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 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.

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

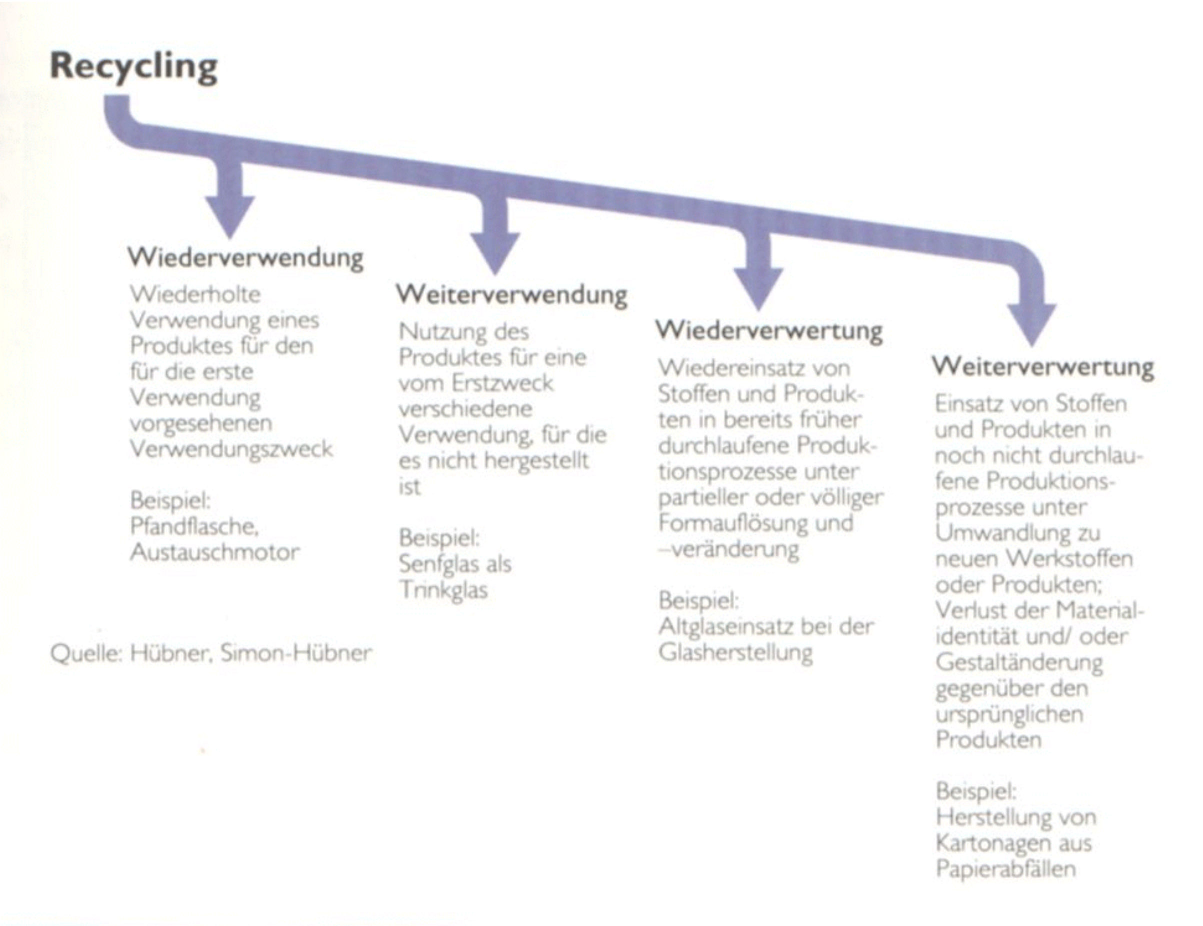

Fig 27: In der Praxis gibt es verschiedene Begriffe für das, was mit Produkten gemacht wird, wenn sie ihre erste Gebrauchsphase hinter sich haben.

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.

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

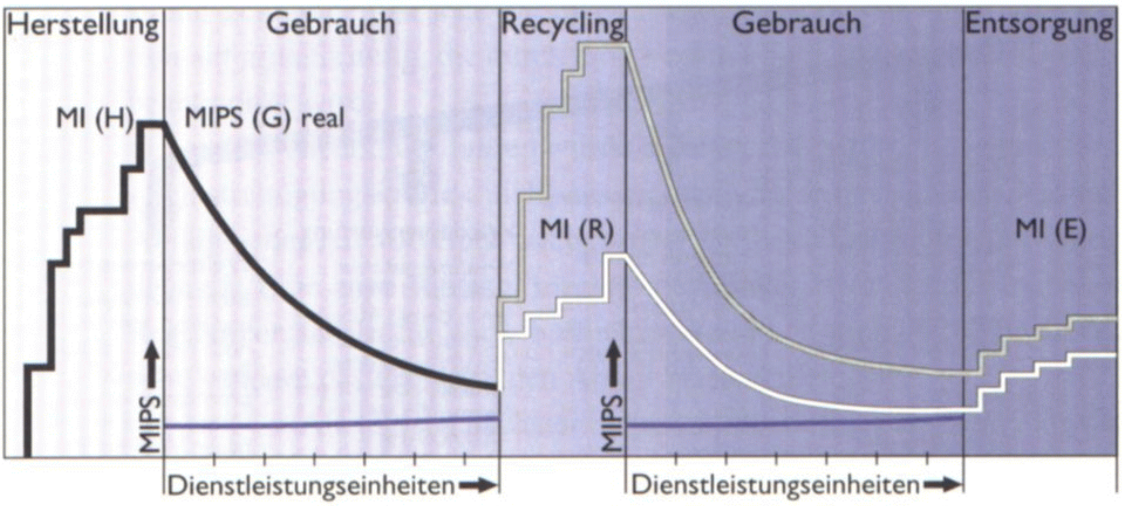

Fig 28: Zur Herstellung, zum Gebrauch, zum Recyling und zur Entsorgung von Gütern sind jeweils bestimmte Material- und Energieeinsätze notwendig. Wenn der zum Recycling notwendige Aufwand den der ursprünglichen Herstellung überschreitet, ist das Verfahren ökologisch sinnlos.

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.

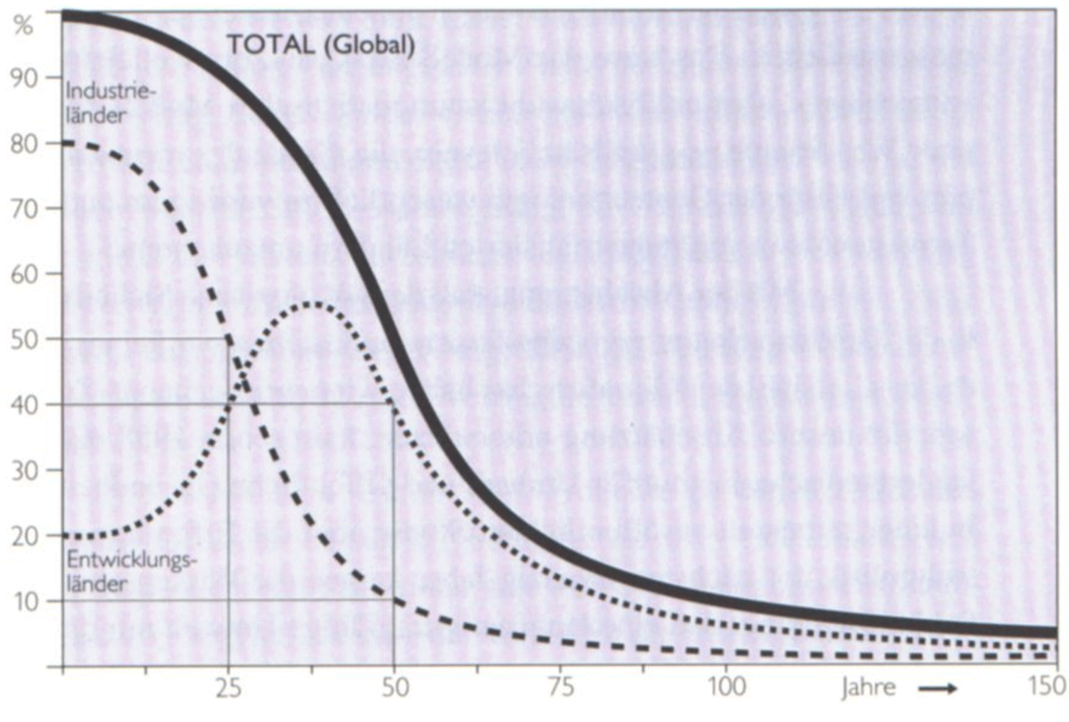

Fig 29: Hypothetischer Verlauf der Abnahme globaler Stoffströme auf 50 Prozent bis Mitte des kommenden Jahrhunderts. Die steil abfallende Kurve deutet die Dematerialisierung industrialisierter Wirtschaften an. Die zunächst ansteigende und dann abfallende Kurve beschreibt den Zugriff der restlichen Welt auf natürliche ressourcen. Um die Darstellung nicht unübersichtlich zu machen, wurde die Zunahme der Weltbevölkerung in dieser zeit nicht berücksichtigt. Vgl. Abb. 5.

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.

We will introduce some examples in this book.

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.

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

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

[3.3] 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.

[4.4] 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.

[5.5] 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.

* . * Christa Liedtke, Material intensity of paper and board production in Western Europe. in: *Fresenius Environmental Bulletin*, 2(8), August 1993.