are still used. The cooling technology remains essentially the same, although a ventilator is added, and the insulation volume is increased noticeably. Altogether, 36.68 kilograms of material are required for the manufacture, in addition to several kilograms of replacement parts over the course of perhaps one hundred years. This is more than the 35.2 kilograms for a conventional refrigerator, keeping in mind, however, that this last number does not include repairs. The decisive difference is that the cold-storage uses these materials for up to a century, whereas the 35.2 kilograms for a conventional refrigerator are required all over again every ten years. All told, the material intensity of a conventional refrigerator can be reduced by a factor of about seven in the case of this cold-storage room.

This calculation does not yet include the "ecological rucksacks" of the materials used: glass, sheet metal, rubber, copper. To date we have almost no information on the associated material flows of any of these source materials. Before we can actually compute the material intensity from cradle to cradle, such a database must be created. Researchers at the Wuppertal Institute are working on compiling a "materials atlas" of the most important source materials used in industry.

If the cold-storage room has such advantages, why does it not exist in the private sector yet? Quite a few reasons can be listed. One is certainly convention or habit: we perceive it as unusual not to own the refrigerator we are using. Additionally, the network of craftsmen is not in place who could be responsible for installation, maintenance and repair. And yet again we bump into the obstacle of a price structure that does not reflect the ecological truth. To help bring about the necessary infrastructure, a governmentally funded initiative would probably be needed that would mandate the installation of such appliances in new construction and renovations. Such an initiative would not be breaking new ground, either. Building codes abound, and energy-saving window and exterior wall insulation has been, and is currently, funded with public money. Instead of the isolated choice of a "refrigerator" we must come up with a "system solution," that consists of more than just the manufacture of an appliance by a producer.

[*] Ursula Tischner, Die Kühlkammer--Ein umweltfreundliches Kühlkonzept für den Haushalt. Diplomarbeit an der Bergischen Universität Gesamthochschule Wuppertal, Fachbereich 5 "Industrie Design", in Zusammenarbeit mit dem Wuppertal Institut für Klima, Umwelt und Energie, 1993.

Chapter 8 The Market and its Signals

Because the markets cannot by themselves internalize environmental cost, it is necessary to establish appropriate environmental laws, institutions and policies to do so.

Joint declaration by the IMF and the OECD, 1991

Where we stand today

"We are systematically destroying cultures in order to erect economies. This is one of the greatest curtailments of the human spirit. I cannot imagine destroying anything greater or more valuable.

"If culture is no longer our concern, if it has become secondary, if it has become unimportant, how can we speak about nature? How can we say that we should concern ourselves with improving our relationship to nature? That is nonsense. Why is it nonsense? Because the only arguments accepted today are economic ones. I must come up with an economic reason why nature should not be destroyed. This means I must have an economic argument to intervene in the destruction of life. It is an ontological barbarity that the economy stands above life, instead of life above the economy. We live in a society today in which people are servants of the economy instead of the economy serving the people."

Professor Manfred Max-Neef, Universidad Bolivariana/Development Alternatives Center CEPAUR, Santiago de Chile (from a tape transcription at the Protestant Akademie Bad Boll in Germany)

Federal and state economic and fiscal policies should take into consideration the overall economic balance. Policy measures are to be selected in such a way that while remaining within the parameters of a market economic order, they simultaneously contribute to price stability, a high level of employment, trade balance and steady economic growth.

The German Law for the Promotion of Economic Growth and Stability, June 8, 1967, § 1

Humans are faced with an enormous problem. The biosphere is showing signs of exhaustion and partial collapse. The reasons for this are sufficiently well known, and no longer surprising from a scientific perspective. Humanity has gotten used to the fact that it continues to grow, and with it the production of goods and services as well as resource consumption. This worked for centuries and no one needed to seriously concern themselves about whether this could indeed be maintained indefinitely: perpetual growth on an apparently finite, non-growing planet.

But the time has come. Thanks to scientific discoveries we even know how urgent any ameliorative action on our part is, even if science cannot provide an exact date on which the collapse of the biosphere will occur with a large bang. This date will never occur, and no one will hear the great bang either. Symptoms will accumulate, one after another, sometimes slowly and sometimes with great speed. We will simply get used to some of these symptoms, with the phenomenal ability of the human mind to forget bygone occurrences and observances, and become accustomed to, and perceive as normal, the environment into which we were born. In the context of a study about early recognition of environmental changes, we asked shepherds in the vicinity of Munich in 1986 about any changes in nature they had noticed throughout their working lives. Their answers were all essentially without relevance. Popular literature has been dealing with the dangerously incremental nature of catastrophes for two decades now. John Brunner's horror scenario "Sheep look up" was published alongside space adventures in a science fiction series[1].

This invisibility associated with slowness will not last. We, humans, will start feeling the reactions of the biosphere. It will probably first hit the people of the South, who are, as yet, not even the main culprits in the biospheric changes. The rising number of environmental- and poverty-stricken refugees who are demanding admittance to the wealthy countries is clear proof that we do not have to wait for this time to come--it is already here. But all predictions gauging the extent of present environmental changes indicate that we in the wealthy countries of the North will not miss out on the effects--even if, at present, these consequences are limited to a stream of refugees.

Our rapid ascendancy to the currently available manifestations of material wealth fills many people with pride and satisfaction. At the same time they instinctively shy away from any changes that might require them to leave their familiar territory. The technical milieu cannot help but continue to change in the future. What we can hope is that this takes place within the ecological guard rails.

In this situation we now hear the good news from the systems analysts: from both a chemical and a technical perspective a dematerialization of present infrastructures, goods and services by a factor of ten or more is possible. It would be technically possible to reduce the metabolism we carry on with our environment by enough to restabilize the biosphere significantly, if not decisively.

Naturally, enormous and very focussed innovation and development efforts would be required to achieve this both in the private and the public sectors. The emphasis of techno-scientific research must be shifted away from the analysis of environmental stress toward an analysis of the consumption of the environment. Dematerialized technical solutions are in demand. Naturally this means that the service delivery machines would end up looking and functioning very differently than our present equipment. In all likelihood they would even be better and more elegant than today's models. It is fairly certain that another consequence would be to accelerate the trend toward increased economic significance of the service sector. This is because we can assume that all efforts to increase the service life of goods through repair and maintenance will gain in importance, in light of the increasing need to circulate the materials within the technosphere for as long as possible before they are eventually expelled.

A systemic change does not occur in the real world just because it becomes technically possible. Many peoole would want to emphasize the beneficial aspects of this phenomenon. Systemic changes must become politically feasible as well as societally desired before they can ever become reality.

From an economic perspective, one of the main reasons why we persist in carrying on un-ecological behavior is that neither the prices nor any other economic signals are encouraging the economy to move in a more sustainable direction. The market itself is simply unable to internalize the externalities--the "costs" of unintentioned environmental changes--it cannot, in and of itself, include them in its price structures. Governments are therefore called upon to carefully adapt their economic and fiscal policies in such a way that ecological management will become more attractive.

This is not a new task for parliament and governments. Such adaptations are quite normal in modern societies, and they find their institutional form in ministries of labor, health, research, science and economics etc. We should note, however, that virtually all adaptations have so far been of a social nature. To carry out the necessary adjustments to achieve an ecologically sensible and sustainable economy is a bit different, as it is not merely people's well-being or the well-being of their society that is at stake, but the preservation of the biosphere as the only home and reliable resource base humans and their descendents have. Do these words sound familiar? We've heard this before? You bet.

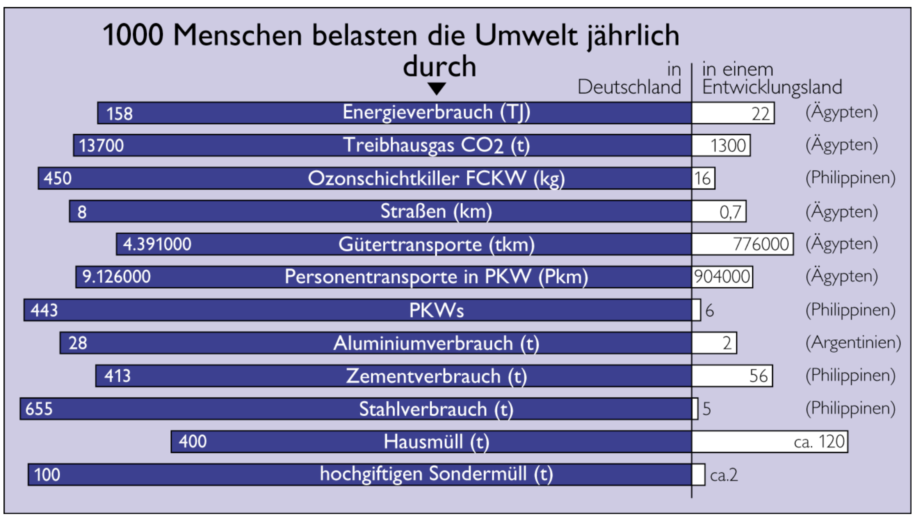
More prosperity through less consumption of the environment!

But eco-politics must go well beyond a "detoxification" of the economy and the environment. Next to the old question about "clean" production, the truly important issue becomes how to satisfy the production and consumption needs with one-tenth the amount of environment. In other words, How do we produce more prosperity while using up less environment? Eco-politics must concentrate on the beginning of the economic process, rather than on solid waste removal. It must render possible the production of wealth by entirely new economic and technical means. The German Minister of the Environment, Klaus Töpfer, also lacks the authority to effect the necessary economic and fiscal policies required for preserving some sort of ecological equilibrium. As the Minister of Economic Affairs is compelled to devote his efforts to increasing national wealth, in step with the aforementioned "Law for the Promotion of Economic Growth and Stability," there is a *de facto* stalemate. It will continue until we understand that we have to quit satisfying our desire for material wealth by displacing enormous amounts of energy and materials and appropriating vast areas, and have instead adopted these tenets into our economic policies. No such thing as ecologically neutral extraction of material exists, just as no ecologically neutral garbage exists. Only a fundamentally new, ecologically oriented, economic policy can change this. Once we have achieved this, and no sooner, can we realistically speak of a market economy shaped by ecological and social concerns.

To date not a single country has a market economy organized around a concern for the environment. The Germans are no exception, and when compared to countries like the U.S.A., Canada and Australia, the German per-capita consumption of resources even turns out to be quite reasonable. Compared with virtually all countries of the "Third World" (as there is no more Second; we should probably now refer to it as the "Second World" in this strange neo-colonialist way of counting), we may consider ourselves members of the exclusive Club of Super-Environment-Wasters (Fig. 31). Raimund Bleischwitz and Helmut Schütz of the Wuppertal Institute have amassed some numbers on this[2].

As our earth is neither divisible nor expandable, our ecological view should confirm that all economic decisions of all nations are of interest to all nations. The ecological meaning of a decision is determined in important ways by both the population level in the deciding country, and by its economic power. If a small, rich country engages in ecological nonsense, it could be worse than if a populous, poor nation continues in the wrong direction.

FIGURE 31



Gross domestic product--the incomplete balance sheet

Robert Repetto, economist at the World Resources Institute in Washington, D.C., illustrates the ridiculousness of present national income accounting with a fairly drastic example[3].

If a farmer cuts wood in his forest and subsequently sells the wood in order to make enough money to build a barn, then he can enter both an asset and a debit item on his balance sheet. The asset item is the barn, which he has acquired as productive, income-generating capital. The debit item is his loss of the trees. He traded in this manner because he calculated in an economically clever way: the barn is more important for his economic future than the forest.

The farmer's decision enters the national income accounting of his country later that year. It is registered in an internationally accepted measure, the gross domestic product. The gross domestic product (GDP) is the monetary value of all goods and services generated by the people of that country. Our farmer has increased this GDP figure in two ways. First of all, he invested--he built a barn and in so doing increased the country's capital stock. Secondly, he engaged in a productive actitivity--he cut down a forest. He took a raw material from nature, thereby entering it into the economic sphere. Both aspects of the farmer's activities were positive.

Only positive? Wasn't a forest there before, where none remains? Didn't the economy begin to deplete a small portion of its capital, the raw material timber, through the activity of the farmer? Shouldn't the country, like the farmer, add a debit item to the two asset items in its calculation to take account of the loss of forest? Indeed it should. At least that is the opinion of a growing number of economists. But it doesn't. The consumption or loss of natural raw materials is not registered anywhere in the GDP figures. On the contrary, if a country loses all its forest and must consequently invest huge sums of money to curb erosion and compensate for ground water subsidence, these investments raise the GDP even further, even though they are investments in repair activities and are not really creating anything of value.

Repetto, and Meadows et al. in their book Beyond the Limits,[4] illustrate this point with the example of Costa Rica. This nation lost thirty percent of its forests over the course of twenty years. In many instances the often valuable tropical hardwoods were not even sold, but simply burned to make room for farms. The result, in this hilly country with high annual precipitation, was unprecedented erosion. The World Resources Institute estimates the loss of topsoil to have been about 2.2 billion tons over the course of two decades--mathematically speaking, a layer of soil twelve meters thick over the capital of San José. The associated siltation, combined with overfishing in the coastal waters severely damaged both the fisheries and the coral reefs.

The net result: in the year 1989 alone, marketable timber with a value of about four hundred million dollars were simply destroyed. Repetto writes: "This amount works out to about sixty-nine dollars per capita for the population of Costa Rica, and exceeded the interest payments on the foreign debt by thirty-six percent." The loss of nutrients due to erosion works out to about fourteen percent of the annual cattle revenue and seventeen percent of the crop revenue. The income of the fishermen sank below the poverty level. Within twenty years, the calculated loss of value in forests, soils and fisheries summed to more than four billion dollars in 1984 prices--a loss greater than Costa Rica's annual GDP figure. This is as if Costa Rica had produced nothing for a whole year and lived entirely off its capital. In Repetto's words, "compared to the size of the economy, the loss is as great as if the entire defense budget of the United States were to disappear without a trace every year."

None of these losses appear anywhere in the national income accounting of the country. Naturally, the country got into financial trouble. The International Monetary Fund (IMF) jumped in, the foreign debt was calculated precisely and programs were implemented to stabilize the currency, but no one seemed to be interested in the loss of resource capital.

As we have portrayed national income accounts, they appear as a gargantuan and absurd undertaking. It would seem as if we had merely to present the example of Costa Rica or of the farmer to an economist of moderate intelligence, to see him so ashamed of the obvious shortcomings in his balance procedures that he would wish himself swallowed up by the ground beneath his feet. But the situation is not quite that simple. The classical procedure of national income accounting has its history and its achievements.

The roots of the presently accepted procedure are found in the last century, the century of industrialization and of exploding international trade in raw materials and products. This century, as well as the beginning of our own, the twentieth century, were marked by phases of unprecedented economic successes as well as tragic recessions, of crass differences between the poor and the rich within otherwise wealthy industrialized nations. The more dramatically this boom and bust cycle proceeded, the less politicians, business executives and economists were willing to put up with not being able to make sense of these fluctuations. They sought for causes and for indicators that could be used as early warning signals.

After the stock market crash of 1929, the British economist John Maynard Keynes proposed a model that became the basis for the currently practised national income accounting. Roughly fifty years ago, the United Nations made it a standard. In this system, a few key characteristics are carefully summed up. The result is considered an indicator, a single number, that gives information about whether the economy is doing better or worse--even when our day-to-day lives give no indication of either imminent euphoria or impending doom. This indicator is the GDP. In the meantime it is used almost everywhere in the world, although not always in the exact way the UN had once intended.

Even Robert Repetto, a critic of the seemingly universal measure of GDP, credits the procedure with some accomplishments. "National income accounting" he writes, "belongs--despite its shortcomings and despite the fact that the general public understands very little of it--undeniably to the most important social achievements of our century." It took long enough for the sciences to figure out how economies can be steered. In the political day-to-day, at least in the industrialized countries, the GDP is considered one of *the* most important economic statistics. Governments are held responsible for every movement of this number. If the number drops, it can mean the end of a Minister or of an entire government. If it remains stable, or rather if it grows steadily, it is considered a sign of political quality, and, ignoring the visible ecological consequences for the moment, this convention has been perceived as a resoundingly positive one for the last several decades.

For citizens of the wealthy countries such as the U.S.A., Japan or Germany, it is still positive, as these countries can afford to devote considerable percentages of their GDP purely to repair-investments. Every traffic accident, every visit to the hospital, every cleanup of Superfund sites, the Green Dot, and every pollution filter are registered as positive contributions in the GDP calculations. It is true that, indirectly, a hospital contributes to the productivity of a country, by allowing sick people--unproductive people--to work again; and in one sense, cleaning up Superfund sites can be considered productive, by restoring land to productive uses. But a business willing to incur incidental expenses of this nature would probably soon vanish from the market. And it would be completely absurd if a business were to buy raw materials at high prices and then sell them cheaply or transform them into products in a less than optimal manner.

With that, we are back to the topic of this book and to the farmer who trades his forest for a barn. When John Maynard Keynes set up his macro-economic model, upon which subsequent calculations of the GDP are based, there was no reason to concern oneself with the fact that raw materials might have characteristics commonly referred to today as "limits," or that their use might be responsible for ecologically destructive consequences. International trade flourished, raw materials flowed from countries of the South to Europe and North America as a matter of course, and these countries' share of the price of the final goods remained minimal.

Let us recall that Keynes was interested in the economic laws of the ups and downs of the world economy. Naturally he too was aware that the value of a good was composed of human labor, investment capital and natural resources. But the prices of the majority, and certainly of the most important, of these natural resources were so low that their exclusion made little difference to the overall computation. Thus the entry "natural resources" faded away quietly (and not at all secretly) in the economic accounts. To date they have not celebrated a comeback.

Narrow-chested resource productivity

Humans now know that each time we take a ladleful of something from the environment soup, we precipitate ecological changes. Whatever we do with the material flows, whether we forget about them after having gotten them out of our way, or whether we make cities, cars, shredders, concrete dwarves or mouse traps out of them, the biosphere does not forget the ladling. Encouraged by ever better machines of the dinosaur brand, forced by increasing population pressure and seemingly caught in the frenzy to provide ever more material wealth for all, humans continue to increase the speed with which resources are extracted. We have left the geologic rate of change far behind and are running the risk of getting ahead of things by turning ourselves and numerous other species into fossils. We are calling into question our own survival on the only planet we have.

We are faced with the decisive question as to how we are going to deal sustainably with the resources available to us. The question is really two questions: first of all, how much wealth do we need, and secondly, how much wealth can we get out of a given amount of resources? These are expressly not the conventional questions of how much labor and capital we need to satisfy our material desires, and which materials are best suited to the task.

The new question is concerned with resource productivity. This smells a bit of thrift, of eco-thrift, and that is as it should be. What is truly exciting about it, though, is the tremendous challenge it provides to human ingenuity and skill to develop new models of wealth, and to create the requisite technologies.

This is especially a challenge to the industrialized countries, whose phenomenal economic successes of the last two centuries were made possible by virtually unfettered access to the planet's natural resources. These successes naturally appeal to the less wealthy countries, and--along with our methods of achieving them--appear exemplary.

What does the reality look like today? If one believes the political stump speeches and campaign pledges of politicians in many countries, but especially of those in the industrialized nations, guaranteeing (preferably ecologically mindful) access to "essential" resources belongs to the most important tasks of economic policy. A focussed revisioning of the efficiency with which we use resources is not on the current list of priorities. Federally funded research fares similarly. Improved supply of resources, including renewable ones, is still given far greater prominence than, for example, the research into resource-saving technologies.

Even military efforts are understood as investments in the supply of resources: the war over oil in Kuwait in the spring of 1991, to which almost the whole world contributed in some way or another, cost several tens of billions. Germany, although it was not involved militarily, contributed about one-third of that sum. Independent of whether one wishes to list other reasons for fighting in Kuwait and Iraq, the fact remains that in the very recent past, oil was subsidized quite heavily through tax funds, instead of making it more expensive as a feature of ecological structural change. Those who have read Al Gore's book Earth in the Balance[5] will look in vain for a call to decisively improve resource productivity. And this book has been praised extensively for its relevance to environmental politics.

FIGURE 32

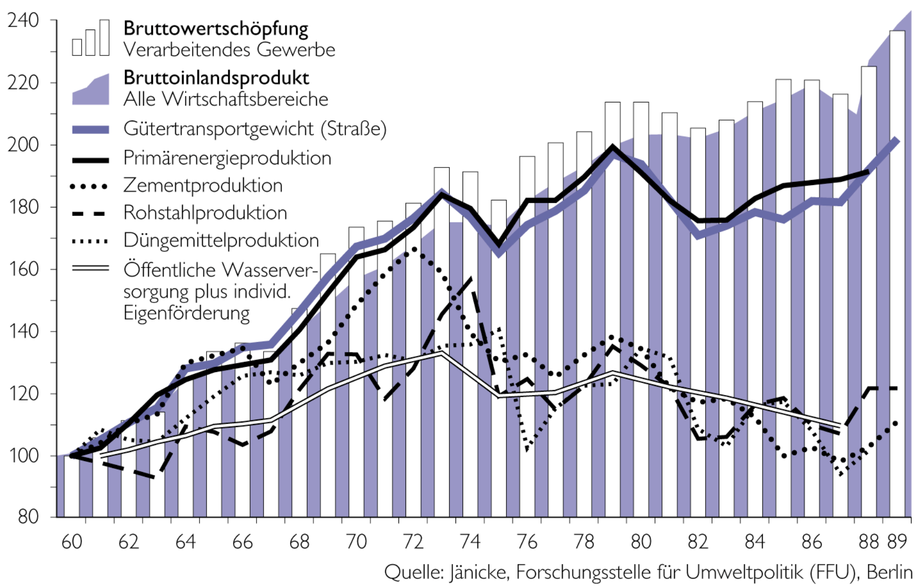
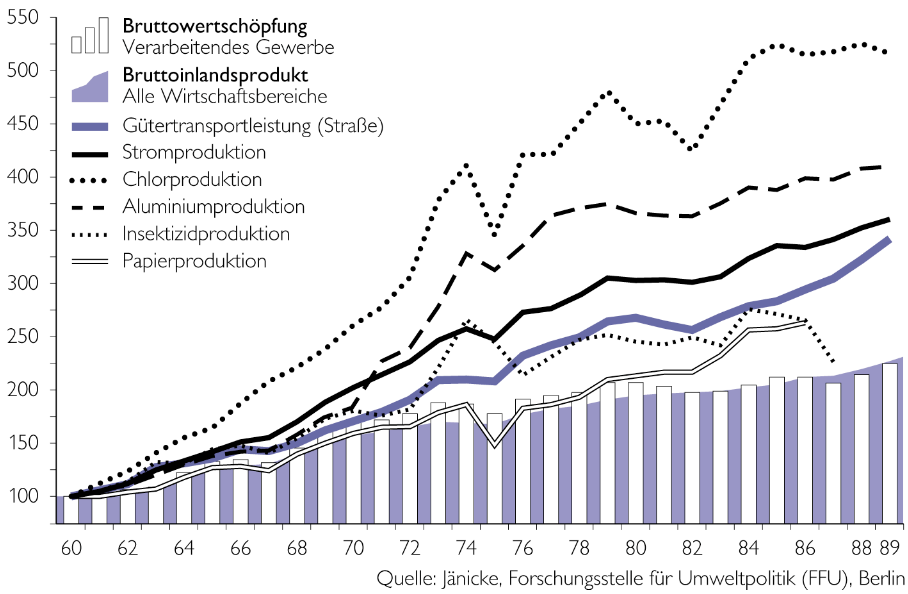


FIGURE 33



Looking at the temporal development of some important industry indicators in the former West Germany shows a mixed, but in some sense also an encouraging, picture. Martin Jänicke has put forth some interesting numbers in this context[6]. Between 1960 and 1989 the production of traditional goods such as fertilizers, steel, cement, and even water supply has become de-linked from economic growth, as measured in the GDP (Fig. 32). The structural environmental stress due to these goods is declining. The use of primary energy and the total weight of transported goods have remained constant since about 1979. While this is not a direct indication of a rise in resource productivity in the production of these goods, it nevertheless charts an increasing independence in Germany of the net value-added from the production of these goods (including the amount of water procured).

On the other hand, the production of certain other goods grew disproportionately over the same time period in Germany. These include electricity, chlorine, aluminum, insecticides and paper. Figure 33 shows the trends.

In an international comparison, Jänicke's results show that especially Japan, Luxembourg and Sweden have succeeded in de-linking a growing GDP from environmental stress, measured in terms of freight transport, energy and water consumption, along with seven other indicators in the field of heavy industry. At the other end of the scale are the Southern European countries, just behind the Eastern European countries. Germany is somewhere in the middle. Countries of Africa, South America and large parts of Asia were not included in the analysis.

One can appreciate that raw materials are far from being in short supply and that the economies have no fears of this changing any time soon, by looking at the trends in their world market prices. In many cases, the prices have fluctuated a fair amount over the last two hundred years, but overall they have dropped, decade by decade. Their prices are so low today, that they rarely sway economic calculations one way or another. But even in the most extreme cases, the cost of raw materials doesn't amount to more than two to five percent of the price, while labor intensity and labor productivity often account for more than eighty percent of the production cost.

We are concerned with economic policies that permit the greatest possible latitude for developing and increasing wealth within the parameters imposed by nature.

In industrialized nations, the per capita costs of a workday are, roughly speaking, worth one ton of raw material. Sand, gravel, water, grain and soil are even much cheaper. What today's prices reflect are the more or less carefully calculated economic truths of the utilized capital and labor costs for providing the material, and the requisite percentage for profit. Ladling from the environment soup is simply not included in the price formation. This is especially true for transport costs. In Germany it is economically rewarding for a firm to ship everyday goods thousands of kilometers during their production in order to save labor costs. Cotton fabric is regularly sent to Kiev in the Ukraine, and back for dying and for other refinement processes, and then sent to Poland and back for similar treatments. The belief that opening the European borders to the East will bring jobs to countries within the European Union is hardly defensible over the long term with transport prices like these. We already discussed the work of Stefanie Böge of the Wuppertal Institute earlier. She charted the breathtaking transport distances of a simple glass of yogurt. Aluminum from the Rhineland, strawberries from Poland, bacteria cultures from Schleswig Holstein and ultimately produced in Stuttgart. Transportation of this sort makes no sense economically, and even less ecologically. It is a typical example of a completely misguided subsidy policy.

We have figured out that resource productivity lags far behind labor- and capital productivity. In part, this is because only in the last few decades have we begun to be concerned with the risky ecological effects of resource use. It is also attributable to the fact that to date only few people take seriously the risks involved in anthropogenic environmental change.

We have put forth the argument that Western economies must dematerialize their activities by a factor of ten if they wish to make substantive progress toward a sustainable economy. The required increase in resource productivity will likely be in the same order of magnitude.

So far it is entirely unknown how the different productivities are related to one another. Labor productivity and resource productivity are almost certainly related and interdependent; they might therefore also not be maximized independently. An increase in resource productivity would be felt in the world of labor. This might lead to an expansion of the service sector.

For clarification, we are not talking here about resource efficiency, but about productivity. For the sake of comparison: as labor costs were becoming the deciding factor of success in economic competition, the truly significant breakthroughs did not come about by improving efficiency of existing processes, but by inventing new machines and quality control systems that delivered markedly better results than had hitherto been possible. The shoemaker did not learn how to make ten times as many shoes in the same time, but instead entirely new methods for producing shoes were introduced. Productivity improvements by a factor of ten, twenty and more were more the rule than the exception. In extreme cases, as for instance in mining, factors of ten thousand and more were realized.

Incorrect prices--incorrect market decisions

Let us accompany someone shopping. Let us say they are buying a variety of items: two wall-hooks, an electric can-opener, a washing machine, some apples and tomatoes, and two pounds of roast beef. The consumer is environmentally conscious. She wants answers to two questions: first of all, Which products are in and of themselves more "ecologically expensive" than others; and secondly, How do I recognize if a competing product is ecologically preferable, and if so, by how much?

What is certain is that the price of an industrial product today has little, if anything, to do with its environmental impact. Even the labelling as a so-called green product only refers to the criteria selected by the producer--for instance--the avoidance of pesticides. Such a declaration says absolutely nothing about water consumption or energy use. Awarding the "Blue Angel" was based from its inception on cleverly selected and transparent criteria--but these criteria are simply limited.

The consumer's first question includes the question of the "zero-option." Does a true demand exist for owning or consuming this product? Even if it is "ecologically expensive"? Do I really need an electric can opener? Does cousin Caroline need one for her birthday? How often would I be using the washing machine? Might it not be cheaper, worth the chat, space-saving, and in the end even more convenient, to go to the laundromat once a week or to use the communal machine in the basement? Should I really always eat so much meat even though the doctor keeps telling me to cut back?

Zero-options in consumption are always ecologically preferable to even the most refined environmentally compatible technical solution.

These days, a confusing flood of advertising containing partial ecological information is printed on ecologically expensive paper and glued to many products. And then we have the Green Dot on top of that. But how much environment do these things really cost, including packaging and disposal? From cradle to cradle, that is. How is a consumer to determine these things in the store? We need easily grasped, expressive information, something like the price, a single number, a mark on a scale, better-worse--something to hold on to, even if, in the final analysis, the information is not precise. Material intensity (MI) or MIPS might bring us closer.

The second question, about competing products, must be answered if the consumer wants to compare and eventually decide; if she wants her decision to be at least the better one. How is that with respect to the wall-hooks, and with the fruit and vegetables? Information exists here, too, some of it even correct information. As we have noticed, though, the environmental significance of the product includes everything from cradle to cradle, which includes packaging and transportation. Buying apples from New Zealand and tomatoes from Portugal in far-away Germany cannot be ecologically sensible, even if they were grown "organically."

Only very few stores of the old kind still exist, where you can simply buy two hooks. Today you generally get ten, because they are packaged that way. It saves labor costs in the supermarket, it discourages theft and it makes the packaging industry happy. You naturally lay the eight extra hooks aside and forget about them, or use others the next time you need some. That's how the economy flourishes. That creates jobs! You think those are small potatoes? If each German bought hooks like that once a year, at one gram a piece, about 20,000 tons of environment would be unneccessarily displaced, not counting the packaging and transport efforts. MI or MIPS on the package would perhaps be more helpful than the Green Dot!

Besides, the best experts in the world could not have helped our consumer very much. As yet, we still lack an internationally agreed-upon method for estimating the life-cycle-wide environmental stress intensity of goods and services that meets the criteria already introduced earlier in the book. Years of research and a fairly large computer would have been required to give our customer even preliminary answers to her questions. Answers, by the way, that other experts would have contradicted.

A further "besides." A "green" Global Agreement on Tariffs and Trade or GATT is not possible, (especially no tariff equilibration for goods that take environmental aspects into account) without an international agreement on how the environmental compatibility from the cradle to the border should be measured. For this, too, MIPS provides a starting point. In fact, thinking about the question of international trade and the environment produced this idea[7].

Free trade with today's goods subsidizes the destruction of the environment.

In order for the market to function reliably, millions of buyers and sellers, those people participating in the market, must continually be making sensible decisions. The market must then react to the sum of these decisions. The market brings forth the products which the buyer demands, or for which the buyer's interest has been awakened. These kinds of products are successful. If a new, more reliable--or for some other reason superior--product is offered, the buyers' collective decisions change, and the sum of their decisions changes the market processes. The "invisible hand" directing the market is the community of buyers. The "invisible hand" is the most important decision making mechanism of the market. The ecological reform of the economy will either take place in the markets or it will not take place at all.

The international criterion for market decisions is the price. Distorted prices are not able to allocate resources in a sensible way. They steer the resource flows in the wrong direction, at the wrong time and in the wrong quantities. If the prices do not speak the ecological truth, if they are based on incorrect or missing estimates of the ecological carrying capacity, what then?

Without the "invisible hand" the market doesn't work, and without honest prices the "invisible hand" gropes in the dark. Unfortunately, it is not too likely that we will get ecologically truthful prices anytime soon. We will try to explain why that is later on. In the meantime, however, consumers need understandable and internationally reliable information about the environmental significance of each process, facility, good and service--in addition to the price. Otherwise they cannot fulfill the role of the "invisible hand," delegated to them through the market. The MIPS approach provides a useable solution for this.

An example of world-historical dimension of the recent past illustrates the economic consequences of jettisoning the market framework: the planned economies of the socialist countries collapsed. A major contributing factor to this development were governmentally decreed prices, which did not even reflect the true *economic* costs.

As we have seen, the prices in our own economies are not correct either. They invite us to over-exploit the environment and help the consumer to undermine the stability of the biosphere. It is hard to believe that the majority of experienced economists harbor deeply held fears of entering into a serious debate over how we are to get ourselves and our economies out of this critical imbalance, and how we intend to effect ecological economic reform. This stands in striking contrast to their willingness, even eagerness, to be helpful to the formerly socialist economies in establishing a market economy.

If the governments of industrialized nations were far-sighted and wise, they would do their best to overcome the flagrant contradictions between the traditional goal of economic policy, increasing national wealth, and the requirements for maintaining global ecological stability. Should this fail, the loss of political credibility will continue. It will continue to erode until the legitimacy of governments and public institutions at the local, national and international levels is gone, bringing about changes not unlike those which are still rocking the formerly socialist world. One of the victims could be the market economy, another the liberal society.

How to bring about structural change?

Some preconditions

Some fundamental conditions should probably be considered before one can seriously begin with ecological structural change. The following are some of these conditions:

First of all, it is absolutely essential that a sound majority of people in many countries, and especially decision makers in both the private and public sectors, are convinced that business-as-usual will necessarily lead to ecological collapse. A collapse which will, in all probability, significantly restrict the viability of continued human life on earth, if it does not make it downright impossible. This scenario becomes more explosive every day, as the not-yet-industrialized countries know of no other model of development than our un-ecological economics which they are diligently imitating. It can be doubted that presently more than a small minority of Ministers of Economics, heads of state and CEOs take seriously the ecological risks. We have a bit of hard work to do here. The "missionaries" should concentrate on the "unconverted." Too many "greens" talk almost exclusively to other "greens."

Germany needs a new industrial culture, new approaches and a completely new predisposition toward risking new ideas. (Peter Mencke-Glückert)

Secondly, decision makers must be convinced that the possible collapse could happen within the next few decades. They must be convinced that decisions have to be made today in order to get technical innovations onto the market in time, so that market instruments (such as ecological taxes) can be introduced with the necessary time frame so that people have a reasonable chance of becoming acquainted with fundamental changes without having to rush things. Especially the high economic growth rates in the part of the world that has not yet industrialized, with the necessarily gigantic investments in transport, energy, and infrastructures, contribute in no small way to diminishing the chance that we will one day be able to restabilize the biosphere.

Thirdly, the ecological reform of the economy must work within societally and technically realistic time frames. Tax and fee increases must consider absolute limits, and should be reliably phased in over decades. They must reflect certain givens, for instance that new key technologies require a decade or two for the bugs to be worked out and to become diffused; that significant societal change takes a generation at the very least.

The *fourth* point warns against arbitrarily and prematurely tearing down and replacing long-term investments in technical fields that were planned prior to the implementation of such structural change with ecologically preferable solutions. Such Luddite behavior can be economically as well as ecologically counterproductive. It is extremely necessary to work out models for ecologically optimizing procedures and behavior. The MIPS approach also provides a suitable foundation for this.

As a *fifth* point, politics and economics must be able to rely on scientific analyses of the essential economic causes of the present ecological mess, in order that purposeful and sustainable "least-cost investments" can be made to improve the situation. The multiplicity of complicated environmental analyses which exist for every conceivable realm and are peddled by every expert group do not hold much promise here. Resilient, simple, cost-effective and directionally stable economic indicators must be developed in accordance with the necessary analyses in order to be used in the planning and execution of ecologically benign and lasting infrastructures, facilities, products and services. These indicators must permit international control of the success of such structural change as well as provide the conceptual framework from which to suggest changes in course. The MIPS approach tries to meet this need. Hardly any doubts should remain regarding the centrality of significant improvements in resource productivity (eco-efficiency) with respect to ecological structural change. As we have mentioned repeatedly, extensions of- and complementary procedures to MIPS are both possible and in some cases necessary. This is especially true for the evaluation of toxic material flows.

As a *sixth* point we find it necessary for the economy to have reliable guideposts for determining how far structural change will have to go in order for future developments to remain within the biospheric guard rails. As a first approximation we suggest the "ecological safety factor of ten" for the dematerialization of Western economies. Globally and with the present distribution of population this would work out to a mean reduction in anthropogenic material flows of fifty percent over the next several decades. The economy also needs a new industrial culture which it must bring about itself. New approaches and a new predisposition toward risk are in order.

Seventh, any future attempt to legislate the specifics of a technically required solution must be avoided. It is the responsibility of the government to articulate the goal that is to be reached. If this precept is not abided by, it will be a far more effective means of obstructing ecological structural change than all the end-of-the-pipe technologies put together.

Eighth, it must be pointed out that steps toward ecological structural change on a national level can only go so far. All people need the earth as a store of resources, not to mention as a home. Over the long haul it will be of little use if only some countries transform their economies, especially if they find themselves economically penalized for doing so.

We note that for successful ecological structural change to occur, international cooperation of all countries must be improved. Here, too, we must append a "but." If large countries like Germany do not wish to lose their leadership role, then they have to muster the courage to point the way, with humor and imagination.

Without innovative ecological demonstation projects, Germany will lose its economic position. (Peter Mencke-Glückert)

Legislative measures

Over the past twenty years environmental protection has been primarily advanced through legislative regulations. In principle, this path is suited to removing specific or describable types of environmental pollution relatively quickly and efficiently, and for creating conditions for industry that preserve competition. In the case of clear and present danger, legislative measures are indispensable, as in the case of accidents involving toxic substances. It must be doubted, though, whether the regulatory path is the most cost-effective approach and whether it actually leads to desirable cost- and resource allocations. So far, this approach has not proven itself as a workable means to achieving ecologically informed prices. Besides, in most nations of the world the infrastructures necessary to enforce environmental protection of a legislated kind are absent. Nevertheless, such regulations will continue to have a place in future efforts to protect the environment. No one would opt for doing away with the *Chemikaliengesetz*, for instance. Legislative measures just might be the proper vehicle for carrying out clearly defined steps toward ecological structural change. With respect to future private transportation in cities, a ban on all but City-cars by the year 2005--if not sooner--might be conceivable as an example of an appropriate legislative act. The technology has existed for some time. It would be even better if the automobile producers would finally figure out that they can initiate and carry out ecologically sensible strategies on their own.

Legislative instruments have the tendency to prescribe technical, scientific and administrative regulations with great specificity. In doing so, they permit comprehensible evaluations of success, but also feelings of achievement on the part of the responsible bureaucrats, as well as at many other levels of administrative institutions. Legislative orders of this sort generate the following types of activities:

- the development and prescription of norms, standards, upper limits, testing guidelines etc.;
- granting of permits and prohibitions and the prescription of restrictions;
- inspection of compliance with legal requirements and regulations;
- monitoring and, if necessary, the punishment of violations of any regulations.

Institutional improvements

Alongside legislative measures, governments should purposefully alter and generously expand prevailing institutional conditions that might accompany citizens on their way to new consumption patterns and new conceptualizations of prosperity. Associations, churches, political parties, firms, universities, community colleges and other institutions can and should contribute importantly to the generation of new stimuli, for instance in some of the following areas:

- vocational and continuing education
- hearings and opportunities for participation
- adapting professional and job training requirements
- limiting or supporting advertising
- ease information access
- expand labelling efforts
- create new kinds of jobs (such as energy or material consultants, crop doctors and others)
- increase transparency of both state and business operations in light of the necessity for ecologically benign activity and improved products.

And finally we remind ourselves that governments often have a lot to gain by giving affected institutions generous space for developing innovative approaches under their own responsibility.

Taking advantage of market forces

What do we mean by economic instruments?

We have already clarified the decisive role of the market in realizing an ecological reform of the economy. By economic instruments we mean those instruments that help to ecologically strengthen the "invisible hand" without recourse to injunctions or prohibitions; that permit the millions of decisions made by market participants to become--on average--more ecologically sound.

The example of solid waste

The solid waste problem with which industrialized countries are currently preoccupied cannot be solved by shutting landfills and incinerators and recycling the stuff ever more frequently; while raw material prices remain in the basement and the input gates, from biosphere to technosphere, are left wide open. First of all, continual recycling with no attendant waste or material and energy demand is impossible; secondly, the amount of material circulating in the technosphere--with no exit--necessarily increases over time. In the final analysis this would mean organizing ever greater stores of material within the technosphere, maintained at rising ecological costs. The material quality will eventually suffer through what is called down-cycling. The price for secondary raw materials then drops, and governmental subsidization runs its course.

A crass example of the international consequences of such policies is now taking place in Indonesia. Tens of thousands of people there have been living off what they could earn by collecting discarded plastics and selling them to recycling firms. Recently, however, and in no small part due to the Green Dot, the imports of plastic garbage from Europe and North America have risen considerably. Recycling firms in Indonesia profess to prefer this garbage, as it is allegedly of higher quality. New processing plants have shot up--and due to high subsidies in Europe, the plastic ends up being delivered free to the Indonesian processors. The result is a steady drop in the price paid to Indonesian plastic collectors; many can no longer support themselves. The German Association for Technical Cooperation (GTZ) is now involved in funding a retraining program for garbage collectors in Indonesia! German tax funds are being used to support a program that is supposed to mitigate the effects of highly subsidized garbage exports from industrialized countries including Germany[8].

Unhealthy, illegal and sometimes even criminal practices in the context of garbage cannot--realistically speaking--be brought under control (or if they can, then only with exceedingly high prosecution costs) as long as an ecologically and market economically coherent material input policy has not been articulated and put into practice. Reports of such incidences crop up every so often in the news media. The aforementioned plastics imports to Indonesia, for instance, contain--according to outraged local agencies--up to thirty percent non-recyclable material and up to ten percent toxic waste.

Over the long term, the waste problem can only be solved by reducing the inputs into the technosphere. This emaciation must be brought about by changes in market signals. More expensive raw materials lead to more marketable secondary materials.

The example of an energy tax

We will introduce here in outline form an example as a clarification of the functioning of economic instruments. We do not wish to provide an exhaustive analysis of the effects of a rise in the price of energy. Many reports and books have been written about this issue[9].

Let us imagine that the European Union has decided to levy an energy tax with the goal of slowly and incrementally increasing energy costs: over the course of forty years, the energy costs are to rise by five percent per year. This would mean that in forty years energy would have increased eightfold in price, not counting inflation and potential price increases of primary energy producers.

First of all, a general comment: Ernst Ulrich von Weizsäcker, one of the most convincing proponents of ecological taxes, has tirelessly pointed out that such taxes are not to be levied for the purpose of filling government coffers. This would weaken their purpose as directive taxes for pointing the way toward a stabilization of the biosphere, as well as serving to undercut their political feasibility. He suggests simultaneously introducing a reduction in, for example, some other tax, such as the income tax, or in conjunction with the incidental wages costs, so that the total tax revenue does not increase.

Let us assume then, that we have an energy tax. How does a private consumer react? In response to an energy tax the reaction would very likely be that the consumer reduces his or her use of energy as much as possible to make up for the increased cost. Insofar as no actual loss of services (lighting, showering, washing, cooking, heating, etc.) occurs, this would be a private sector energy productivity increase of the first order. As we have pointed out, the "zero-option" almost always exists alongside the others: doing without certain services or eschewing the ownership of certain appliances or other goods. Zero-options are always ecologically correct, unless one squanders the benefit to the biosphere in some other way, for instance through increased driving or on vacations to faraway places.

Furthermore, industry will busy itself with developing more efficient technical means for living with less energy for private, institutional and industrial energy consumers. Industry will do its best to fill the new niche. (An example of this are the already available energy-saving light bulbs.) They make money, gain market advantages and even create new jobs. (Some old ones may fall by the wayside, too.)

This reaction from industry should be equated with an increase in energy productivity for two reasons: first of all, the private or institutional final consumer--for instance a school--saves more than they were already able to do on their own, and secondly, the energy use in producing virtually any good will drop in the case of those firms who invest in the new technology to save on their energy bills. But, these investments do cost money--they have to pay for themselves. To explain this to an investor can get so complicated that a new vocation might develop--an ecological purchase and use consultant (comparable, perhaps, to a tax consultant). This too could contribute to an increase in jobs.

With continually increasing energy prices, ever more competition is generated in industry as well as with other countries to produce better, more elegant and cheaper energy saving devices--the service delivery machines of the future. The transition to an ecologically inspired market economy will have been successful.

As the MIPS discussion has shown, we would have to ascertain first whether the increased energy productivity actually covers the entire life cycle of the product, and if it has not perhaps been achieved at the expense of material productivity. Otherwise the success may be deceiving. Estimates of this kind, with the help of MIPS, are indispensable. A further analysis should be performed as to whether or not more toxic materials were substituted in the new technologies. Whether these factors are relevant in the case of the aforementioned light bulbs remains to be seen.

It is entirely possible that more ecologically benign service delivery machines will be more expensive to purchase than conventional solutions; the efficient light bulbs are a case in point. Should this prove to be a general rule in the future, and some things point in that direction, then certain adjustments with respect to how ecological structural change would be financed are in order. An example of this need might be the concern over how poorer families would find themselves able to adapt to the changes. In other words, the options in the area of renting and leasing would have to be reexamined and possibly extended to other product categories.

Energy price increases could very well precipitate price increases for industry and thus also for consumers, at least in the interim. This would register negatively in national and international competition. Industry has made a point of repeating this over and over again, and has so far blocked any energy price increases by so doing. This may be taken as an indication that those responsible in industry and government do not consider the ecological risks to be either imminent or very threatening.

In the context of an ecological reform of the economy, resource productivity would have to be improved considerably. This is true for geologic resources as also for water, soil and energy. An important question is whether an increase in price (taxation) of all these resources is sensible or not. The answer is yes--but. One can make steel so expensive that it would pay to steal the train tracks at night, or mailboxes. This can hardly be considered a sensible strategy. Stealing energy, on the other hand, is far more difficult. It is particularly hard to store, and when we are talking about commercially interesting quantities, it is downright impossible. Storing water is also a tricky thing--an expensive proposition--if for no other reason than that it is liquid. This means that one would have to sit down and think about which materials to make more expensive, by how much, and how to go about it, in order to improve resource productivity in specific target areas. It might make sense to increase the price of cement through a special energy tax if one is interested in improving the productivity of cement production. In this light, energy seems to be particularly suited to a "general tax," especially as all technical activities require energy in one form or another. But we must remind ourselves that the amount of energy used is not a reliable measure for the resulting environmental stress. Last but not least, we should take into account that federally implemented energy price increases within the European Union can and will have repercussions on the oil, gas and coal producers in other countries.

An interesting example of how one can turn conventional thinking in the electricity supply industry on its head is provided by electric utilities in the United States. By giving away hundreds of thousands of energy-saving light bulbs, they avoided having to build additional power plants. This turned out to be a commercial success, as well as doing the environment a good turn; the construction, operation and demolition of conventional power plants involves high MIPS all the way, even if the power plant in question is a nuclear one. Amory Lovins calls this the sale of "negawatts"[10]. We call it incentive reversal and will return to it shortly.

The example of subsidies

Subsidies are--as we have seen--fundamentally good at falsifying market prices and altering economic structures. In brief, they successfully weaken the efficiency of the "invisible hand." We will deal with a few examples of subsidies as they pertain to ecological structural change.

The subsidies that are afforded each year in Germany amount to about forty billion Marks. Many indirect subsidies are certainly not captured by this number, either. All presently existing subsidies are more or less un-ecological. As is generally well-known, rescinding subsidies is not an easy matter. Attempts in the areas of agriculture, steel and coal have made this clear. Those who watch television know of the demonstrations of protest. Besides market distortions, personal and societal dependencies manifest themselves as well. Subsidies artificially freeze economically unstable situations.

It would be desirable if, in the future, the news media--in addition to providing extensive coverage of regions in which subsidies are being rescinded and the attendant difficulties experienced by those people, cities, and regions affected--would also illuminate the significance these changes have for effecting ecological structural change. This transformation will necessarily bring with it the demise of certain lines of business, as well as creating new ones. We can appreciate here how carefully and with what foresight the path toward a sustainable economy must be conceptualized, and how important it is to give people a reasonable chance to acquaint themselves with the changes that lie ahead. But we cannot butter our toast on both sides. We cannot hope to prevent an ecological collapse while simultaneously continuing to root around in the earth as we are at the moment. The industries which introduce raw materials into the economy, such as the sand, gravel, potassium and coal industries, must be relegated to the "sunset" sector.

The solid waste industries are well on their way to generating massive subsidy diversions in the medium term. Employment in this sector is skyrocketing (also because of the Green Dot.) Should our demands for a dematerialization of the economy be realized, and should the waste flows be reduced accordingly, the demand for continued employment will be heard there as well, as expensive capital equipment rapidly loses its value. In this way, an ameliorative sector can become harmful to the general cause.

Structural changes have always occurred, otherwise most of us would still be farmers. What distinguishes ecological structural change is that one can predict with some accuracy which lines of business will have the capability of making significant contributions to the dematerialization of the economy. To name only a few: communications, bio technology (if, in the future, it can make do with less water), micro- and nano-technology, chemicals, a new transport industry, construction, civil engineering as well as a decentralized low-voltage DC-current supply network.

Basically we have a fairly broad-based political consensus on the need for reducing subsidies, if not abolishing or transferring them. This sentiment could be channelled in a socially considerate manner in the direction of a sustainable economy. As a first step in this direction, a sound comparative analysis of the ecological character of major subsidies within Germany and the EU should be undertaken. The MIPS approach can be of some help here, too. In addition, an objective and comprehensive picture of direct and indirect subsidies, must be worked out before any sensible attempts to reduce and transform existing subsidies can be recommended.

New U.S. estimates of the direct and indirect subsidies of private automobile traffic in the United States are relevant in this context. They add up to an astronomical 300 billion dollars per annum! The use of streets for free parking in cities, the demand for health care resulting from the use of the automobile, as well as the investments in police, government bureaucracy, information and communications were included in the study. This figure is much too preliminary for us to draw any conclusions from it, but it does indicate that reliable analyses in this area can give valuable insight into market distortions on a large scale.

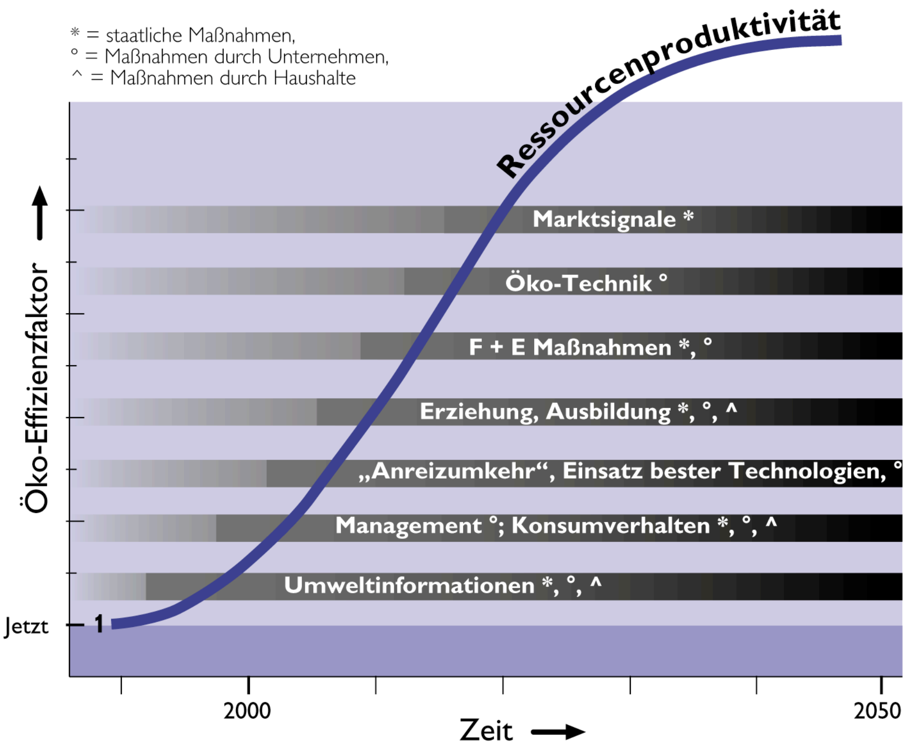
Various economic instruments

In the following, we wish to enumerate the most important kinds of economic instruments which the government can access on the path toward a sustainable economy. As in every situation, it will require an intelligent combination of measures to reach certain ecological goals. This applies both to the combination of instruments as well as to their temporal sequencing.

In the fiscal realm, governments can do the following:

- dismantle un-ecological subsidies
- levy resource consumption taxes; if necessary, in conjunction with reductions in other taxes
- require fees (solid waste, effluents)
- grant tax exemptions
- facilitate the use of write-offs
- enact user fees
- require deposits
- use its own purchasing power to influence product and service provision (fleet purchases, etc.)
- fund research and development programs
- offer direct financial assistance in the form of low-interest loans and other financing options
- permit tradeable emission and effluent licenses
- alter ownership and use rights
- influence insurance premiums
- set liability parameters.

FIGURE 34



Beginnings of ecological structural change

We now direct our attention to a difficult undertaking. We will make a first attempt to describe different ways of initiating ecological structural change as well as relating them to one another.

We have already mentioned an energy tax and have discussed several aspects related to the effects of subsidies. Measures in these areas will have great significance for ecological structural change. In both cases, however, it is the government that must act, and in Germany's case, the supra-national obligations within the EU must also be taken into consideration. This takes time. Because of this, we want to look at a few more alternatives that only require the government's intervention in a limited way, or not at all.

Figure 34 shows a type of phased plan for realizing some of the options along the way to a sustainable economy. It is a purely hypothetical construct and makes no claims of either completeness or realism. The only thing that is important is that we develop strategies for practical mastery of this extraordinarily complex task.

Incentive reversal

An example of reversed incentives: Architects today earn a percentage of the total cost of building the structure they design. That is how the fee scale operates. In this situation they are not left with much of an incentive to save on either materials or energy in the construction or operation of the building--the reverse is actually more likely.

We must not forget that a substantial portion of the material input in buildings is required by federal, state and local building codes as well as by other health and safety norms. This is not meant as a diatribe against safety, but an invitation to all involved to rethink such norms and codes in light of the idea of resource productivity and international experience. As has already been mentioned, if every German were to unnecessarily purchase ten grams of steel per year, 25,000 tons of environment would have been displaced for nought.

Back to the architects. One possible incentive reversal would be to agree upon remunerations based on the amount of material and energy saved. The basis for such an arrangement could be a comparison between a conventional solution and a highly conserving solution with comparable durability or service life. This would be a MIPS comparison, with the "S" in MIPS (the service) being equivalent in both cases. An appropriately well-negotiated contract would yield many winners: clients, architects and especially the environment. There would be losers, too: the cement industry.

The example of hundreds of thousands of energy-saving light bulbs that were given away can also be an example of such a reverse incentive. The idea of Least Cost Planning, which aims to limit the amount of energy sold in a region by considering a plethora of different methods of conserving energy, belongs in this category as well. Peter Hennicke and his associates from the Wuppertal Institute are working intensively in this area.

This appears to us to be an area well worth more intensive work and thought. Options and practical experience in the areas of land use, material savings (including water), as well as a reduction in energy use should be collected and adapted. It is quite conceivable that a thoughtful compilation of approaches and case studies that also considers the potential for diffusion, could make a significant contribution to ecological structural change. All of this could in fact occur without significant loss of time, in many cases without substantial investment, and without any dependence on the actions of the state.

Management

Repeatedly, experience has shown that significant improvement potential still exists in the area of resource productivity, both in the private and public sectors, if people would improve their "housekeeping" and keep their eyes open. In discussions with engineering firms who perform audits for companies, the tenor is that, almost always, twenty percent or more energy and material can be saved without incurring costs for expensive technical equipment; or, if they do cost money, the payback period is usually between one and two years.

Often such savings are achieved through continued (and often tiring) watchfulness and reminding. At Dow Chemical, a system of rewards for energy-saving measures led to substantial savings. Such savings are not necessarily once and for all. They can require considerable time, and the total savings are always necessarily limited, one way or another. It would therefore be very helpful if it could be made easier to access affordable electronic monitoring and optimization equipment for residential and commercial structures.

Possible ecological savings through improved management could include getting rid of dead-end streets in cities and doing away with some of the traffic signals, or at least turning them off for most of the day. Having to stop and wait in a car is equivalent in fuel consumption to driving for several hundred meters. These strategies should be taken seriously, especially where City-cars are the only or primary users of inner-city roacs and streets.

Research and development

Alongside politics, science and technology are especially called upon to look for possibilities for reducing material inputs on a grand scale. Science and engineering research and technology programs, but also social science research institutes are included here.

As the situation stands, we need not hope for the private sector to come up with alternatives with which to improve resource productivity. Research and innovation are based on expectations over the very long-term, and from the perspective of industry it is far from clear that the transition to a sustainable economy is really gaining momentum. For this reason the state must come up with definitive commitments. The European Union can be considered a "state" in this context as well.

The most important economic competitors of Europe, Japan and the United States have made it abundantly clear that they intend to strengthen the degree to which their governments support and fund research in technology. Japan has developed plans for ecological structural change called "New Earth 21" along with a large scientific institute charged with developing environmental technologies. President Clinton announced a new program for developing technologies that combine increased environmental protection with high-income job opportunities.

In neither case is an increase in resource productivity or a comprehensive dematerialization of the economy for the purpose of stabilizing the biosphere explicitly mentioned. Either way, we see here a momentous chance for Europe to access future export markets. A prerequisite for this would obviously be to establish and carry out sufficiently funded research and development programs. The participation of the private sector within the usual framework of financial support can be assumed. Yet again, we wish to emphasize that parallel to the pursuit of technical solutions, questions of how new models of wealth and prosperity might look need to be answered as well.

The need for policy analysis is a real one, and is especially important in overcoming diagnostic hurdles in the political sphere. Such efforts furnish the crucial link between a more theoretical and abstract kind of research and the development of practical political strategies for dealing with societally important issues.

In the very general areas of technology and management, the potential contributions to be made by sub-fields such as nano-technology, micro-electronics, micro-sensing devices, bio technology, and automation and materials research (especially in chemistry) for materially *extensive* processes, goods and services, are to be examined. New approaches to product design should be examined with an eye toward sustainable solutions. Approaches which aim to use and reuse materials through cascading should be systematically supported, especially in those cases where carbon constitutes a high percentage of the material. If they are already in the technosphere, then we might as well use the products, their parts, and eventually the materials of which they in turn are composed, in as many incarnations as possible--from highest to lowest quality, concluding with a thermal usage at the very end. The Life Cycle Analysis methodology should be revamped and internationally harmonized. Norms and safety standards should be dissected with an eye to their potential for wasting energy and materials. Developing energy systems with low total consumption of material and energy should be made a priority. Models of gradually decentralizing production, distribution, and energy provisioning systems should also be developed. A database should be compiled of the most important basic materials of industry and mass-produced goods, that includes information about the material, energy, and surface-use intensity over the entire life cycle. International harmonization, constant updating and access possibilities for as many interested parties as possible should be considered in compiling such a database. A "green GATT" would, for instance, require this information. Management strategies need to be developed for initiating and maintaining dematerialized product lines and service offerings. New transport and infrastructure systems that require a minimal amount of energy, material and surface area for their establishment, maintenance, operation and demolition should be examined with the help of case studies.

Overall, the development of technologies is and must continue to shift from an emphasis on mass and energy to intelligent solutions--from manufacturing of scale to manufacturing of scope. Intelligent solutions imply more information intensity, which requires a greater emphasis on the politics of research and development.

In the area of *environment*, we consider the following research, development, and policy themes to be a priority:

- development and examination of practical, economically relevant and internationally harmonizable indicators for measuring the environmental stress intensity of goods, services, regions and economies;
- development of methods for cost-effective and reproducable Life Cycle Analyses;
- development of ecological optimization principles for recycling, reuse and the inclusion of renewable materials;
- calculation of the material, energy- and surface-use intensities (the "ecological rucksacks") of the thirty to forty most important input materials for industrial processes;
- development of practical approaches for estimating the ecological carrying capacity of the earth;
- testing of our hypothesis that over the long term, OECD countries will have to reduce the material intensity of their economies by a factor of ten.

In the area of the *social sciences* we consider the following to be priorities:

- development of models for socially and politically acceptable approaches to significantly reducing the material and energy consumption of our economies;
- development of alternatives to the current inflation of demand; delimitation of the different aspects of sufficiency; development of options for dematerialized consumption;
- examination of the relationship between material ownership and the perception of status (with reference to ostentatiousness);
- development of measures for our perception of wealth;
- development of models for an improved cooperation between industrialized and non-industrialized nations in the implementation of measures toward sustainable development.

In the area of *economics* the following seem to be of primary concern:

- development of economically effective approaches toward a marked increase in resource productivity;
- development of models for financing ecological structural change;
- examination of the interdependencies between labor markets and structural change ("rationalize resources instead of labor") while considering an economically feasible time frame for structural change and the transition from producing economy to service economy;
- examination of the international ramifications of national and international efforts to increase the price of resources;
- inquiry into the order of magnitude of current direct and indirect subsidies in the countries of the EU, and the development of ecologically desirable changes;
- development of national balance sheets that combine the physical basis of the economy with appropriate indicators for economic success;
- development of political strategies for an ecologically defensible world trade (modification of GATT);
- examination of the effects of different incentive systems toward sustainable development (i.e. Least Cost Planning as applied to water and other materials, not just to energy);
- analysis of the conditions under which individual countries could be financially supported in light of their ecological predicament;
- examination of the possible effects of a rising resource productivity on the demand for goods and services;

- analysis of the economic effects on those countries which must take on the leading role in the move toward sustainable development.

Chapter 8

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Nature versus culture--the agricultural exception

If one wants to represent the effects of agriculture on the biosphere in the terms of Material Itensity Per unit of Service, one has to take certain peculiarities into account. Christiane Richard-Elsner of the Wuppertal Institute did just that in her comparative study of cotton plantations in Arizona and Uganda with respect to material inputs*.

Agriculture replaces existing biological circumstances with a new set of conditions. When the crop in question takes up water and nutrients from the soil, when it affects the carbon cycle, as well as influencing many other parameters, it is not simply a matter of counting up the water, nutrients, CO_2 and others things to get the material intensity. Before the agricultural conditions were in place, another form of ground cover existed, that also did all--or most--of the above. The latter scenario must provide the baseline.

A materials balance of agricultural activity must therefore resemble the procedure for a firm or factory. While in a factory situation raw materials are brought into the factory and subsequently sold again as intermediate or final products, capital exists there, too, which remains in place and changes only very gradually. Machines, buildings and other infrastructures are worn out, and this trend must be accounted for. Nature fares similarly, as it is "worn out" through agricultural practices: soil quality usually changes, and the hydrologic cycles are almost always altered in some way. The difficulty here is to obtain the data relating to the conditions prior to agricultural intervention--the material flow relationships in existence prior to the present use. If, as in Christiane Richard-Elsner's case, an adjacent piece of land with which to compare one's findings is available, the data can be considered all the more reliable.

Cotton is one of the most important export commodities in the world. Twenty-one million tons are produced each year. The results of this study show that humans displace between 6,000 and 10,000 kilograms of natural "environment" to produce one kilogram of cotton fibers, severely influencing natural cycles.

The differences between the various sites where cotton is grown are considerable. In Arizona, lots of irrigation and fertilizers are used, and machinery is employed for harvesting the fibers. In Uganda entire families manually work the fields, and because of the abundant rain, irrigation can be omitted almost entirely. Pesticides are used in both regions, however.

Although all of this points to an environmental advantage in favor of Uganda, the study shows the exact opposite. More than 10,000 kg of "environment" are displaced in Uganda for 1 kg of cotton, and in Arizona "only" slightly more than 6,000 kg are displaced. The material productivity could thus be improved in both regions.

In cotton agriculture the water productivity is especially low. Almost 100 percent of the material flows are water--both in Arizona and Uganda. Roughly 10,000 kg of water are displaced in the African country to produce 1 kg of cotton; in Arizona "only" slightly more than 6,000 kg of water are used. All other flows almost vanish by comparison: in the U.S. they add up to five kilograms; in Uganda it is fifty-four kilograms.

The low water productivity is ecologically fatal in both regions. In Arizona, cotton is grown in a virtual desert that must be irrigated. In Uganda the natural precipitation is utilized, but the cotton plants take up considerably more water than the native plants, and between them the water takes away large quantities of soil. Forty-four kilograms of soil per kilogram of cotton are lost! Naturally one cannot count the precipitation as an effect of agriculture--it would rain even in the absence of cotton plantations. But due to the greater surface area demands of cotton agriculture in Uganda per kilogram of cotton fiber the rainfall adds up to such a staggering number.

The CO_2 balance is an example of the "before-after comparison." In Arizona's desert, the cotton plants take up more CO_2 than the natural vegetation--in Uganda it is exactly the reverse. The tropical vegetation fixes more carbon than the cotton that has replaced it.

The purely anthropogenic portion of the material inputs is comparatively simple to calculate. The amount of fuel per season was determined, and the weight of the machinery was divided over the number of harvests for which it can be used. In Arizona this amounts to one kg per kg cotton, in Uganda roughly one hundred grams per kg cotton.

This calculation does not include the figures for the steel, rubber and fossil fuels that were necessary to produce and operate the machines, and which in turn required large amounts of environment for *their* production. These "ecological rucksacks" of industrial raw materials are only partially known to date.

Chapter 9 The International Side of Ecological Structural Change

"Can we rely on the fact that enough people will bring about a solution quickly enough to save the modern world? This question is frequently asked, but no matter what the answer is, it will be misleading. The answer "Yes" would lead to smugness, the answer "No" to despair. It would be desirable to leave these speculations behind and get to work."

E.F. Schumacher

Ecological structural change will happen internationally or it won't happen at all

Should the Western approach to satisfying service demands, presently enjoyed by twenty percent of humanity, be expanded to one hundred percent? This sometimes seems to be the present dream of all of humanity--were it to come true, the trend toward ever greater changes in the biosphere initiated by the industrialized world would increase in speed by a factor of five. The consequences would not necessarily be reinforced linearly; they would probably reinforce each other much faster, reducing even further the time remaining in which to realize any form of sustainable development.

In 1992, thousands of decision makers from all over the world met at a UN conference in Rio de Janeiro, the "Earth Summit." The industrial nations referred to it as a conference on

"Environment and Development." Representatives from Southern countries preferred to speak of--or at least to think--in terms of "Development and Environment." The word game represents diametrically opposed priorities and a conceptual separation of the world into two spheres, which--although it has no correspondence to the cultural and economic diversity of the peoples of this earth--might nevertheless prove very significant in the future.

The term "developing country," or formerly "undeveloped country," is a term coined by President Harry Truman in his inauguration speech. He was referring to some of the most pressing economic needs of several countries immediately after the Second World War, but the concept inadvertently precipitated a strange and simplistic division of the world into two camps. Some of the "developing countries" are now and have always been richer than some OECD or NATO member states.

Many of the "developing countries" are unwilling to make any sort of concessions in favor of the environment, as long as they fear that the countries of the North are merely paying lip-service to environmental change. They fear that any contractual commitment on their part would only further cement the present economic imbalance between North and South. They claim their share of the world's resources, the most radical of their spokesmen even admitting that they will do so at the expense of the environment.

In October of 1992, the Malaysian Minister of Economic Affairs threatened the people of the world with burning down the Malaysian tropical rainforests, if the industrialized nations succeeded in carrying out an import-ban on tropical hardwoods. In that case--the Minister quipped--they would simply be forced to farm these areas. Independent of whether he was merely bluffing or whether he was aware that the action would be suicidal for his own country, this example makes one thing abundantly clear. We are entering an era of unmerciful conflicts over the resources of this earth. The population growth curve is still pointing steeply upward in most countries of the Third World. If we are determined to grant them the freedom to develop themselves out of poverty it would mean an increase in their demand for material and energy until we are able and willing to provide them with dematerialized alternatives.

Provide? Does that mean give? Well, maybe not. But the planning and development of processes, facilities and goods with radically improved resource productivity is first and foremost *our* responsibility in the Western world, if for no other reason, then because other countries do not have the capacity for such developments. We should tackle these problems jointly with experts from the less fortunate countries, developing larger facilities such as energy and transport infrastructures together--and with their needs in mind--as well as our own. We will not only learn from such efforts, but will also work out technologies and export opportunities for the world markets of tomorrow. As for the money: we presently spend billions every year on "economic aid." In reality, these are often *de facto* export-credits for our un-ecological fossil-technologies that contribute their share to the rapidly worsening ecological situation. We could probably improve on these arrangements.

By persuasiveness, doing without, the development of convincing technologies, and altered consumer behavior in the industrialized countries themselves, it will be possible to persuade the "South" to strive for the ecologically preferable. For almost two hundred years the OECD, and especially the G-7 countries, have managed to displace ever greater energy and material flows, strengthening their economies to the point of their present power. Their success has become the world-wide model for development. For the people of the "Third World," therefore, an automobile has become a major goal along with a full stomach and decent health care.

There is no national biosphere.

The conference in Rio showed how difficult even small steps can be at times when the industrialized countries are not experiencing rapid enough economic growth. If an international redistribution of resources is to take place peacefully, then far more drastic steps will be necessary than were agreed upon in Rio. Such steps must be voted on and monitored internationally; they require international economic and technology policies worthy of the name; they need international eco-policies for their realization. Without these international ties, a transformation of the economy will encounter great difficulties in trying to deal with the global flow of goods and services, if such a transformation will be possible at all. Presently existing international organizations are not in a position to successfully support these fundamental changes. New--and often regional--institutions will be necessary to coordinate the economic and ecological questions and answers--circumventing the otherwise frequent popularity contests between economy and ecology. Even at the OECD in Paris, the symbiosis between the two merely takes the form of weary assertions. One need only take a look at the most recent OECD report on Germany's ecological situation[1]. It would help the productivity of such organizations if, in the future, international secretariats were instituted for fixed terms. Every ten years or so, they would then have to disband, unless an overwhelming majority of the member states demanded an extension.

Each year developing countries spend more for military purposes than all Western economic aid put together. The five continuous members of the UN security council, the United States, China, France, Russia and Great Britain, belong to the greatest weapons exporters of the world. Germany, too, belongs to the greats in this lineup. One needn't be an expert to see how the use of such technology affects humans and the environment. Television shows it daily. A believable shift toward international ecological politics will also have to take these facts into consideration. But if the remaining contradictions between the traditional economic and military goals on the one hand, and the conditions necessary for maintaining global ecological stability on the other are not dealt with in a convincing fashion, the loss of political credibility will continue unabated. These relationships will have to be dealt with in a serious manner.

GATT--the wrong signal

World trade has made a significant contribution to the dissemination of technology, even with respect to environmental technology. The United States corporation, General Electric, for instance, is producing energy-saving light bulbs in Hungary, and is meeting a pressing need of the Eastern bloc. They are delivering energy efficiency to a location where energy has been wasted most unscrupulously. Free world trade has, in fact, made it possible for many countries to acquire such technology. According to a Worldwatch Institute study, in 1990 the U.S. and Europe were already exporting "environmental technology" to the tune of twenty billion dollars a year[2]. This must be said in advance, before we now concern ourselves with present world trade, with GATT, and with the role of ecological principles as they relate to these issues.

According to the source just quoted, the Worldwatch Institute study indicates that 3.5 trillion dollars worth of raw materials and goods were exported in 1991, world-wide. Each product has managed to accumulate an "ecological rucksack" by the time it makes it to the border of the importing country. In other words, it has already taxed the global environment to a greater or lesser extent from the "cradle to the border," and will obviously continue to do so during its service life and throughout the various steps necessary to eventually dispose of it. This is true regardless of whether it is a raw material, an intermediate, or a final good. It must be considered an international task to determine and subsequently minimize the environmental burden of each phase of a product's life cycle--and the results of these inquiries must appear in international agreements, including GATT A high standard of environmental quality for goods and services must be organized and harmonized internationally. As long as free world trade with products that significantly stress the environment is encouraged and supported, it will remain all but impossible to achieve sustainable development, as ecologically less "expensive" goods will stand little chance of finding a market.

Many goods and services are primarily or exclusively traded on the international market. International trade therefore contributes directly to international environmental pollution. If these dangers are not met with an internationally harmonized platform, this may lead on the one hand to unfair trade advantages in countries with "cheap environments"--to environmental dumping--and on the other hand, to non-tariff trade barriers.

The improvements toward stabilizing the biosphere would be small indeed, if the call for international harmonization were misunderstood as an invitation to agree on the lowest common level of environmental protection. We are absolutely convinced that a sustainable economic development will never come about unless the environmental burden of everything that is presently traded on the market is significantly reduced. After all, the principle of free trade is not extended to the categories of weapons, medicines and drugs. Products with high environmental stress intensities belong to this category of traded goods in the same way as the above. It is fairly certain that "environmental dumping" will be considered as unacceptable in the future as other forms of dumping are today.

For ecological reasons, high-MIPS products, those with low resource productivities, belong in the same restricted class as ammunition and drugs, which are there for health reasons. They should not be traded freely.

The dictum that economies work better, more rationally and more justly the more international they are in character, is a common one. But is it true? Many things seem to indicate that a thoughtless internationalization of the economy is fundamentally un-ecological and would be counterproductive in the event that the goal of dematerialization were taken seriously. One reason for this is the high ecological effort required for providing cheap transportation, which has become a matter of course over the last few decades. Who would have known, for instance, that some of the flowers which you can buy on any given street-corner in Germany are flown in from as far away as Brazil. The transport prices are so absurdly low, that even goods of marginal economic significance are transported halfway around the globe before they achieve the status of a final product. This cannot be the last word if one includes surface area, energy and material intensity in the calculations. For ecological reasons, a certain amount of regionalization will be necessary. Products won't be export goods so much as will capital, knowledge and information.

In international trade, the resource intensity of products and machinery, from cradle to grave, from extraction of the resources to the eventual disposal of the worn-out product, is never examined. Frequently, basic materials are brought together from all over the world, are subsequently assembled somewhere via transport-chains and incremental production steps, before being shipped all over the world again as final goods. As likely as not, they will even be exported as garbage one day, too. The last step is usally called materials export, because it is not proper to export garbage; in some cases it is even highly illegal.

We have set up global networks, again because the share of the final price constituted by the resource or material intensity is so insignificant, to the point where the assembly line for a Cadillac Allanté has to stretch from Southern Italy to Detroit--and is considered a matter of course. Henry Ford got along just fine with an assembly line which was about 150 meters long. The production of the European Airbus manifests similar absurdities. It appears to have no noticeable effect on its price that the plane has accumulated a good deal of its own frequent-flier miles before it ever learns how to fly itself.

Trade has experienced an extremely intensive internationalization since the Second World War, which has led to the situation today in which it is immaterial whether a car is built in South Africa, Japan or at the North Pole. It is competitive on the world market, independent of transport effort. This is ecologically nuts.

If, in the future, the material intensity were to be assessed as a whole, including the packaging and transport intensity of the product, we will discover that packaging and transport intensity often make up a considerable portion of the total material intensity. In that case, it will be ecologically preferable to concentrate all of the less material intensive aspects, such as design, development, research, marketing, and financing, in one, central location, while organizing the production itself (as well as all requisite re-manufacturing and recycling) closer to the consumers in a more decentralized manner. The present market signals, on the other hand, encourage world trade with ecologically questionable goods. GATT encourages free trafficking with goods, the production and use of which threaten the biosphere. This holds for flowers from South America as well as for cars, refrigerators and plastic knives and forks.

GATT rules permit a single member country to restrict the import of goods by tariffs or outright bans if these goods are considered to be dangerous to either health or the environment in that country, if the same restrictions are binding for domestic producers. But GATT does not allow an import duty to be placed on a product that has been produced with excessively high material and energy effort. According to GATT, it is immaterial whether fruit is grown under ecologically optimized conditions or on large plantations with considerable use of water, pesticides, fungicides and fertilizers, as well as with high levels of soil erosion. Ecological rucksacks do not exist for GATT.

Eco-technologies for economic aid

Let us imagine the future technological arrangements in developing countries. Roughly 2.5 billion people, or about forty percent of the world population, live in these countries, and their economies are growing at between three and ten percent per year. The overarching goal for some of them is to build and own precisely those dinosaur-technologies which should be relegated to the past as quickly as possible because of their energy, material and surface-use intensity--our Western technologies. The same, with the exception of the economic growth rates, holds true for the former East Bloc countries. They are all doing their best to erect exactly those infrastructures, production systems and consumption institutions (with all attendant increases in waste and pollution) that are undermining any attempts at restabilizing the biosphere. Our direct financial and technical aid is doing its share as well. They don't even have a choice. Their social responsibility, not to mention the perceived limits on time and capacity, prevent them from imagining an alternative course from delaying the transition for the purpose of incorporating as yet non-existent futuristic technologies. Only the OECD countries have the means of bringing about a global technological transformation. With respect to the developing countries, this is particularly true regarding long-term investment goods in traffic and transportation sectors, for buildings, for decentralized energy supplies, as well as for water-saving technologies for all lines of business and the various economic sectors.

The opportunity seems to present itself for planning these technologies in the context of aid programs, working closely with experts from the recipient countries, and carrying out demonstration projects. In doing this, not only would technical facilities be exported, but knowledge as well. A degree of technological leapfrogging could occur that might contribute to a greater level of acceptance in those countries, while maintaining future trade advantages for the aid-giving countries.

Economic aid programs can only hope to be successful over the long term if all partners can benefit. The time has come to see the benefits to ourselves in postponing--or better yet in preventing--the next ecological catastrophe. The improved market opportunities for our eco-technologies will exist in future world markets too. The un-ecological economic upturn in the Third World is decisively shortening the remaining time in which to avoid the painful reactions of the biosphere. The development there quite obviously reduces the overall success of any attempts in the West several times over.

If China succeeds in maintaining its present rate of economic growth over the next five to six years, then roughly ten percent of Chinese families will be able to afford a car. That would be about forty million cars. That many are presently driving around in all of Germany, or in all of Africa. Cars need roads, gas stations and parking lots. We can be sure that the large car manufacturers have already realized this, too. Meanwhile we are getting nowhere in Germany with the effort to pass a speed limit for five-passenger cars that rarely carry more than one person. The United States Congress recently voted down a gasoline tax of roughly five cents per gallon.

The ecological prospects are still pretty dim. We lack understanding.

Chapter 9

[1] *OECD, Environmental Performance Reviews: Germany, 1993.*
[2] *Süddeutsche Zeitung, 29 March 1993.*

APPENDICES

APPENDIX 1

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.

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 cradle. 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] Umweltbundesamt, Ökobilanzen für Produkte--Bedeutung, Sachstand, Perspektiven. eds., (brochure) Berlin, 1992.
[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] Projektgemeinschaft "Lebenswegbilanzen", Methode für Lebenswegbilanzen von Verpackungssystemen. München, Heidelberg, Wiesbaden, September 1992.
[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] Umweltbundesamt, Ökobilanzen.

APPENDIX 2

THE INTERNATIONAL FACTOR 10 CLUB's 2010 DECLARATION[2]

A COALITION OF WILLING STATES NEEDED TO CATALYZE A TEN-FOLD LEAP IN ENERGY AND RESOURCE EFFICIENCY

1. Good living, prosperous economies, high levels of employment and peace require a healthy environment, including an agreeable climate and rich biodiversity. Today, all are threatened: urgent action to change course and reduce the overuse of fossil fuels, water and material resources is of paramount importance. To this end, the Factor 10 Club in 1994 called on governments to achieve within a generation a ten-fold increase in the efficiency with which their economies use energy, natural resources and other materials. The technologies required for a four-fold increase exist and, with appropriate policy reforms, a tenfold increase could be achieved.

2. The Club's ten-fold target entered the international political agenda in June 1997 on the fifth anniversary of the Earth Summit. Soon after, the EU proposed that industrialized countries pursue a progressive path toward this target with a 25% increase by 2010, a 75% increase by 2030 (Factor 4) and a 90% increase by 2050 (Factor 10). The target also received a favorable response from sections of business and industry including the World Business Council for Sustainable Development.

3. Despite this, progress has been dangerously slow. Although Gross World Product has more than doubled over the past two decades reaching almost US$ 60 trillion in 2010, the UN's 2005 Millennium Ecosystem Assessment found that this historically unparalleled growth was based mainly on unsustainable forms of energy, agricultural, industrial, urban and other development. The Assessment found that 15 of the 24 major ecosystem services that support the human economy—services such as providing freshwater and food, purifying air, and regulating the climate—have already been or are being pushed beyond their sustainable limits. This overshoot has reached a point where even the US Pentagon felt compelled in its 2010 Quadrennial Defense Review to warn that continuing climate change and environmental destruction will have significant geopolitical impacts around the world, contributing to poverty, instability, mass migration, conflict and the further weakening of fragile governments.

4. Bringing fossil energy and resource use down to a sustainable level is the common thread running through any potentially successful response to the ongoing security, economic and environmental crises. Moreover, since all materials taken into an economy end up sooner or later as emissions and wastes, it is essential to reduce not only emissions but also the overall flows of resources drawn from nature.

5. We know of course that very large flows of resources occur naturally, either from volcanoes or land erosion or other biosphere processes. Together these flows amount to some 50 billion tons per year, although more research is required to establish a precise number. However, human induced flows of resources into the economy now exceed this by an estimated factor of two. In line with the precautionary principle, we should aim at reducing these human induced flows by that factor of two. Assuming seven billion people on planet Earth, a figure that will soon be surpassed, that would result in an allowance of about 6 to 8 tons per capita per year. In devising reduction strategies, fossil energy flows which drive climate change should continue to receive priority. Reducing water flows is also a priority concern in many parts of

[2] Meeting at the Factor 10 Institute in Carnoules, France September 9-12, 2010

the world. Beyond that, further research is required urgently to determine the other resource flows which require priority attention.

6. Some may feel that a ten-fold reduction in the use of fossil energy, water and resource use would entail a correspondingly dramatic cut in humanities' quality of life. Fortunately, that is not the case at all. Since the technologies for achieving such a reduction exist or are on the way, introducing them over a generation should in fact result in a steady improvement in the competitiveness of business, along with expanded possibilities for employment and increased potential for wealth creation and the quality of life of people and their communities.

7. A transition to accelerated gains in energy and resource productivity is not a simple matter however, and will not happen by itself. It will require action by governments, industry and society on many fronts.

8. The most important change needed is to bring market signals in line with both economic and environmental realities. In a market economy, the most important and pervasive signal is price and the idea is eventually to make prices "reflect the ecological truth", so that economic advantage and ecological sustainability reinforce each other. Governments regularly intervene in the market through taxes, subsidies, fiscal, trade and other policies but today these interventions serve largely to increase rather than reduce the consumption of fossil energy, water and other resources. This must be reversed and in the real world governments can do so using a gradualistic approach involving steady year-by-year incremental changes.

9. For example, as experience in some countries demonstrates, governments can gradually overhaul the way they raise revenues. They can gradually reduce taxes on income, savings and job creating investments while gradually increasing them on energy, resources and products with a high environmental impact. They can do this without adding to the overall tax burden. Moreover, if prices increase no faster than the average efficiency of energy and material use, the average annual price paid for energy and resources should remain stable. Obviously, for reasons of equity, matching reforms should be introduced simultaneously to compensate those living at minimum levels of consumption.

10. Governments can also gradually reduce economically perverse, ecologically destructive and trade distorting subsidies which are now estimated to exceed $1 trillion a year. According to the OECD, the production and consumption of fossil energy alone is encouraged by tax-supported subsidies exceeding US $500 billion annually. They could also modify the present restrictive interpretation of trading regimes to allow consideration of the ecologically destructive effects of production processes as well as products.

11. Through these and other similar reforms, governments would gradually harness market forces to support rather than oppose the urgently needed transition to a low carbon, dematerialized and resource efficient economy. Announcing and smoothly enacting incremental reductions in perverse subsidies and changes in prices for energy and resources would lead to a decisive acceleration of resource productivity.

12. Discussing these reforms reveals the inadequacy of the traditional approach to so-called "environmental" issues. Reacting to the symptoms of environmental degradation after the damage has been done and the economic and social costs of that damage have been incurred, has failed completely as a strategy. According to Lord Stern, the costs imposed far exceed the costs of changing course. It makes far more sense to deal with the root causes in the first place. These root causes are to be found largely in the tax incentives and subsidies, and in the fiscal, trade, energy, agricultural and other policies of government, which not only drive environmental destruction, but also drive it at a pace and scale well beyond the capacity of even the most vigorous react-and-cure strategies to keep up, let alone catch up. However, this will require governments to take a more "systems" approach to developing and applying

policies. It will require them to view issues like climate change as economic, trade, energy, social and national security issues, not simply as environmental issues. It would require them to recognize that these issues are the responsibility of the head of government and his/her key economic and security ministers, and not simply that of the minister responsible for environmental protection. And it will require them to recognize the priority need for precautionary strategies, not simply after-the-fact react-and-cure strategies. We therefore urge governments to take a more "systems" approach to the development and application of policies on these issues.

13. In support of these changes, there is an urgent need for robust directional indicators. It is now generally recognized that if governments don't measure the right thing, they won't enact policies to do the right thing. Still, obsessed with indicators of annual increases in G.D.P., they consistently fail to assess changes in other factors which can have a decisive impact on economic prosperity and human well-being, such as the economic and social costs of climate change, resource use and environmental degradation. They are mislead in other ways as well. Current national accounting systems have no capital account and no proper balance sheet. If corporations didn't recognize consumption of man-made capital, they'd soon go bankrupt. Because of their inadequate accounting systems, however, governments do not recognize or measure the consumption of their natural resource capital. Consequently, it is possible to show high levels of national income by running down environmental and resource stocks, even when this resource degradation is sure to bring declining incomes in the future. Current systems of national accounts also fail to place any value on the economic services provided by natural resources, 15 out of the 24 of which have already been or are being pushed beyond their sustainable limits according to the UN's 2005 Millennium Ecosystem Assessment mentioned above.

14. Over the years, a number of alternative accounting systems to measure progress have been proposed, most recently by two Nobel prize-winning economists, Joseph E. Stiglitz and Amartya Sen. We call upon governments to adopt new means of measuring wealth and new indicators for human progress.

15. We also call upon governments to introduce some universally applicable measures for assessing the ecological stress potential of material flows. One of these, the "Material Footprint MIPS", was developed in the Wuppertal Institute in the early 90s. MIPS is the material intensity, the life-cycle material input per unit output, and is highly suited as a sustainability indicator for decoupling the use of natural resources from generating wealth. One of its strengths is that it can be used as a metric for both economic and environmental costs. We suggest that Material Footprint MIPS be universally accepted.

16. Finally, we would ask all heads of government, corporate leaders and the EU to begin to take seriously the goals they so solemnly adopted at the 1992 Earth Summit and reaffirmed at many subsequent international and regional conferences. They need urgently to develop national strategies to reach these goals and begin belatedly to implement them. It is evident from the recent climate conferences that not all countries are able or willing to move at the same pace. We therefore urge the creation of a Coalition of States willing and able to take the lead and act as a spur and catalyst for the others. On Planet Earth, time is the most limited resource we now have.

Jacqueline Aloisi de Larderel, Stephan Baldin, Willy Bierter, Stefan Bringzu, Yi Heng Cheng, Wouter van Dieren, J. Hugh Faulkner, Friedich Hinterberger, Huang Hai Feng, Miki Goto, Gert Irgang, Leo Jansen, Toennis Kaeo, Ashok Khosla, Kora Kristoff, Satu Lähteenoja, Christa Liedtke, Harry Lehmann, Franz Lehner, Michael Lettenmeier, Jim MacNeill, Marie Madeleine Marchal, Michal Miedzinski, Holger Rohn, Wolfgang Sachs, Ken Sasaki, Bio Friedrich Schmidt-Bleek, Friedrich Schneider, Walter R. Stahel, Leon Tzou, Ernst Ulrich von Weizsäcker, Jola Welfens, Anders Wijkman, Markku Wilenius, Heinrich Wohlmeyer, Ryoichi Yamamoto, Ding Jian Zhang, Da Jian Zhu.

APPENDIX 3

The following Glossary was produced in March 2011

GLOSSARY
SUITED FOR THE APPROACH TO ECOLOGICAL AND ECONOMIC SUSTAINABILITY

Abiotic raw materials are the resources extracted domestically – excluding agricultural and forestry products – and all imported abiotic materials (resources, semi-finished products and finished products), including extracted materials which are not used (for example mining waste, excavated material from constructing a basement or a house, other excavated materials, etc.).

Abiotic Raw Material Productivity This sustainability indicator expresses the life-cycle-wide amount of abiotic raw material (in tonnes) used to produce one unit of output, e. g. gross domestic product (in EUR, price-adjusted), a product, one unit of utility or service (See Material Productivity)

Air is included in the MIPS concept if it is changed in its chemical or physical characteristics due to chemical, biological or physical processes in the technosphere.

Auxiliary materials (operational materials) are materials which are involved in a process but merely fulfill an auxiliary (supporting) function and are not present in the end-product (for example solvents, cleaning or cooling agents). They are part of the MI in MIPS.

Biotic raw materials are all organic materials extracted directly from nature, for example mushrooms, grass, fruits, timber, fish, wild animals, and unprocessed cotton.

Capacity utilization denotes the actual use of the volume or the capacity for which a good is designed (for example, a fully-occupied car = 100%, a half-filled dishwasher = 50%).

Capital in the language of economics denotes the total assets of money, machinery, facilities, as well as land. To describe monetary assets only, the term financial capital is used.

Capital productivity is the amount of goods and services produced per unit of capital employed. If the same product can be produced in the same quantity and quality on two different machines which have different prices, then capital productivity is higher if the cheaper machine is purchased. (Note: one does not talk about "capital efficiency" as opposed to the case of natural resources!)

COPS (Cost Per Unit of Service) refers to the monetary costs for a defined unit of utility which is rendered either by a person with the help of technology, or by machines directly (for example, dispensing cash). All services generated in the technosphere require products, energy and infrastructures.

Cycles are natural and technical material flows which return to their original state at their point of origin. There are no technical cycles without energy and material losses.

Dematerialization is the radical reduction of natural material resources for satisfying human needs by technical means. Neither environmental nor economic sustainability can be attained without dematerializing the current western economy.

Eco-efficiency means the delivery of competitively priced goods and services which satisfy human needs and produce quality of life while progressively reducing ecological impacts and resource intensity, through the life cycle, to a level at least in line with the earth's estimated carrying capacity (Frank Bosshardt, Business Council for Sustainable Development, 1991) (Compare Efficiency, Productivity, and Intensity related to the use of natural resources).

Eco-innovation means the creation of novel and competitively priced goods, processes, systems, services, and procedures that can satisfy human needs and bring quality of life to all people with a life-cycle-wide minimal use of natural resources (material including energy carriers, water, and surface area) per unit output, and a minimal release of toxic substances. (Reid, Alasdair, Miedzinski, Michal (2008), EUROPE INNOVA, Final Report for the EU Sectoral Innovation Watch Panel on Eco-Innovation, www.europe-innova.org) [3].

Eco-innovation is the introduction of any new or significantly improved product (good or service), process, organisational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle." – Eco Innovation Observatory, EIO (2010)

Eco-industry is that part of industry which conducts eco-innovation in a pro-active and verifiable manner, including businesses that provide new solutions for legal standards, norms, and requirements.

Eco-intelligent services satisfy needs in a purposeful manner, using technical means with the highest possible resource productivity (materials, water, space).

Ecological price of a good encompasses the entire material input or the material added value in units of weight (kg or metric tons) from the cradle of the resources to the product when it is ready to be placed on the Market in order to provide a service. It is the ecological rucksack of the product plus the product's weight, measured in mass units.

Ecological rucksack of a product is its complete material input MI (including all materials needed to generate the energy) for manufacturing a product from "the cradle to the point of sale", minus its own weight (own mass). Unit: kilograms, metric tons.

Ecological rucksack of a technology-based service is the sum of the shares of the rucksacks of the technical means ("Service delivery machines") employed (for example, equipment, vehicles, refrigerators, buildings, and infrastructures), plus the sum of materials and energy (including rucksacks) used while the "service delivery machines" are employed for delivering a unit of service.

Eco-system services (services of nature) (Life-supporting functions of the ecosystem) - such as sewage "treatment", air purification, flood control, pest control, restoration of soils, pollination, the preservation of species, and the regulation of the climate - are essential for all lfe on earth and the human economy. Many have already been or are being pushed beyond their sustainable limits. Services of nature cannot be generated by technology on any noticeable scale. Services of nature are indivisible and cost-free available to all humans around the globe. If they could be traded on the market, they would obviously carry an infinitely high price. Services of nature are vulnerable to human economic activities. The root cause for these changes is the indiscriminate use of natural resources, material, water, and land. Already today, consequences thereof can be observed, e.g. massive soil erosion, water shortages, desertification, loss of species, and climatic changes, including increasing catastrophic events like hurricanes and floods.

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[3] *F. Schmidt-Bleek, „The Earth: Natural Resources and Human Intervention", Haus Publishers, London, 2008;*

Ecosphere is mankind's natural environment.

Efficiency is the measurable extent to which (in each case total quantity of) time, effort, resources or energy are *well* used for the intended task. Originally, the term was used to describe the quality of a technical *performance, e. g. the „ratio of the work done by a machine to the energy supplied to it*" (The American College Dictionary). Today, resource efficiency and resource productivity are frequently being considered synonimous. However, when using the term „productivity" of a process, the emphasis is on the *outcome* (the good, service or value generated), not on its *performance*. Consequently, when describing the efficiency of decoupling the connection between the use of natural resources and environmental degradation, the term *productivity* should be preferred. When computing either the „resource efficiency" or „resource productivity", the *totality* of the productivity factor resource must be considered. In other words, the life- cycle-wide consumption of nature (materials, water and space - surface area) for the service or value created must be considered. (compare productivity)

Emissions are material contaminations of the air, or noises, vibrations, light, heat, radiation, and similar energetic or material phenomena emenating from the technosphere.

Energy carriers are materials of all aggregate states that yield thermal energy (for example mineral oil, oil sands, coal, firewood, or uranium ores). Fossil energy carriers are non-sustainable materials containing carbon.

Enterprise is an organizational unit created for making profits. The size of "Small and Medium Enterprises – SME's depends upon the size of the economy within which they operate. In Austria, SME's may employ up to 400 people, in Germany ten times more.

Environment encompasses animals, plants, microorganisms, water, air, and soils as well as all the interactions between them.

Environmental capital comprises all natural resources that can be used in the technosphere to produce welfare. This term is somewhat peculiar for non-economists because the ecosphere cannot be used for economic gains without changing its life-sustaining eco-systemic services and functions. These changes are rarely predictable, and can seldom be measured, simulated or quantified, nor can they be localized in all cases.

Environmental media are soil, water, and air.

Environmental protection strategy as developed first in the early 1970ies has failed completey as an approach to sustainability. (Factor 10 Club Declaration 2010). This protection policy has not been able to stop continuous environmental deteriororation because it concentrates on *reacting* to *individual symptoms* believed or known to be ecologically disruptive (like climatic change) or detrimental to human health (like mercury in fish). In other words, this policy *reacts* predominantly *after* economic, financial and technical decisions have been made. Invariably it generates „additional" costs and leads to tedious, unsatisfactory and unproductive international debates („Copenhagen"). (See Systemic policies).

Environmental stress (or impact) potential is the capacity of a process, activity, a good or a service to cause environmental change, altering life-sustaining eco-systemic services and functions of the ecosphere. Environmental stress is approximated by indicators such as MIPS on the economic micro scale or "Total Material Consumption – TMC", the yearly "consumed" natural material by a country, including the material rucksacks.

External costs are costs incurred during the production or use of a good or a service that are not contained in the price of these goods and services. They are "externalized", often at the expense of consumers.

Externalized environmental costs (externalities): Cost-inducing effects of goods, processes, systems, services, and behaviors that occu(compare productivity)r via environmental media air, water, and soil. Typically, the costs of such external effects must be borne by the general public, even though the OECD has concluded in the early 70ies that such costs should be born by the producer (Producer Pays Principle). For instance: An external effect of fossil fuel use is climatic change, changes in green plants, and the damage to historic buildings. Environmental externalities can be quantified/monetarized only in rare cases because it is normally *not* possible to link all causes and effects completely and un-equivocally, even for a single type of molecule like CO_2.

Factor 10 is the strategic goal pioneered by Schmidt-Bleek in 1990 for maintaining life-sustaining eco-systemic functions and services, meaning that a strategic *economic goal* must be to generate human well-being with (on average) ten times less natural material resources (from cradle to cradle) by the middle of the 21st century, compared to wealth production in industrialized countries in 1990. Factor 10 includes all natural materials used for energy generation. Schmidt-Bleek has suggested in 2008 that by 2050 the life-cycle wide consumption of 6 to 8 ton/year-capita should be reached worldwide, including fossil energy carriers. For Germany this would mean a ca. tenfold reduction in material use, for Japan an eightfold, and for the USA a ca eighteenfold reduction.

Factor 4 was suggested by E. U. von Weizsaecker in 1995 for using two times less material and energy in order to generate two times more human wealth.

Factor X and Factor Y are variations on Factor 10, reflecting the fact that the need of using less natural resources for generating welfare depends on specific circumstances, e. g. the availability of water.

FIPS (in German: Flächeninput pro Einheit Service = surface area per unit of service) is a robust and directionally reliable indicator for the comparison of functionally comparable goods or services regarding their life-cycle-wide surface area requirements. A quantitative measure for the "use of natural surface area" per unit of utility or unit of service. The "ecological surface area price" for utility.

Goods are machines, products, equipment, objects, means of transport, buildings, infrastructures (including works of art and musical instruments).

Greenhouse effect: Sunlight falls on the earth's surface, where it is transformed into warmth and partly reflected towards outer space. Some constituent parts of the earth's atmosphere, especially water vapor and carbon dioxide, are involved in the process of capturing part of this warmth. If this natural greenhouse effect did not exist, the Earth's average temperature would not be fifteen degrees Centigrade, but as cold as minus eighteen or nineteen degrees Centigrade. Mankind is currently changing the relative amounts of important greenhouse gases in the atmosphere, especially carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and ozone. As a result, the man-made greenhouse effect is added to the natural greenhouse effect, changing the Earth's climate.

Human Capital refers to (according to the internet) the stock of competences, knowledge and personality attributes embodied in the ability to perform labor so as to produce economic value. It is the attributes gained by a worker through education and experience. Many early economic theories refer to it simply as workforce, one of three factors of production [4], and

[4] *Capital, Labour, Resources*

consider it to be a fungible resource homogeneous and easily interchangeable. Other conceptions of this labor dispense with these assumptions. From a natural science point of view a non-measurable quantity with questionable value, and from a humanistic point of view unacceptable. In Germany „human capital" was officially chosen as the „No-Word" of 2006.

Indicators are measurable and directionally reliable quantities that reduce and reflect the complexity of facts and situations (see resource intensity, resource productivity, MIPS).

Industrial products are goods produced, or partly produced, by a technical processes.

Infrastructure is the term used to describe technical installations or facilities which support modern human life, such as roads, schools, transportation and information networks..

Input includes everything that is inserted into a process. It determines nature and quality of the outcome. In the MIPS concept, the inputs are materials (including all materials for making the needed energy available), counted on a life-cycle-wide basis, measured in kg or tons. (see also Material Input and Resources).

Market is a spontaneous structure involving sellers and buyers, organized as competition by regulations.

Life-cycle-wide (cradle to cradle) means taking all phases of a product's life into account: from resource extraction, through production, distribution, storage, use, and recycling/disposal.

Material flows as defined in the MIPS concept are all movements of materials in the ecosphere and the technosphere which are put in motion by technical means.

Material input (MI) includes the life-cycle-wide use of material inputs required to produce a good (see "ecological rucksack"), or generate service, value or utility (see MIPS). In the MIPS concept, this also includes all fossil fuels as well as the materials which are required to make the necessary energy available. Unit: kilograms or metric tons.

Material Intensity indicators are the inverse of *productivity* indicators. Material productivity and material intensity are decoupling indicators that describe the relationship between the use of natural resources (e.g. materials) and economic growth or industrial activity. Material productivity can be expressed as the inverse of MIPS, namely S/MI. It is the unit of good or service (value or utility) that is obtained trough the life-cycle-wide sum of all material inputs for producing the good that yields the service, including those masses needed for providing the energy.(see Resource Productivity).

Material Productivity is defined as the quantity of output produced per unit of materials inputs used in the production of the output on a life-cycle-wide basis.

MI Factors or rucksack factors (MIF) are the material intensity values for individual input materials (raw, basic, and building materials) and energy quantities that are required for the life-cycle-wide generation of a service by goods and infrastructures. Unit: kilogram per kilogram or kilogram per megajoule etc.

MIPS = MI / S = material intensity = life-cycle-wide Material Input Per unit of Service (of benefit, value, or utility). MIPS is the life cycle-wide mobilization and input of natural material, including fossils, required to fulfill a specific human desire or need (S) by technical means. MIPS ist the material footprint of a service. MI is measured in kg or tons; S has no dimension and must be defined for each individual case (for example 'cleaning five kilograms of clothing' or 'transporting one person for a distance of one kilometer'). MIPS is the unit of decoupling the use of natural material from material wealth generation.

MIPS is a robust, measurable, and directionally reliable *indicator* for directly comparing functionally comparable („like") goods or services, regarding their material and energy "consumption". MIPS is a quantitative measure for the life-cycle-wide "use of natural materials and energy" or the "ecological materials and energy price" per unit of utility or per unit of benefit or service. MIPS could be considered representing the ecological costs (referring to materials and energy use) for making a service available, or the subsidy provided by the environment per unit of service. In the MIPS-Concept, goods are considered to be *"service delivery machines".*

Mobilization includes all movements of earth caused by technology in the construction, agriculture, and forestry sectors, as for instance overburdens, plowed earth, erosion, etc.

Nanogram = A unit of measurement, the prefix 'nano' means 'one billionth.'

Natural Biotic Products are substances, materials and organisms generated by nature through the interaction of energy, water, and nutrients - organized by information stored in DNA.

Natural location or setting of natural resources (material, water) is the place where they are found in nature and from where they are mobilized and removed for producing goods and infrastructures (for example a seam of coal).

Natural Resources in the MIPS-concept include all naturally available abiotic and biotic raw materials (minerals, fossil and nuclear energy carriers, plants, wild animals), materials invested to convert flow resources (wind, geothermal, tidal and solar energy), air, water, and soil.

Output encompasses everything that results from a process, a procedure or a behavior. Output need not be material in nature; enjoyment and pleasure can also be outputs.

Person-kilometer: The number of people transported multiplied by the distance in kilometers yields the number of person-kilometers (pkm). A unit of measurement for transportation performance.

Processes are procedures or techniques in which inputs are intentionally transformed into at least one output (for example, shaped sheet metal, a chemical, or the enjoyment of a painting).

Product is the usable result of a technical or natural process.

Production is the purposeful generation of goods and services by technical or natural means.

Productivity is the life-cycle-wide quantity of a productivity factor (capital, labor, resources) needed to generate a defined economic output.

Productivity of labor: A term used to denote the amount of products or services which can be produced with a given amount of work, that is, within a given period of time by a given number of people.

Prosperity is *not* to be confused with material wealth. Prosperity also includes health, freedom from fear, displacement, and social marginalization, as well as the opportunity for self-determination, freedom of opinion, and the inviolability of the dignity of the individual.

Renewable energy encompasses all forms of energy derived from *non*-exhaustible sources, like solar radiation and geothermal heat. The use of renewable energy does *not* automatically support the approach to sustainability because its transformation into useful energy forms can be very resource intensive, including the non-sustainable use of land. A typical example is the production of bio-fuel by way of planting and harvesting cash crops, even if the so-called CO_2 balance shows an advantage.

Resources (natural) are raw materials, soil, biomass, water, air and land surface. All are limited on planet earth.

Resource productivity and *resource intensity* related to approaching sustainability are key concepts used in sustainability measurement as they attempt to decouple the direct connection between resource use (raw materials, soil, biomass, water, air and land surface) [5], [6] and environmental degradation. Their strength is that they can be used as a metric for both economic and environmental costs. Although these concepts are two sides of the same coin, in practice they involve very different approaches and can be viewed as reflecting, on the one hand, the efficiency of resource production as outcome per unit of resource use (resource productivity) and, on the other hand, the efficiency of resource consumption as resource use per unit outcome (resource intensity = RIPS; material [7] intensity = MIPS = material footprint). The sustainability objective is to maximize resource productivity while minimizing resource intensity (partly from the internet).

Resource Productivity in *monetary terms* is the quantity of goods or services (outcome) obtained for the input of resources, expressed as the monetary yield per unit resource expressed in monetary units. For example, when applied to crop irrigation it is the yield of crop obtained through use of a given volume of irrigation water, the "crop per drop", which could also be expressed as monetary return from product per use of unit irrigation water (internet).

Root cause *(physical)* for *endangering eco-systemic services and functions* is the extirpate mobilization and use of natural resources (material (including fossils), water, and land use). The *economic* root cause for excessive resource use is the near zero costs for using nature.

Root causes for *unhappiness and inadequate wellbeing* of people can include: unemployment, social unrest, missing protection of human rights and dignity, lack of freedom of speech and from violence, unfair wealth distribution, as well as insufficient health care and education. Bhutan has decided to measure the happiness of its people rather than GDP.

Root causes for *economic and financial instabilities* include: lack of systemic policies, poisonous products (Stiglitz), wrong market prices of products and services (e. g. caused by subsidies), low productivity of natural resources, short term planning, inadequate book keeping, and excessive profit taking. Many of these causes are also responsible for the environmental crisis.

Service within the economy is the purpose-oriented fulfillment of a need by technical means.

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[5] *Schmidt-Bleek, F. "Wieviel Umwelt braucht der Mensch? MIPS, das Maß für ökologisches Wirtschaften", Birkhäuser, Basel, Boston, Berlin, 1994.*

[6] *Hawken, P., Lovins, A. and Lovins, L.H. 1999. Natural Capitalism: Creating the Next Industrial Revolution. Earthscan, London. Hargroves;*
K. and Smith, M.H. 2005. The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century. Earthscan, London.

[7] *raw materials, soil, biomass, water, air*

All man-made services require the use of technical infrastructures, equipment, vehicles, and buildings etc. Services can be rendered by humans using machines or by machines directly. From the end consumers' point of view, technology based service is the ability of goods to satisfy needs or provide utility.

Serviceable products are goods that were produced for use or consumption and that can provide utility by being used (for example, robots, sundials, automobiles, mousetraps, spoons, oil paintings). There are also non-serviceable goods, such as bars of gold or aluminum profiles.

Sufficiency means reducing environmental damage by refraining from excessive personal consumption ("Erhalten durch Masshalten"). Sufficiency means saving money. In the MIPS-Concept, sufficiency is the reduction of MI by volontarily reducing S. A case in point is the use ot towels in a hotel for several days rather than using fresh ones every day.

Sustainability means the capacity of the economy to create wellbeing and welfare for *all* people while ascertaining that the natural, social, economic, and institutional bases are maintained upon which this capacity depends.

Sustainability has several dimensions: *ecological, economic, social* and *institutional*. The ecological dimension forms the guardrails within which the human society must function because (1) the earth's natural resources are limited, (2) because economic activities can damage and destroy the vital eco-systemic services and functions of the ecosphere, and (3) because these natural functions *cannot* be re-placed by technology.

Ecological Sustainability means the continuous existence of vital life-sustaining eco-systemic services and functions of the ecosphere that are suitable for the biosphere as we know it. Currently one assumes that a maximum of 6-8 tons of non-renewable natural material (including fossiles) could be „consumed" per year and person in order not to put the ecological stability in question.

Economic sustainability means generating wellbeing and wellfare for *all* people comparable to that enjoyed by effluent societies at the beginning of the 21st century. This economy is service oriented and knowledge based (see service). The radical dematerialization of the western type economy is a necessary, but not sufficient condition for approaching sustainability.

Sustainability Indicators are not as yet available in internationally harmonized fashion for the social and economic dimensions of sustainability. For the ecological dimension, agreement seems to emerge that resource intensity and resource productivity are important (key) indicators (see also eco-innovation).

Systemic policies aim to improve happiness, welfare and wellbeing of people by optimizing the efficiency and precautionary nature of measures by avoiding and eliminating *root causes* of harmful developments, rather than separately repairing their symptoms, which regularly provokes the risk of delaying, increasing the costs of, and even preventing the solution of others. Systemic policies reduce the risks associated with taking actions by optimizing precautionary measures in all policy areas. The need for systemic approaches apply to all policy areas.

Technosphere is the environment created by mankind, using natural resources and energy.

Total Material Flow (TMF) or Total Material Requirement (TMR) is a robust economic indicator to measure the annual total amount of natural materials (abiotic, biotic, and movements of earth) – including rucksacks – which are processed through an economic entity by technical means (metric tons per year).

Utility (benefit, value, service) is generated by utilizing goods and energy for satisfying people's needs. Utility has a higher value than the goods and services employed to produce it. MIPS is the ecological price of utility.

Wastes are materials or products without economic value which are either disposed of or recycled.

Water as defined in the MIPS concept encompasses all water taken directly from nature. It is advisable to differentiate between surface water (including rainwater), groundwater, and deep ground (fossil) water.

WIPS = WI / S stands for Water Input Per unit of Service (of benefit, value, or utility). It is the life cycle-wide mobilization and input of water, which is required to fulfill a specific human desire or need (S) by technical means. WIPS is the water footprint of a service. WI is measured in kg or tons; S has no dimension and must be defined stringently for each individual case (for example 'cleaning five kilograms of clothing' or 'transporting one person for a distance of one kilometer'). WIPS is the unit of decoupling the use of water from material wealth generation.