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[i] 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[ii] 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 (Fig. 12).

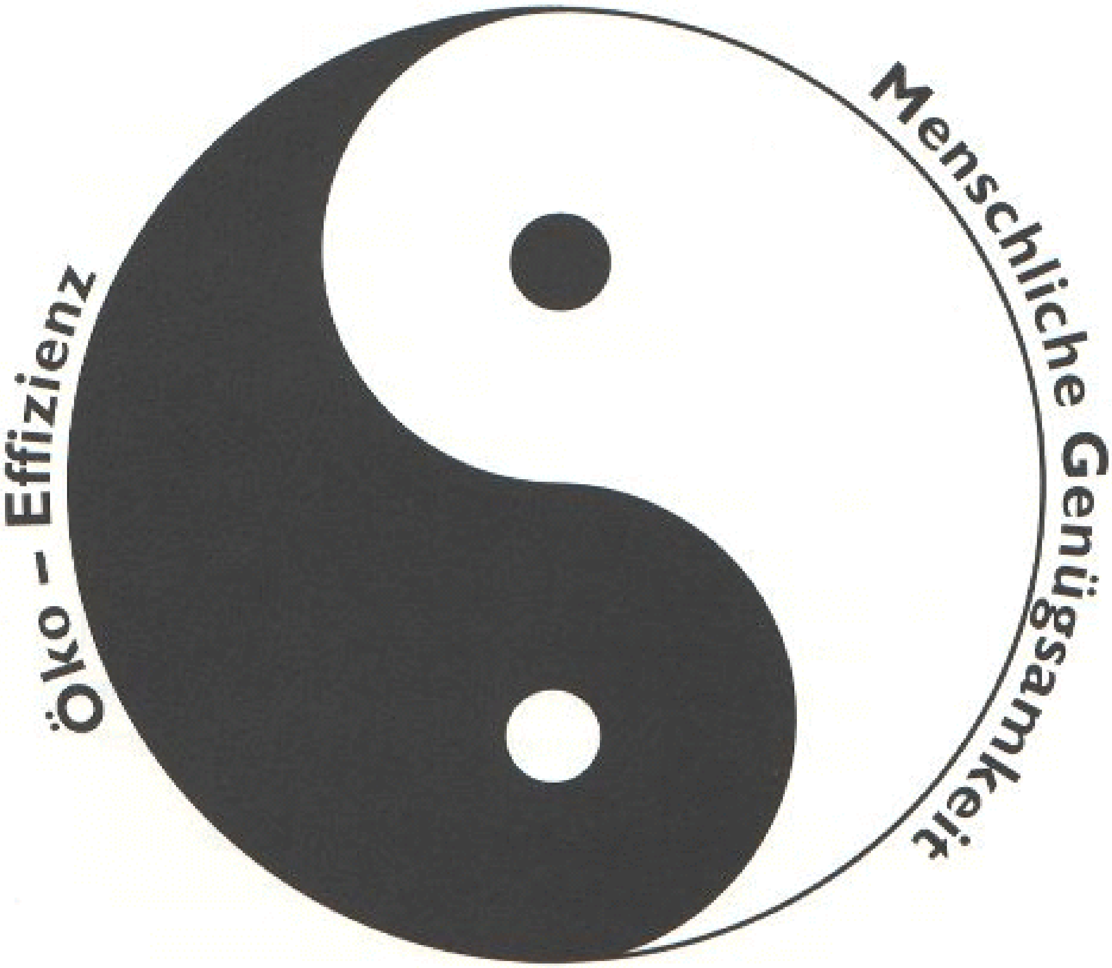

Fig 12: Das neue Yin und Yang der ökologischen Zukunft

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

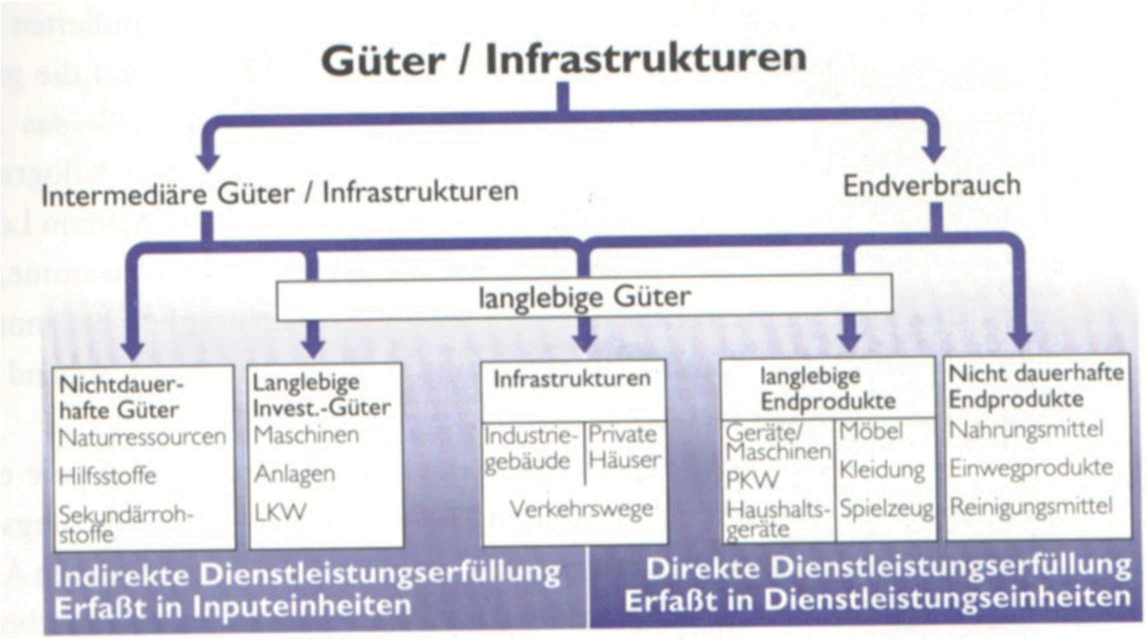

Fig 13: Durch den Einsatz verschiedener Güter sind entweder indirekte oder direkte Dienstleistungserfüllungen möglich.

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.

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.

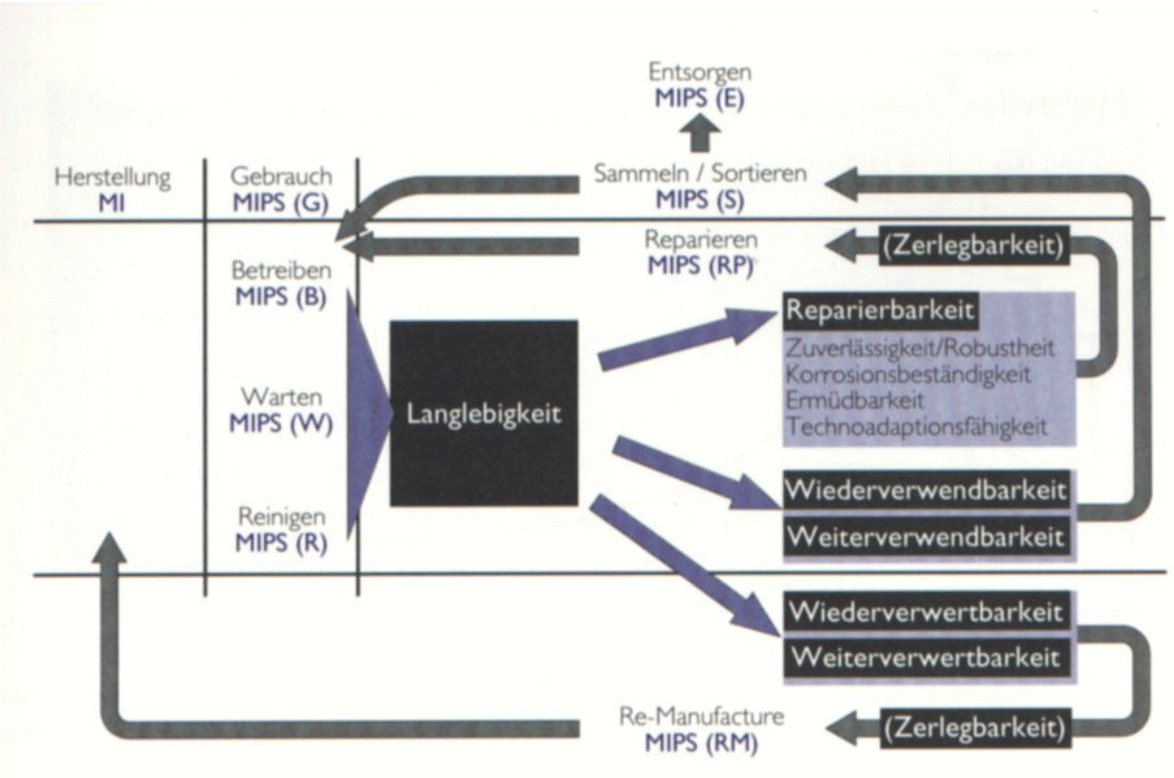

Fig 14: Überblick über die verschiedenen Abschnitte im Leben eines dienstleistungsfähigen Endprodukts und die dazugehörigen MIPS.

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.

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.

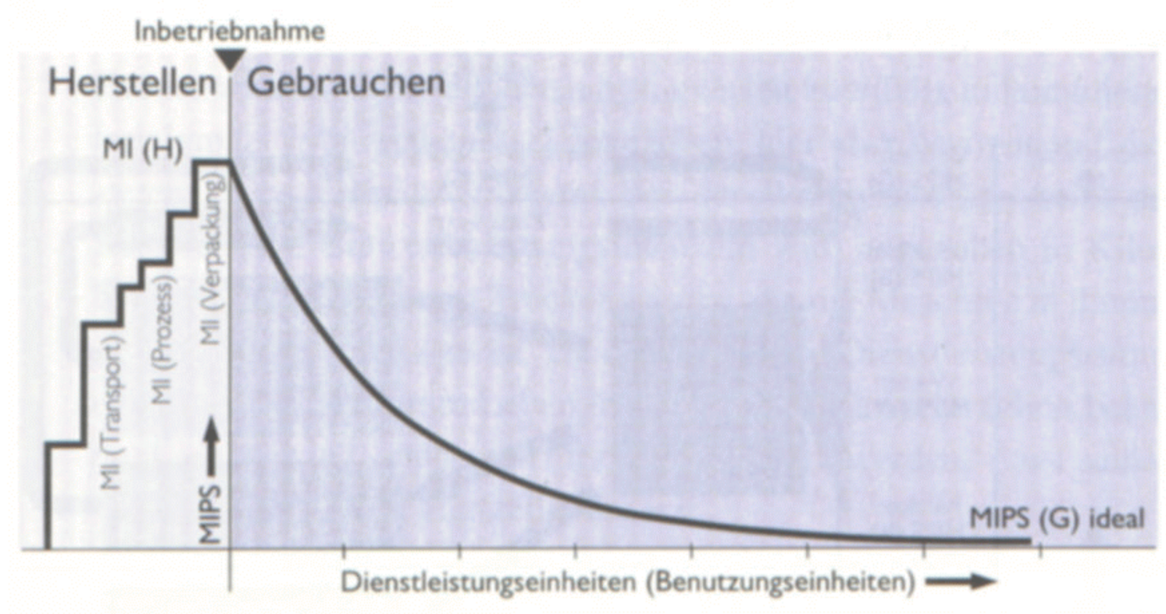

Fig 15: Der hypothetische Verlauf des Anstiegs der Materialintensität eines Gerätes während der Produktionsphase. Die Stufen deuten verschiedene Prozesse an, einschließlich der Transporte. Nach Fertigstellung des Produktes beginnt seine Nutzung, und die Materialintensität nimmt mit wachsender Zahl von Dienstleistungsjahren ab.

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

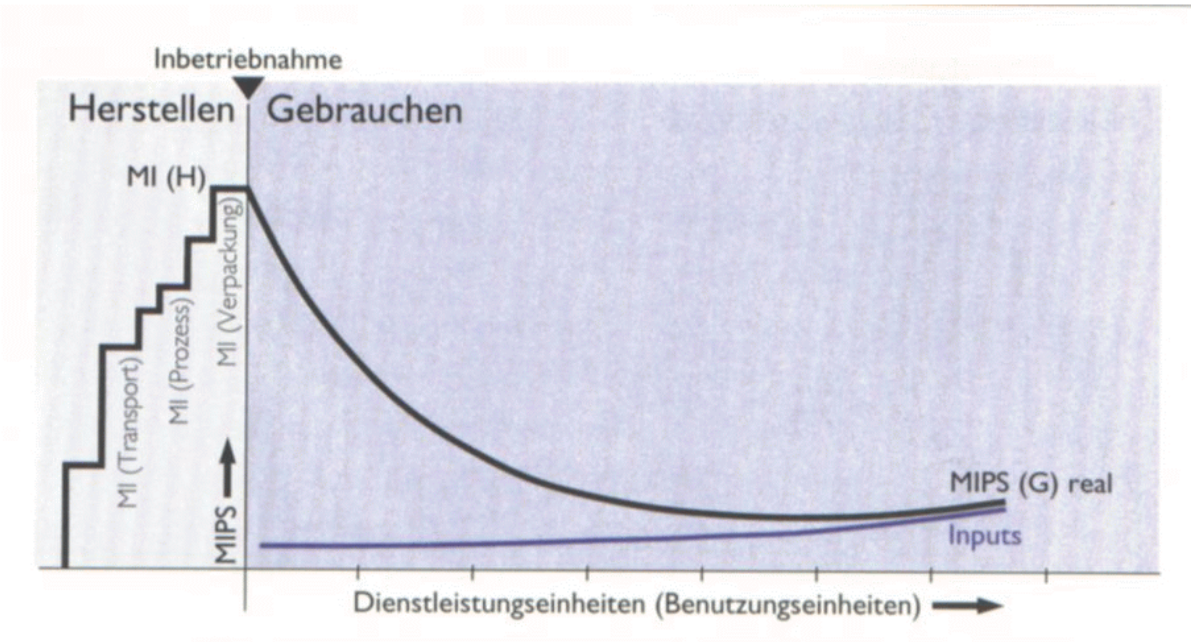

Fig 16: Der Verlauf von MIPS bei wachsender Zahl von Dienstleistungseinheiten, etwa einer Waschmaschine. Die Abnahme von MIPS wird, verglichen mit Abb 15, durch die notwendigen Inputs bei jedem Waschvorgang (Wasser, Energie, Waschmittel) verlangsamt. Nimmt der Verbrauch an Betriebsmitteln mit zunehmender Alter der Maschine deutlich zu, so kann die MIPS-Kurve ein Minimum durchschreiten und wieder ansteigen.

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.

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.

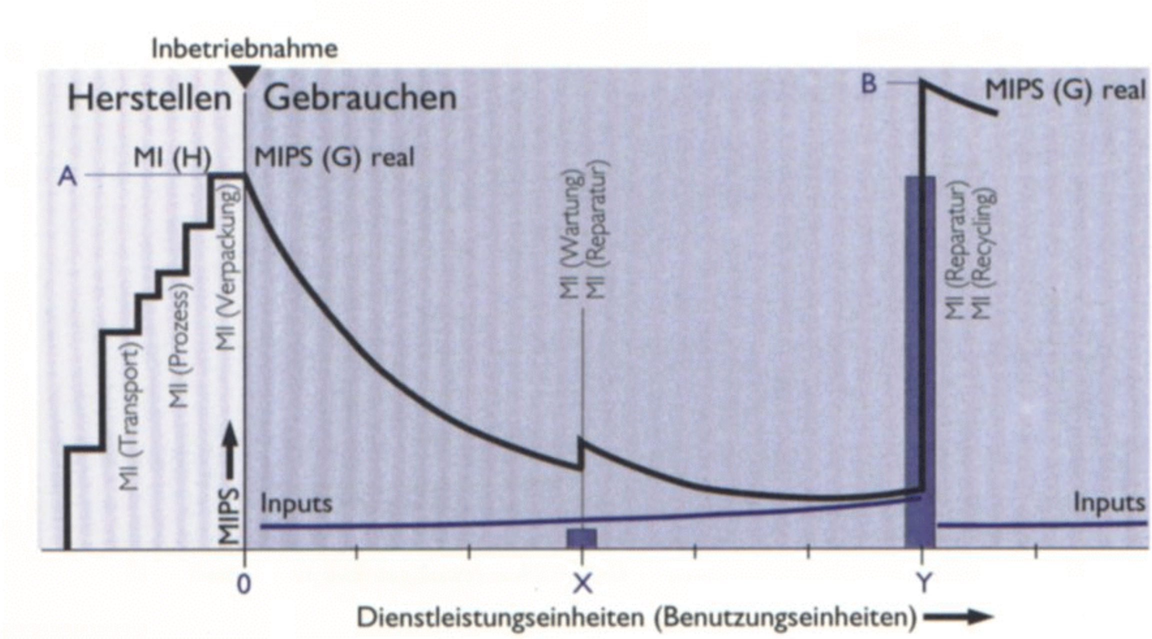

Fig 17: DerVerlauf von MIPS bei wachsender Zahl von Dienstleistungseinheiten, etwa einer waschmaschine. Zunächst tritt an der Stelle X eine kleine reparatur ein, die die MIPS-Kurve verändert. An der Stelle Y schließlich wird eine sehr aufwendige reparatur fällig - viel Energie, Material und/oder Transport -, die aus ökologischer Sicht zu unsinnigen Ergebnissen führt.

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[iii]. 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[iv].

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 tenthousand-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

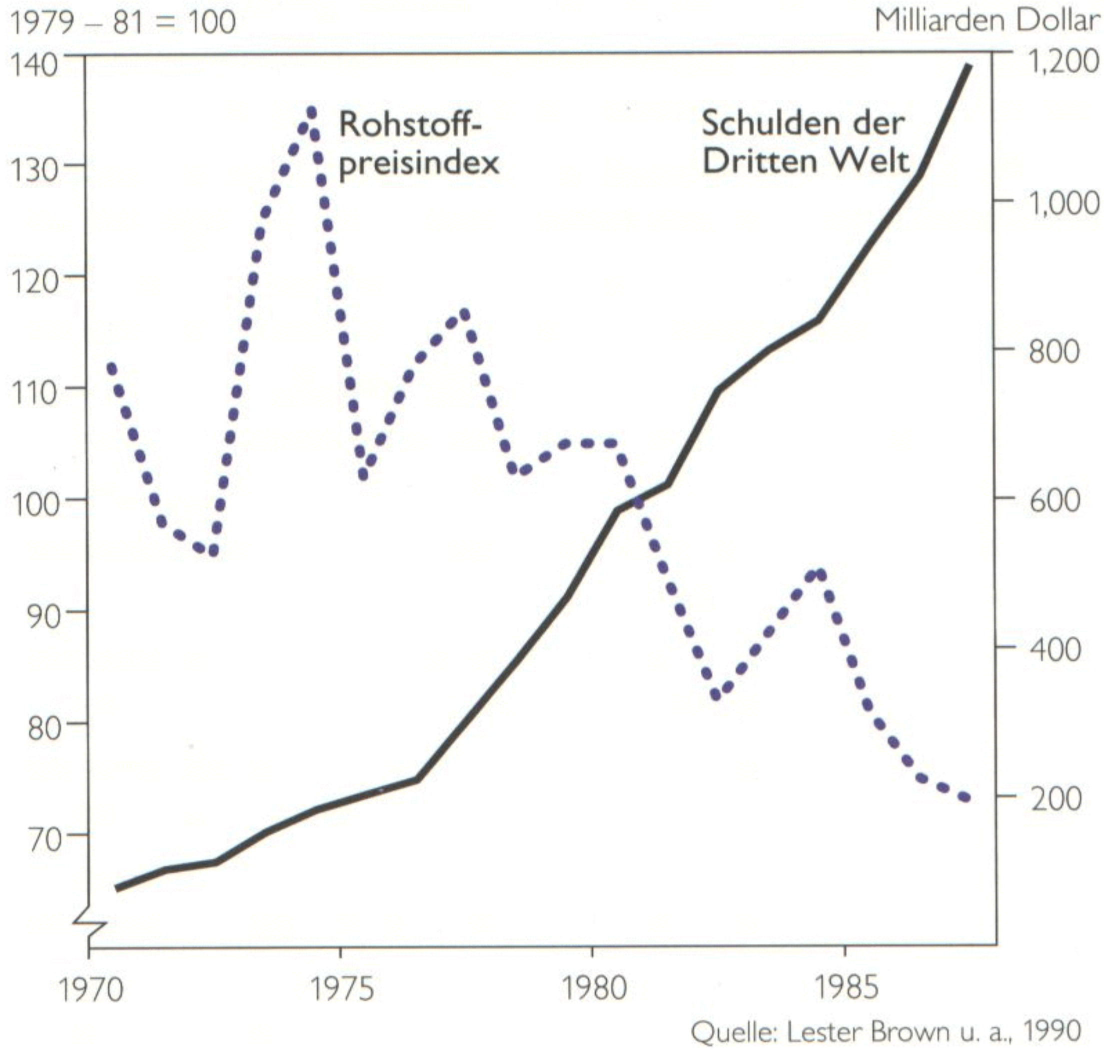

Fig 18: Die absoluten Kosten für Rostoffe sind auf dem Weltmarkt in den letzten Jahrzehnten stark gefallen, während die Schulden der Driite-Welt-Länder drastisch anstiegen.

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 efrigerator 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.

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[v] 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[vi], the debate over the extent and availability of resources has gone back and forth. We will not add anything to these inquiries.

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.

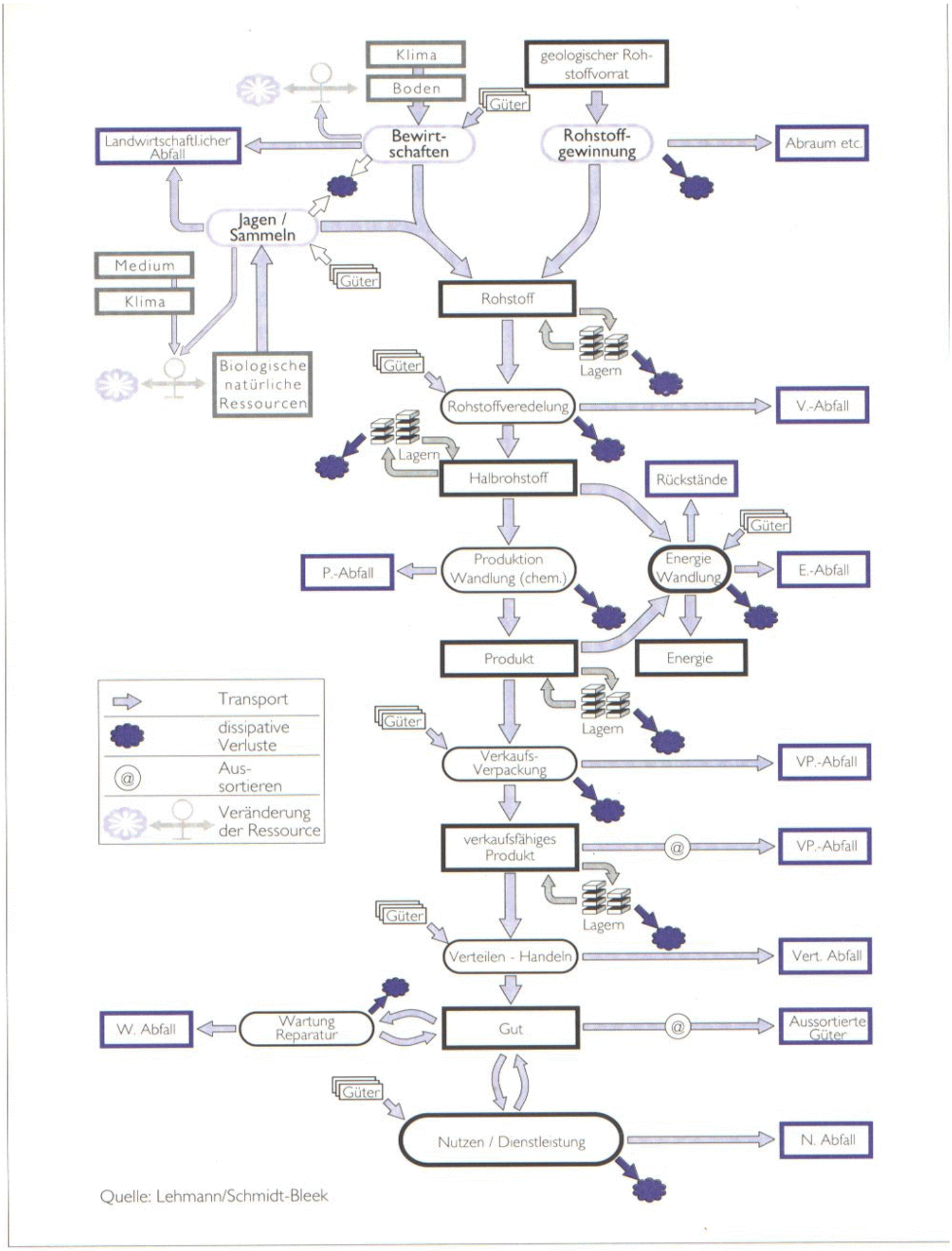

Fig 19: Die drei verschiedenen Quellen in der Ökosphäre, aus welchen die Stoffströme in der Technosphäre gespeist werden, sowie der Lauf der Materialien durch die Technosphäre, einschließlich der Transporte.

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[vii]. 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[viii],[ix].

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. As Figure 19 shows, 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

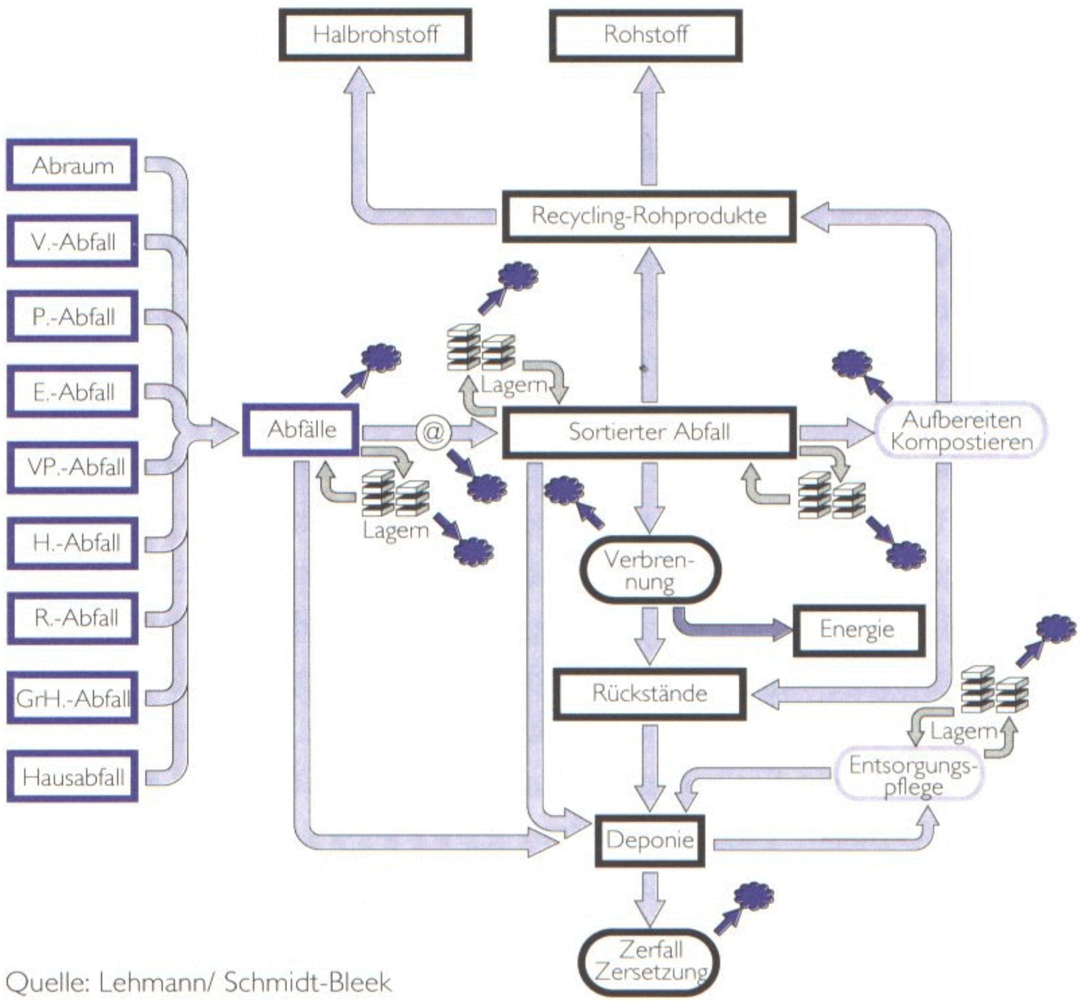

Fig 20: Fortsetzung von Abb 19, veranschaulicht die vielfachen Grenzübergänge von Stoffströmen aus der technosphäre zurück zur Wiege, zur Ökosphäre.

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.

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.

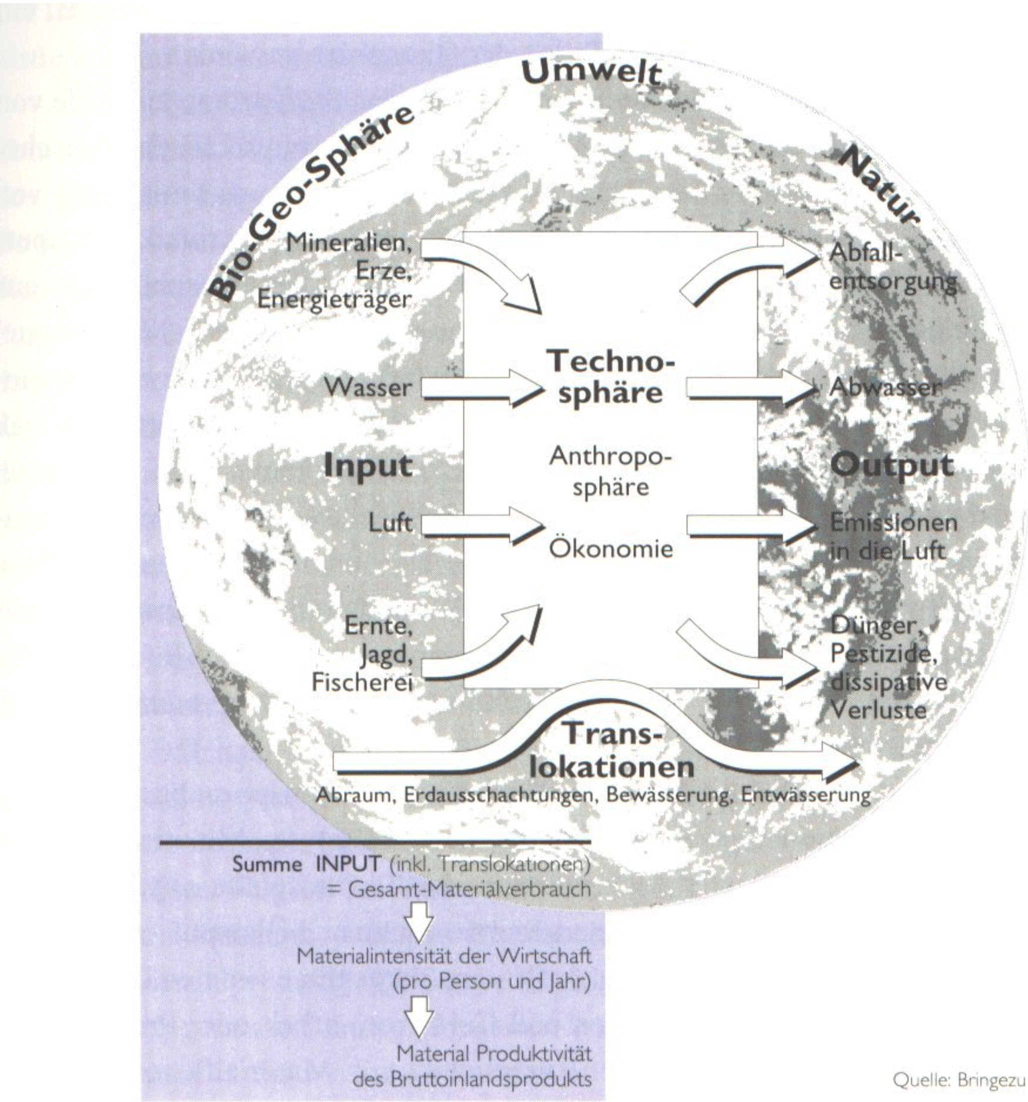

Fig 21: Überblick, welche Stoffe in der Natur bewegt werden (Translokationen), und welche Stoffe aus der Natur in die Wirtschaft hereingenommen werden, um materiellen Wohlstand zu schaffen. Ein großer Teil der Stoffe verläßt die Technosphäre wieder, in Form von Emissionen, Einleitungen und Abfall, andererseits aber auch in Form von Produkten, die aufgrund ihrer Anwendungsmuster direkt in die Umwelt eingebracht werden, die sogenannten dispersiven Anwendungen (etwa Pestizide, Haarsprays, Anstriche).

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[x].

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[xi]. 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 rucksacks of the automobile and of chemicals

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.

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.

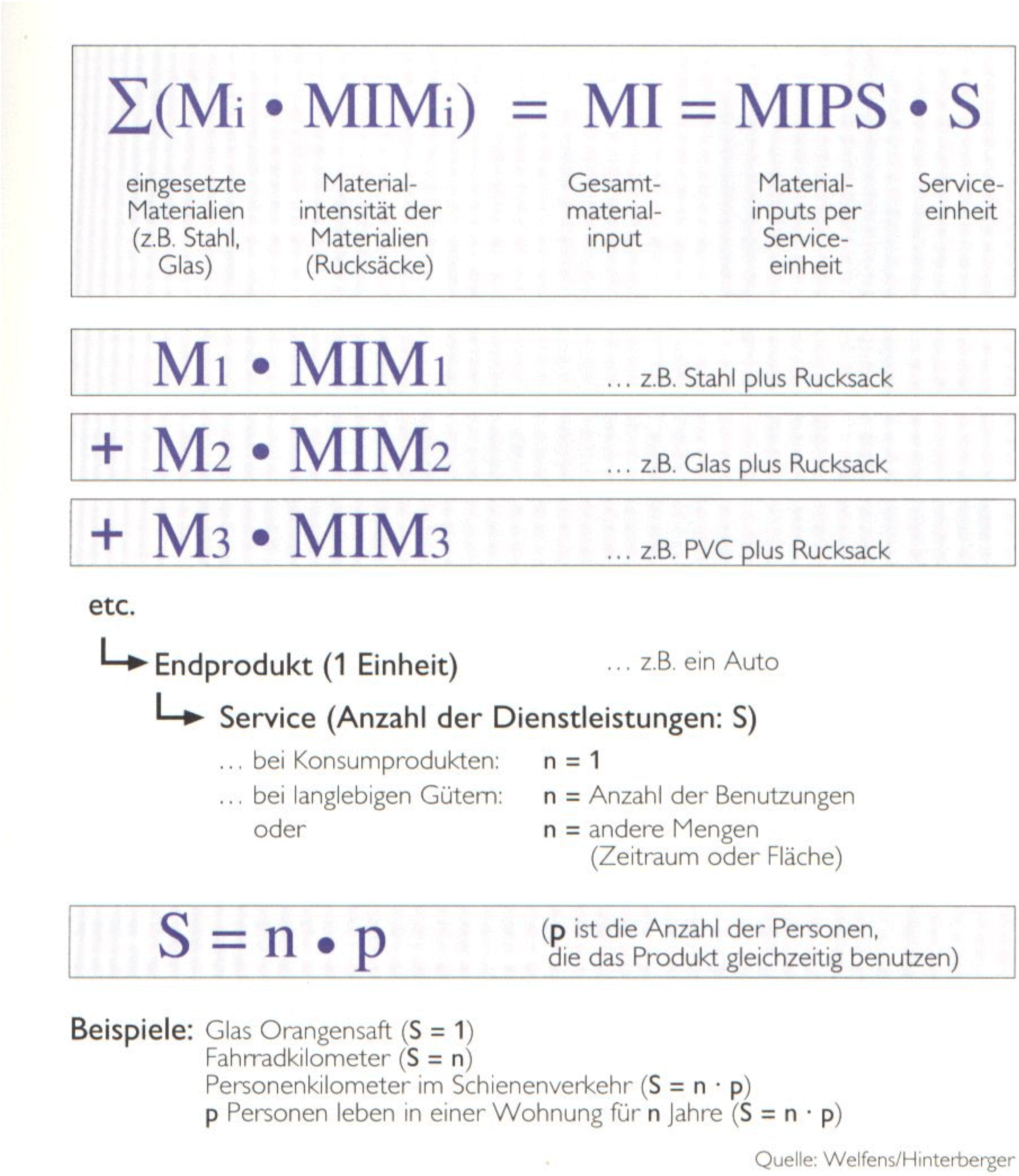

Fig 22: Andeutungen des rechnerischen Vorgangs der Abschätzung der ökologischen Rucksäcke von Eingangsmaterialien für die Produktion eines dienstleistungsfähigen Produktes, zB. Eines Autos, und des Verfahrens, wie sodann MIPS abgeschätzt wird.

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

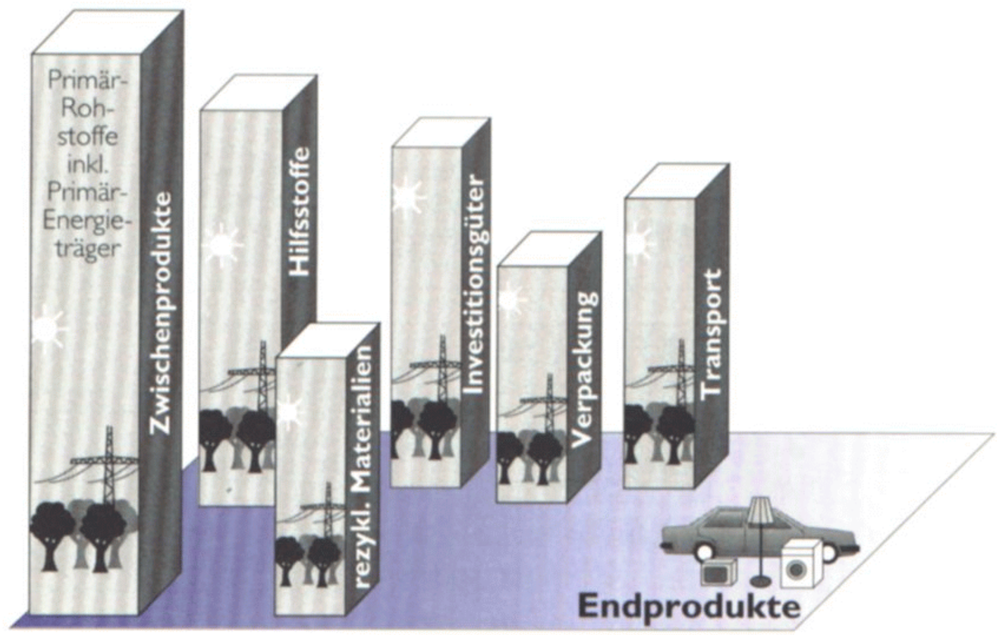

Fig 23: Abb. 23 und Abb 24: Bildhafte Darstellung, wie der ökologische Rucksack eines Automobils zustande kommt. Vgl. Auch Abb. 19.

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.

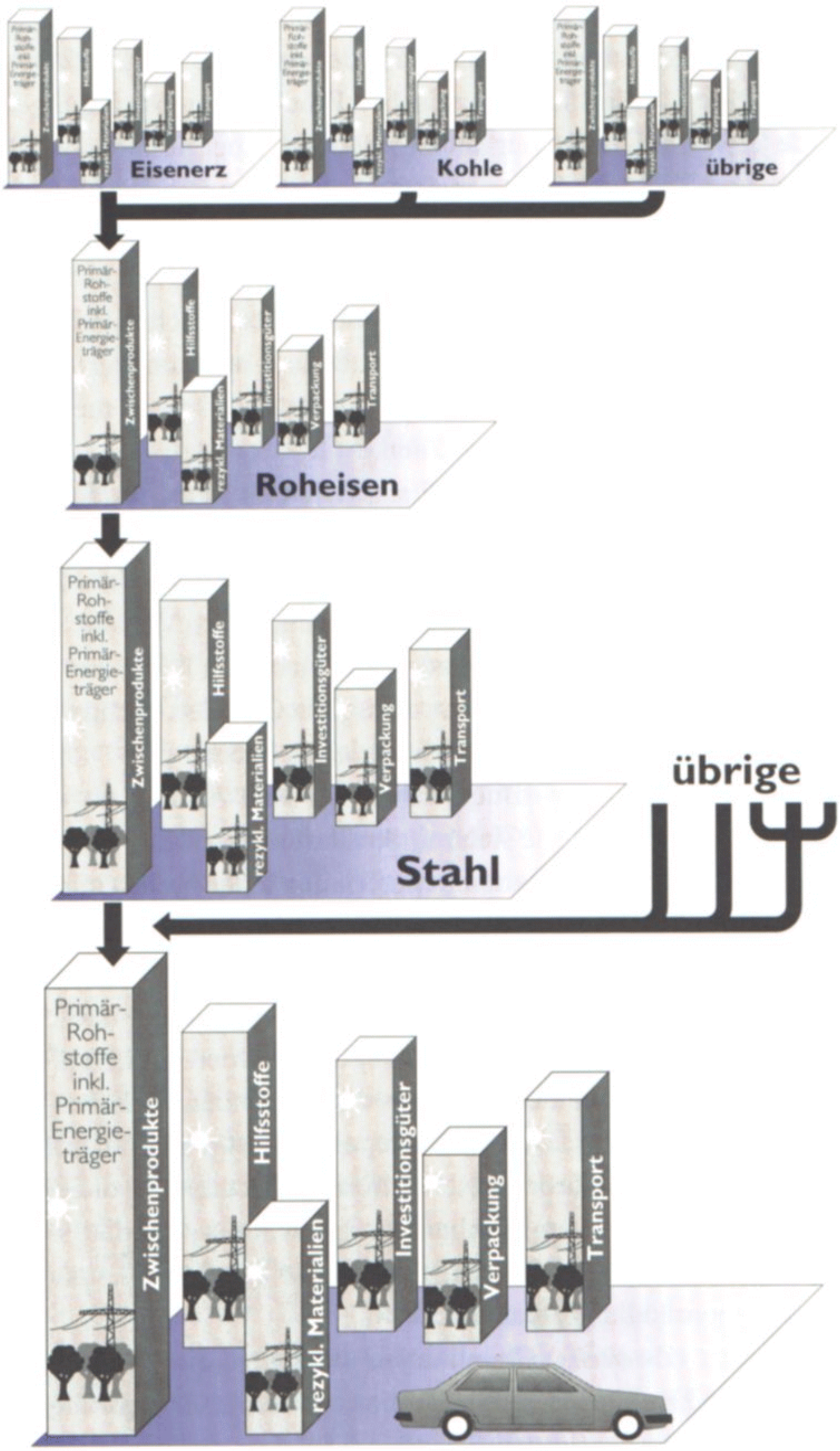
Eisenerz
Kohle
übrige
Primär-Roh-stoffe inkl. Primär-Energie-träger
Zwischenprodukte
Hilfsstoffe
rezykl. Materialien
Investitionsgüter
Verpackung
Transport
Roheisen
Stahl
übrige

Fig 24

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.

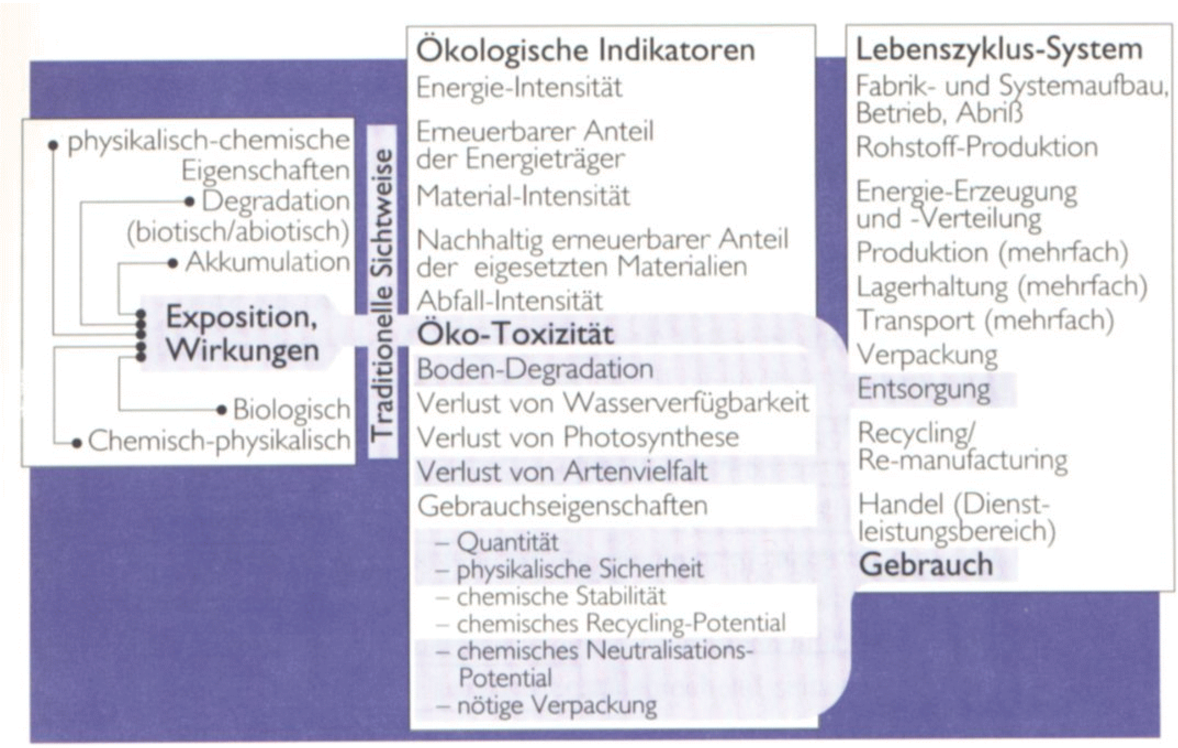

Fig 25: Hier wird verdeutlicht, für welche Eigenschaften von Pestiziden heute Anmelder Unterlagen vorgelegt werden müssen - und wo Lücken bestehen. Die anschließende behördliche Prüfung bezieht sich offenbar nur auf Abschnitte des Lebensweges dieser Chemikalien. Die “Ökologischen Rucksäcke” dieser Chemikalien sind den Behörden nicht bekannt.

As Figure 25 shows, 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.

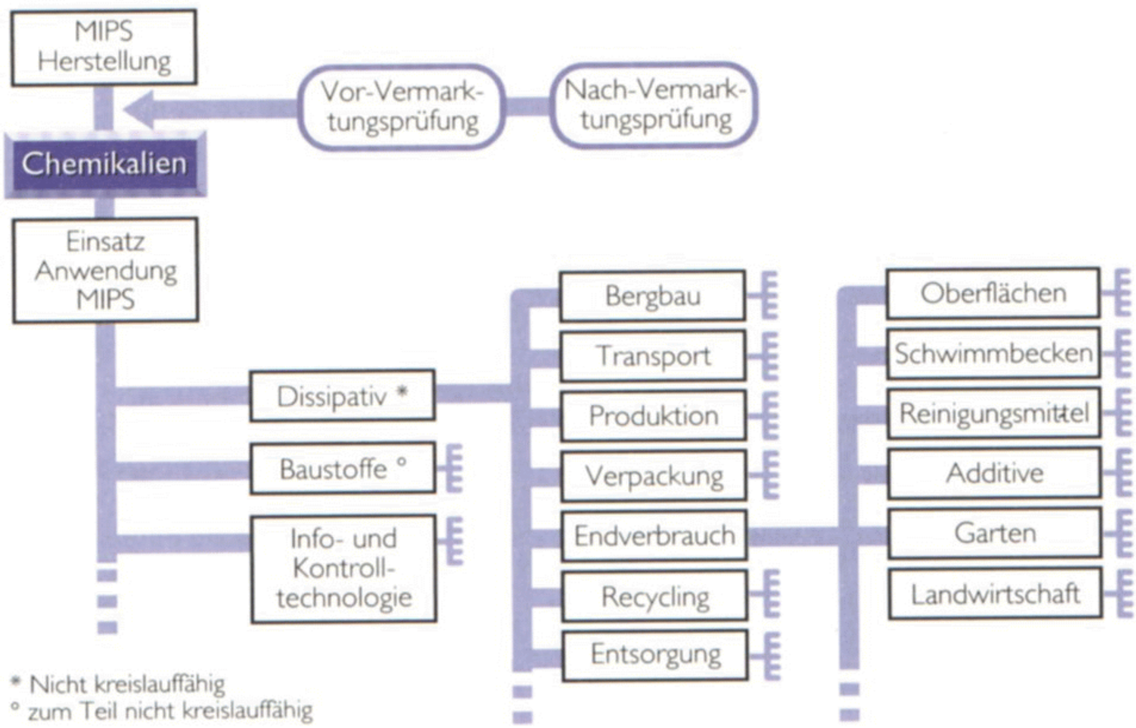

Fig 26: Die ökologisch relevanten Eigenschaften von Chemikalien und deren Anwendungsgebieten.

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[xii] 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.

i. personal communication

ii. personal communication

iii. Aluminum-Zentrale, Düsseldorf, und Verband deutscher Schmelzhütten, informational brochure and personal communication.

iv. Hartmut Stiller, Material Consumption.

v. Thomas Robert Malthus, An Essay on the Principle of Population. London: Johnson, 1798.

vi. Donella H. Meadows et al., The Limits to Growth, New York: Universe Books, 1972.

vii. A compilation of important work on this question can be found in the Fresenius Environmental Bulletin, 2(8), August 1993.

viii. 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.

ix. Peter Baccini and Paul H. Brunner, Metabolism of the Anthroposphere. Berlin and Heidelberg, 1991.

x. Ulrike Brüggemann and Harry Lehmann, Computer aided material flows analysis, "CAMA". in:*Fresenius Environmental Bulletin*, 2(8), August 1993.

xi. Helmut Schütz and Stefan Bringezu, Major material flows in Germany. in: *Fresenius Environmental Bulletin*, 2(8), August 1993.

xii. 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.