SCHRIFTENREIHE
SOZIALE ÖKOLOGIE

BAND 22

A PARADISE FOR PARADIGMS

Outlining an Information System on Physical Exchanges between the Economy and Nature

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WIEN, 1992

ERSCHEINT IN:
B.AYRES, U.E.SIMONIS: INDUSTRIAL METABOLISM.
NEW YORK (UNU) 1993.

Impressum
Medieninhaber, Verleger, Herausgeber:
Interuniversitäres Institut für interdisziplinäre Forschung und Fortbildung (IFF),
Abteilung Soziale Ökologie, A - 1070 Wien, Seidengasse 13
Tel.: 0222-526 75 01-0, FAX: 0222-523 58 43

A PARADISE FOR PARADIGMS
Outlining an Information System on Physical Exchanges between the Economy and Nature

Marina Fischer-Kowalski, Helmut Haberl and Harald Payer[1]

1. Introduction

The notion of "industrial metabolism" draws attention to a materialistic view of the economy as a huge physical system, driven by energy flows. Such a conception is less trivial than it seems, since money functions as a "unifying principle of economy" to such an extent that it is difficult to raise awareness and understandig for physical (non-monetary) concepts. Physical dimensions usually are discussed only as tools for the development of monetarization, not as autonomous concepts[2]. Similarly, besides economics, the social sciences tend to view social reproduction as a system of communication (Luhmann 1986), and not in physical terms.

If you conceive of the economy as a physical system, drawing physical inputs from its natural environment, processing them internally, and generating physical outputs to this environment, you have to define a boundary between the "system" and its "natural environment": you have to be able to tell what is "inside" and what is "outside". This boundary is both omnipresent and fugitive. It certainly cannot be a "physical" or topographical boundary: The same physical elements will be both part of the economic system and part of its natural environment, depending on the point of view. There can only be constructed a functional boundary, and this has to be done with care. Two approaches may be chosen:

(1) An apriori theoretical approach would discuss the possible functional labels of physical entities and processes that should define them as "inside" or "outside" the system; this might be their function as goods and services on markets (a narrow approach that would leave aside the so-called "free goods", and could not easily be applied to elements of subsistence economies); it might be their function for "humans"

in terms of a biological species (which would be a very broad approach, difficult to connect to a specific concept of economy). We feel the most promising approach would be the functional link to property: property is specifically human and it constitutes a functional connection between physical entities and economic "subjects". But we will not pursue this discussion in our contribution any further. We would like to encourage such a discussion, though. As long as this question is not resolved satisfactorily on a theoretical level, we prefer to speak of the "socio-economic system" rather than of "industrial economy". Sometimes we also use the term "economy" implying a wider historical range of modes of production.

(2) Another approach is a strictly "constructivist" one. It presumes that society "constructs" its boundary towards its natural environment by the environmental information system it uses. The environmental information system itself defines what is to be considered as part of the system, and what is to be considered as an element of its (relevant) "natural environment". Practically speaking this is the approach we chose within this paper, and it leads to an implicit definition of the boundary between the socio-economic system and its natural environment.

This leaves us with the need for a mode of selection of physical processes that are relevant within an environmental information system that is supposed to describe socio-economic metabolism. This mode of selection should be self-referential to the socio-economic system in the sense that it selects for the possible present or future harms feedbacks from the natural environment to the system may cause. In view of our limited knowledge of interdependencies it should also take into account the self-regulating qualities of natural systems for their own sake. Part 2 of our paper attempts to outline what we think to be basic paradigms for conceiving of such interdependencies.

Part 3 then is devoted to the overall structure of an information system that might qualify for the standards set. We have proposed this information system to be established by the Austrian Government, with some chance for success. In parts 4 and 5 we then proceed to empirical illustrations of how the Austrian economy would perform within such an information system.

2. Distinguishing between "harmful" and "harmless" characteristics of socio-economic metabolism with its natural environment

There exists a variety of conceptions to distinguish between what is "good" (or at least harmless) and what is "bad" (harmful) for the "environment". These conceptions vary according to scientific discipline and according to political (or ethical) understanding of the man-nature relationships.

This variety of conceptions can be ordered into four basic paradigms:

- "poison paradigm"
- "natural balance paradigm"
- "entropy paradigm"
- "conviviality paradigm".

Each of them is guided by a specific reference concept, and each of them is able to catch important aspects of the possible meaning of "damages" society causes to its natural environment. The paradigms are not mutually exclusive in the sense that one specific aspect of environmental damage might not occur in more than one of them. But they cannot be reduced upon one another, nor can they be merged into one single "grand paradigm"[3]. Each has its specific structure of reasoning, its own scientific and political tradition, and its audience. But all four paradigms taken together permit a complete scanning of what can be meant if people talk about the socio-economic system "causing environmental damage". (see Figure 1)

"ENVIRONMENTAL DAMAGE" CAUSED BY THE SOCIO-ECONOMIC SYSTEM: FOUR BASIC PARADIGMS

Paradigm 1: "Poison"
(favoured by medical scientists, chemists, and large parts of the public)

Which substances are toxic, noxious? (toxic for humans, phytotoxic, ecotoxic..) → **environmental policy** Where are noxious substances emitted? (by whom, through which process)

political bargaining process: limiting volumes → restrictions: limits for concentrations, amounts of emissions

control of adherence to standards set

Paradigm 2: "Natural balance"
(favoured by biologists, climatologists, agriculturalists etc.)

How does a (specific) natural system work? → Where are natural systems put out of balance? (by whom, through which process)

political bargaining process: which natural systems are worth protecting? → protection of natural systems (conservation of nature, prohibition of uses, re-naturation)

control of effectiveness: Do natural systems survive, keep or regain their balance?

Paradigm 3: "Entropy"
(favoured by physisists, environmental economists etc.)

Laws of thermodynamics (applied to energy and matter) → Where do we use energy/resources at a speed exceeding its reconstruction / input from the sun?

political bargaining process: value of human labor vs. value of natural resources → reduction of use of energy and resources

control of effectiveness: do we live from "natural income" or from "natural capital"?

Paradigm 4: "Conviviality"
(favoured by philosophers, moralists, nature preservationists etc.)

Preconceptions about "commoness", mutual interdependence and respect for life on this planet → Where do we unneccessarily destroy, harm or dominate the living conditions of other species?

political bargaining process: how much harm to others is justified for human well-being → reduction of the amount the human species lives at the expense of other species

Is the degree of human dominance over other species increasing or decreasing?

Figure 1

Let us illustrate the functioning of the four paradigms for a special case: the damages caused by car traffic.

(1) In the "poison paradigm", the main argument would be: Car traffic causes about 60% of the toxic gaseous emissions to the atmosphere (CO, NO_x, C_xH_y). Thus limiting volumes for the exhaust should be issued. Catalytic converters are a good solution, since they reduce toxic emissions by 80% or more.

(2) In the "natural balance paradigm", it would be said that car traffic contributes with about 15% to the destabilization of the earth's climate, and also effects several ecosystems severely. Catalytic converters would not do, since they cannot reduce CO_2, but maybe electric or solar cars could.

(3) In the "entropy paradigm", it would be argued that car traffic requires about 50% of the end-consumption of liquid fossil fuels. Thus we need a technological innovation towards solar cars, for example, while catalytic converters are relatively irrelevant or even counterproductive since they require platinum, a very rare resource.

(4) In the "conviviality paradigm" attention would be drawn to car traffic as a major cause of unintentional and useless animal killing (insects, birds, rodents, amphibious animals etc.). It would also draw attention to the road system cutting the living space of many species into areas too small for a decent life and exposing them to all kinds of disturbances. Solar cars wouldn't help.

We think that an information system on environmental impacts of the socio-economic system should bear reference to all these four paradigms and should present evidence concerning the central set of variables in each of them. It should not deprive any one line of reasoning of its possible empirical basis, or priviledge one over the other. Political discussion and the political decision making process would then have to weigh arguments and to solve existing contradictions.

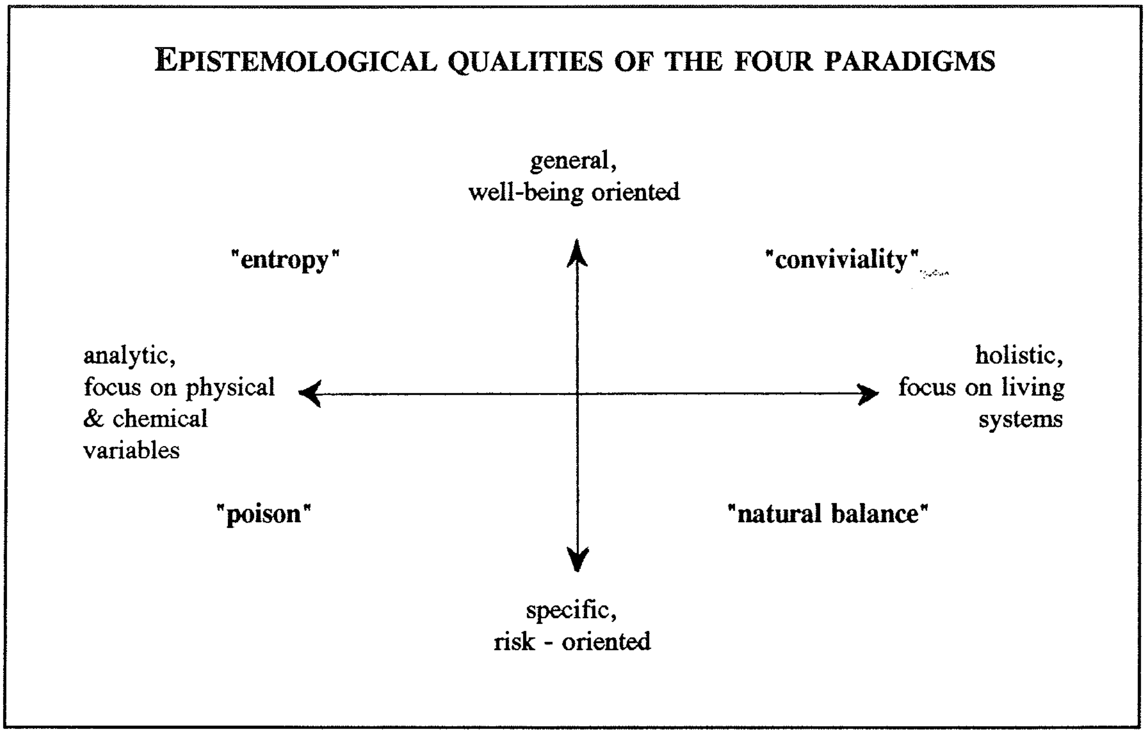


Figure 2

This recommendation can also be supported by considering the empistemological qualities of the four paradigms (see Figure 2). Regarding the horizontal dimension, the "poison paradigm" and the "entropy paradigm" are more closely related to established ways of analytical thinking in chemical and physical dimensions, whereas the "natural balance paradigm" and the "conviviality paradigm" present holistic views referring to living systems. These two are more recalcitrant to relate to analytical systems such as (economic) national accounting - but holistic approaches may be the ones to come. The vertical dimension, specific vs. general, and at the same time risk-oriented vs. well-being oriented, also has implications for the possible acceptability of the paradigms. For the time being it is easier to argue for political measures in defense against specific risks than in favour of long term well-being. But this (hopefully) may change within the next decades, and an information system now created should be open for such changes.

3. Outline of an information system for the metabolism of the socio-economic system with its natural environment

Let's come back to the notion of "metabolism". In biology, this term is commonly used to describe the internal biochemical pathways of organic and anorganic inputs and their conversion to organic/anorganic outputs which are neccessary for an organism to grow, maintain its living and produce its offspring[4]. Functionally speaking, a specific metabolism is all an organism needs to survive.

Strictly speaking, the socio-economic system certainly is not an organism: neither is it as highly integrated internally, nor can it die - because it does not "live" in a biological sense. It is a system on a different hierarchical level for which it is difficult to find a suitable biological analogy[5]. For systems of higher complexity (such as ecosystems) the exchange processes with their environment have to be conceptualized on a more complex level than the input/output-logics of "metabolism" will provide. For describing the "metabolism" of a system it is sufficient to conceptualize its "environment" as a large pool providing nutrients and sinks. For a proper description of the socio-economic system's interactions with its natural environment it is indispensable, we think, to conceive the natural environment as an array of various **systems** into which **interventions** take place. These interventions aim at colonizing the environment. This is equivalent to purposive restructuring of certain system characteristics of the environment so it would serve specific socio-economic uses. We will explain this idea in more detail below.

So the information system we propose[6] stretches the concept of metabolism by considering not just inputs from and outputs to the natural environment, but also interventions into various natural systems.

Figure 3 gives an overview of the information system we propose in relation to the four paradigms described above. There are three modules of indicators that differ in their theoretical reference, in their (natural sciences) background and in their data bases. Methodologically though they have common features: They are all expressed as physical flows over the (systemic) border between the economy and its natural environment per time period (a year); They are all formulated on a level of abstraction that (in principle) allows all economic actors to produce such flows[7]; and they are attributable to specific economic actors (branches of activities, including private households) on an institutional, not a functional basis[8].

THE RELATIONSHIP BETWEEN THE PROPOSED SETS OF INDICATORS AND REFERENCE PARADIGMS OF ENVIRONMENTAL DAMAGE CAUSED BY THE SOCIO-ECONOMIC SYSTEM

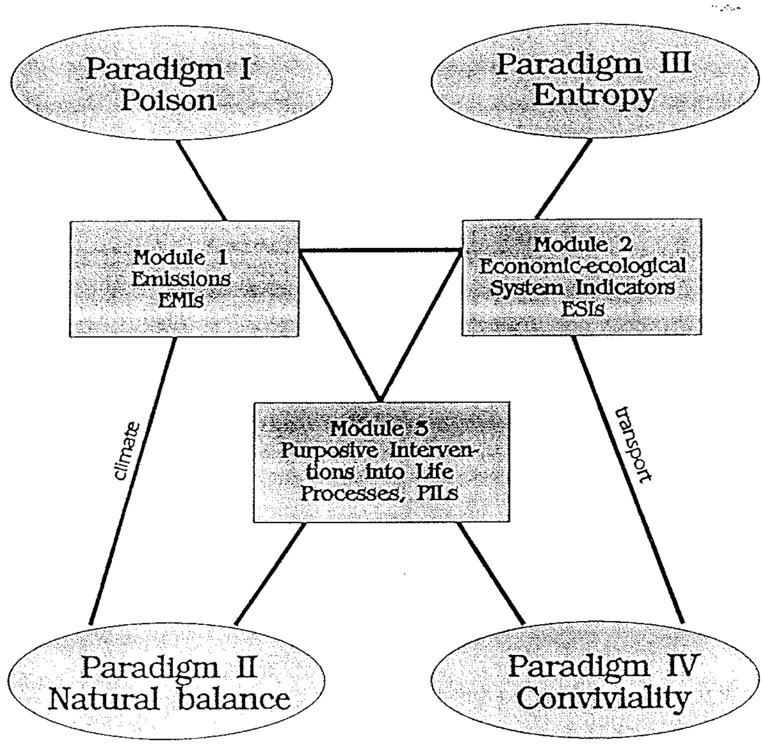


Figure 3

So, what distinguishes the information modules? What is their content? And how do they relate to the concept of metabolism?

Module 1, **emissions (EMIs)**, is the most obvious in this context. It specifies indicators for gaseous, liquid and solid emissions (each with a number of sub-indicators agreed upon in a series of expert workshops) per economic branch of activity, and expressed in tons per year. For gaseous emissions we suggest two effect parameters, namely "climate affecting emissions" (where several different substances are recalculated on a CO_2-basis according to international standards), and "ozone-layer affecting emissions" (again a recalculation of various gases in F_{21}-equivalents). Similarly for liquid emissions we suggest an effect parameter for "eutrophication" (in total P) and for "deoxidation" (in BOD_5), and another for toxicity. Whereas it was possible to find acceptance among experts for a fairly comprehensive list of indicators selected for importance, ubiquity and methodological feasibility, the empirical basis for calculation is extremely weak. So we do not give any empirical example in this chapter, but we suggest further research on technological emission factors for future calculations. With regard to solid emissions, even the conceptual basis for specifying anything but sheer amounts (in tons per year) is highly unsatisfying.

With reference to the metabolism-concept, EMIs represent only a rather simple feature, namely outputs of the system into its environment, selected for possible noxious quality.

Module 2, **economic-ecological system indicators (ESIs)**, informs about the physical dimensions of the economy in terms of matter, energy and time/space. This rests upon the assumption that ceteris paribus the economy will have the less impact upon its environment the smaller the physical quantities handled by the system are. Several aspects can be expressed by this module. One aspect is the "size" of the economy relative to its natural environment. Another aspect is the ecological "wastefulness" of the economy: The more energy, matter and movement (space/time) is processed for a given degree of need-satisfaction, the more ecologically wasteful the system is. Still another aspect is the relative "closedness" of the system: how much input from the environment does it need and how much output does it produce in relation to the amounts circulated within the system?

The indicators in this module are expressed in physical amounts (e.g., how many tons of materials are handled per year, imported from and exported to the environment? How much energy in terms of Joule per year is consumed resp. downgraded? How many kilometers*tons are being transported per year?). These amounts are very meaningful in absolute terms, be it for comparisons over time or between branches of economic activity. In a second step they also can be related to the monetary side of the economy and expressed as "intensities", e.g. net-energy used divided by gross domestic product. This draws attention to the relative independence of the physical and the monetary "size" of the economy: An economy may very well shrink in physical terms (which should be environmentally beneficial) and at the same time grow in monetary terms (which would be environmenally rather irrelevant).

These indicators have in common that they are fairly close to standard economic statistics, in a sense they represent their physical dimensions. They also have in common a number of (sometimes overlapping) environmental implications. (We will come back to this for the case of materials and material intensity in more detail below[9].)

ESIs have close relationship to the concept of metabolism: On a very general level they allow, in combination with economic input-output analysis, a screening of the whole transformation process this term implies.

Module 3, **purposive interventions into life processes (PILs)**, is the most unconventional of the modules. It distinguishes from emissions in that it seeks to operationalize purposeful actions. Emissions may be regarded as unintented side-effects of economic production and consumption, whereas here we aim at interventions in favor of a particular social use. Roads for example purposefully extinguish vegetation and animal life from a particular area in order to remove barriers to human mobility. Agriculture purposively uses pesticides to prevent other species from eating the crops. Pestizides are not an "emission" (or only when they, as a side-effect, get into rivers), but are applied for a specific economic purpose.

PILs have in common with EMIs that they do not portray the metabolism within the economy, but flows over its boundaries to the environment. Other than with EMIs these flows cannot be properly identified as either "intakes" or "outputs", but have to be described (on a different functional level) as interventions into environmental systems. An example is given below.

4. An empirical example for ESIs: Material balances and intensities for the Austrian economy

We regard the materials-intensity of economic processes as one of the basic general criteria for their environmental impact. Most of the current environmental damages are significantly connected with the extraction and transportation, the processing and using of materials[10]. Therefore the aim is to devise a consistent set of macro-indicators for materials-intensity, which should give information on the physical extension (and efficiency) of economic activity[11].

The suggested indicators for materials-intensity trace the material flows from the environment through the economy and back into the environment. The concept of flows as shown in Figure 4 follows the laws of thermodynamics which state that materials cannot be used up in a physical sense. Nothing gets lost. Macroeconomic material balances always end up with identic sums of material inputs and outputs in terms of mass. The concept of material flows is thus perfectly compatible to the monetary input-output cycles basic to the System of National Accounts (SNA).

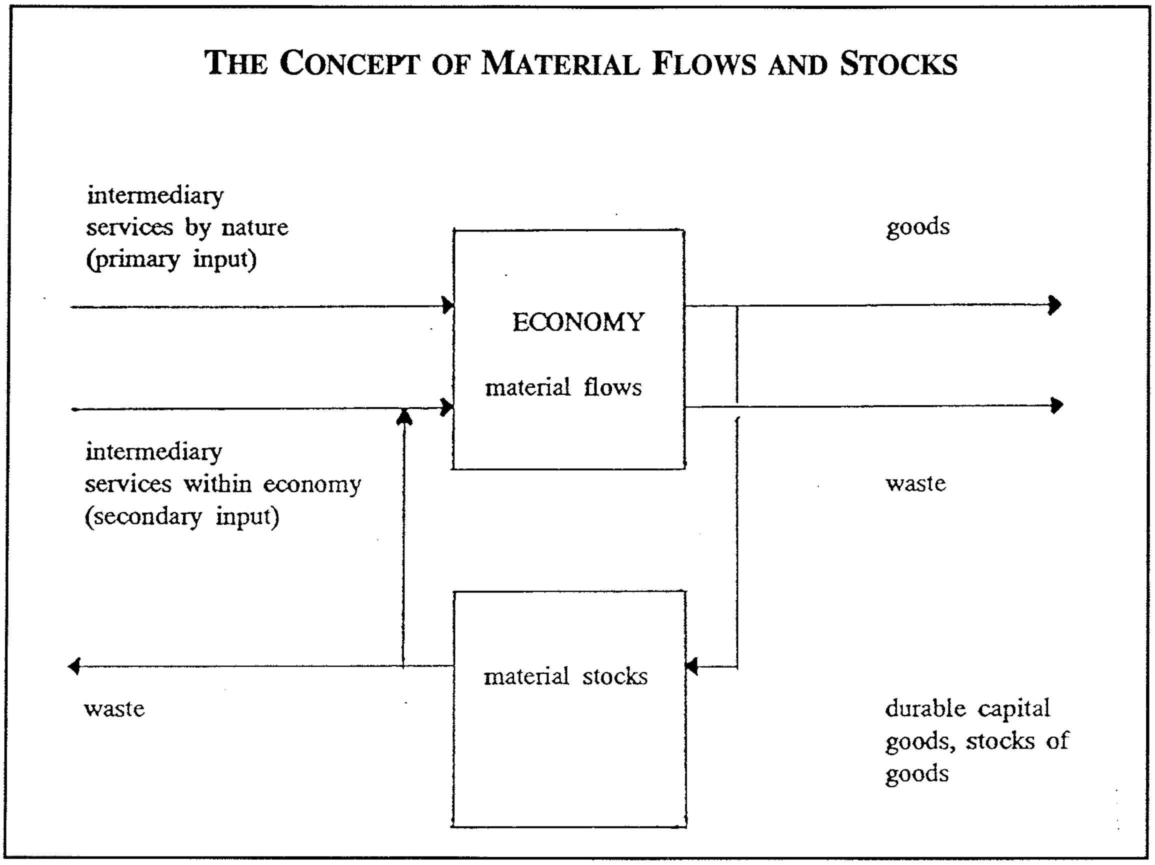
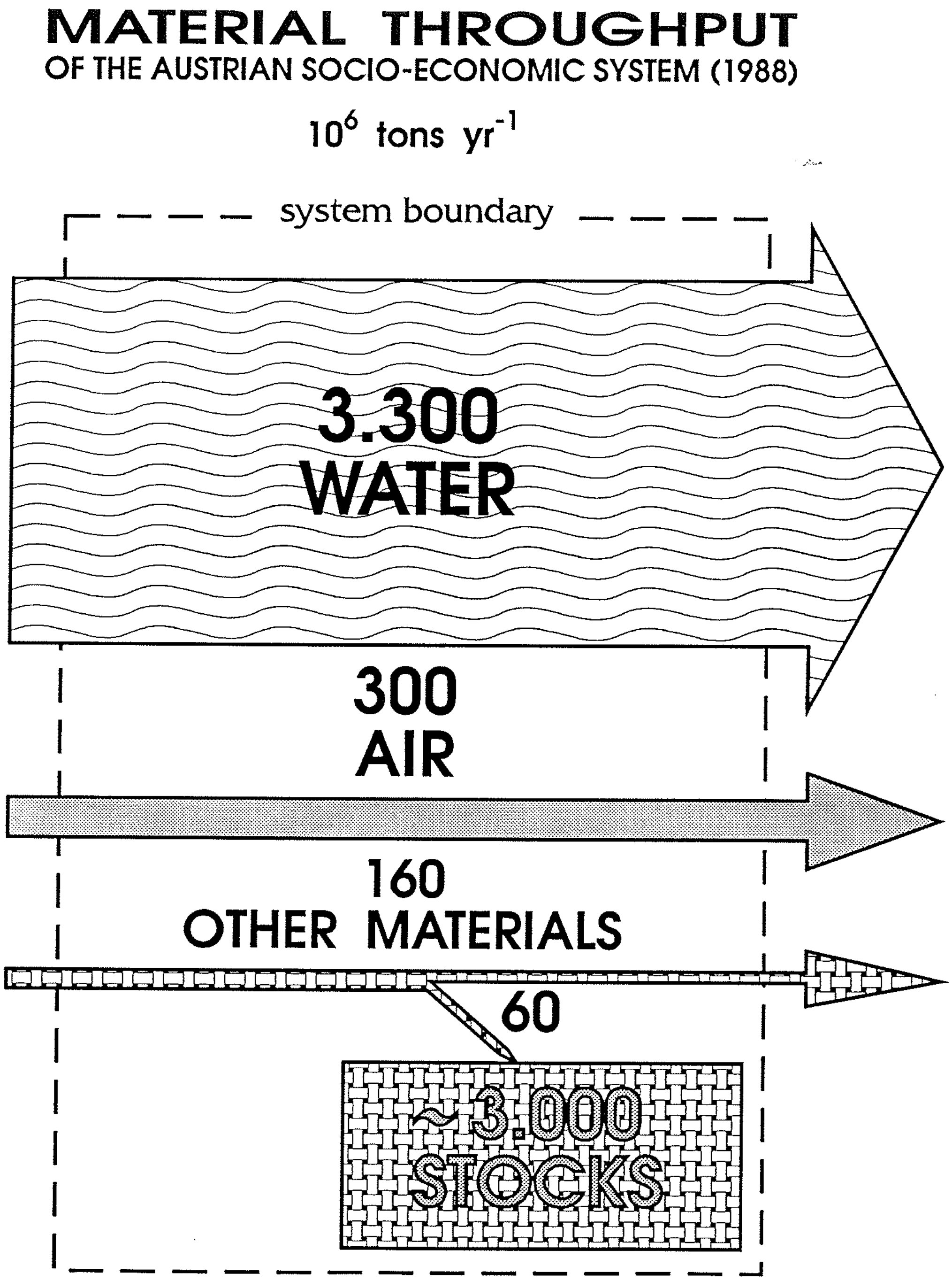


Figure 4

Figure 5



Source: Steurer 1992

The material balances include the total material throughput of the economy in million tons (as measure of mass) per time period. Figure 5 presents a quantitative overview of the material throughput of the Austrian economy in millions of tons per year, calculated by Steurer (1992) from all sources available. The economy very much resembles a living system: 88% of the throughput is water (more than half of that for cooling purposes), another 8% is air (combustion only), and only the tiny proportion of 4% consists of other materials. These other materials are mainly accounted for by construction materials, food and energy carriers. Just 1.6% of the yearly primary input is put on stock. The whole stock could be estimated to amount to no more than 80% of the yearly throughput; more than 90% of the stock consists of buildings and roads.

On the level of the whole socio-economic system in effect almost all inputs are directly drawn from nature (even the imports are clearly dominated by primary inputs such as energy carriers, see Steurer 1992, p.23), and most outputs are released into nature within the course of a year. This holds true for practically all water and air, and for about half of the other materials. The rest is either put on stocks (with an estimated durability of 30-50 years), invested into goods of a somewhat longer durability (5-10 years) or exported. Thus for the aggregate level of a national economy the distinction between primary and secondary inputs is not very meaningful.

It is very meaningful though when looking upon sectors within the economy.

Table 1 shows empirical material balance-sheets for four selected branches of the Austrian Economy, namely extraction of crude petroleum and natural gas, manufacture of refined petroleum products, manufacture of pulp and paper, and electrical industry. As a result of such material balances it is possible to create a consistent set of material indicators (or indicators for material-intensity) for each branch, which is shown in Table 2. The balances are differentiated into primary input, secondary input, output in the form of goods, and output in the form of non-reused wastage.

Primary input are directly extracted material inputs from nature, which contributes the major part of total input, particulary in basic industries. The portion of primary input in the form of water is extremly high in all industries regarded - it varies between 44% and 97% of the whole material input (see Table 1). So it makes some sense to distinguish between materials-intensity indicators inclusive and exclusive of water. It is indeed interesting to see that the role of water as primary input to the industrial system is about as dominant as for ecosystems.

A very high portion of total input is also primary and consists of oxygen and nitrogen, which are particulary consumed in all processes of combustion. However, that part of the primary input we have not calculated for this empirical presentation[12].

Secondary input are all material intermediary services within the economic system (from one branch to another). Secondary input can be divided into reused waste-material, renewable resource input, and direct packaging-input. Secondary input in the form of durable capital goods or stocks of goods is not defined as material flow and therefore stay out of regard within the flow concept, but would have to be part of material stock balances.

One strategic gap of material flow balances is the difference between total input and total output in the form of goods. That difference is identical with the total material wastage (in gaseous, liquid or solid form) of production, which will not be delivered to further steps of any socio-economic processing and is deposited in the environment in one form or another. The amount of that difference, respectively the total wastage, has a high information value with regard to the checking, controlling and completion of emission-data, whose current availability in Austria, however, is very limited. According to Table 1 the total material wastage amounts to 46% - 98% of the total input (if water is included), respectively from less than 3% to 31% (if water is excluded).

TAB.1 MATERIAL BALANCES FOR FOUR SELECTED BRANCHES OF THE AUSTRIAN ECONOMY (1988, IN MILLIONS OF TONS)

		Extraction of crude petroleum and natural gas	Manufacture of refined petroleum products	Manufacture of pulp and paper	Electrical industry
INPUT					
primary input (intermediary services of nature)	directly extracted resources	2,153	-	-	-
	water	1,761	12,598	220,700	13,811
	oxygen and nitrogen	?	?	?	?
	other resources	-	-	-	-
secondary input (intermediary services of economy)	energy carrier	0,063	0,664	0,386[1]	0,041
	other[2] secondary input	0,005	8,247	5,427	0,686
	(thereof: reused waste materials)	-	-	3,825[3]	0,005
	(thereof: direct packaging input	0,000	0,000	0,051	0,035
Sum		**3,982**	**21,509**	**226,513**	**14,538**
OUTPUT					
goods		2,153	8,129	4,105	0,607
total material wastage		1,829	13,380	222,408	13,931
total material wastage (excl. water)		0,068	0,782	1,708	0,120
Sum		**3,982**	**21,509**	**226,513**	**14,538**
employees (annual average)		2.813	3.391	12.474	72.379
production value in billions of AS		2.916	16.571	36.446	60.415

[1] excl. combustible waste material
[2] incl. deliveries of unprocessed primary inputs by other branches
[3] incl. combustible waste material
[4] as balance of total inputs less goods

Source: Own calculations

In order to compare different industrial activities, different time periods and different countries, we suggest to establish indicators such as those exemplified in Table 2.

TAB.2 INDICATORS FOR MATERIAL-INTENSITY FOR FOUR SELECTED BRANCHES OF THE AUSTRIAN ECONOMY (1988)

		Extraction of crude petroleum and natural gas	Manufacture of refined petroleum products	Manufacture of pulp and paper	Electrical industry
total input per employee (tons/em.)[1]	incl. water	1.416	6.343	18.159	201
	excl. water	790	2.628	466	10
total input related to production value (tons/1.000 AS)[1]	incl. water	1,37	1,30	6,22	0,24
	excl. water	0,76	0,54	0,16	0,01
material wastage per employee (tons/em.)	incl. water	650	3.946	17.830	192
	excl. water	24	231	137	2
material wastage related to production value (tons/1000 AS)	incl. water	0,63	0,81	6,10	0,23
	excl. water	0,02	0,05	0,05	0,00
material efficiency[2]	incl. water	0,54	0,38	0,02	0,04
	excl. water	0,97	0,91	0,71	0,83
packaging intensity[3]		0,00	0,00	0,01	0,06

[1] excl. oxygen and nitrogen
[2] percentage of material output in the form of goods to total material input
[3] percentage of direct packaging input to material output in the form of goods

Source: Own calculations

As can be seen from Table 2, the variability of material intensity between the branches of the economy is very high: wheras in the electrical industry only 10kg of material input are needed to achieve a production value of 1000.-AS, in the petroleum extraction industry 760kg correspond to this production value. The indicator for material efficiency shows quite a different pattern. Here the manufacture of pulp and paper appears to be the most wasteful of the branches analyzed, whereas the petroleum extraction industry as least wasteful. So for these cases there exists no positive correlation between the value of the input and the efficiency with which it is handled.

In order to be able to analyze and properly interpret data of this kind, it would be neccessary to investigate several more branches of the economy and more points in time than we could do for exemplary purposes. As economic statistics in Austria are currently organized it would be quite a tedious task to calculate a complete physical input-output matrix of this kind, let alone the reconstruction of material flows within the economy. Still we think, this task would be indispensable for an empirical description of "industrial metabolism".

5. Purposive Interventions Into Life Processes (PILs)

Purposive interventions into natural ecosystems are historically the oldest form of modification of the environment for economic purposes. It characterizes the beginnings of agriculture and animal breeding. This exchange with the environment is quite different to simple "input", e.g. intake of plants or meat as nutrition - and it is specifically human, at least as specifically as making use of tools.

There are many indications that PILs will gain even more importance in the future. As Moscovici (1990) and Oechsle (1988) stated, emissions are a typical problem caused by a "mechanical" mode of economic production (and a corresponding mechanical paradigm of nature). The necessity to reduce emissions is broadly accepted by now, and in the long run their importance will certainly diminish in relative terms. On the other hand, a new, "cybernetic" mode of economic production (and paradigm of nature) is arising, which is characterized by qualitatively new and enhanced possibilities of human control over nature.

This new tendency can be seen in many examples: The application of analytical-chemical methods in ecology yields new possibilities of directing and utilizing natural processes in order to meet human demands (Korab 1991); new biological technologies are developing rapidly and are politically strongly promoted - last but not least because it is hoped that they will lead to "clean technologies". This tendency can be described as replacing EMIs with PILs, for example using biological instead of chemical techniques (Fischer-Kowalski et al. 1991b).

We developed the following module of indicators in order to mirror relevant processes with which the socio-economic system intervenes into life processes in favor of particular social uses (Fischer-Kowalski et al. 1991a, Haberl 1991, Wenzl und Zangerl-Weisz 1991):

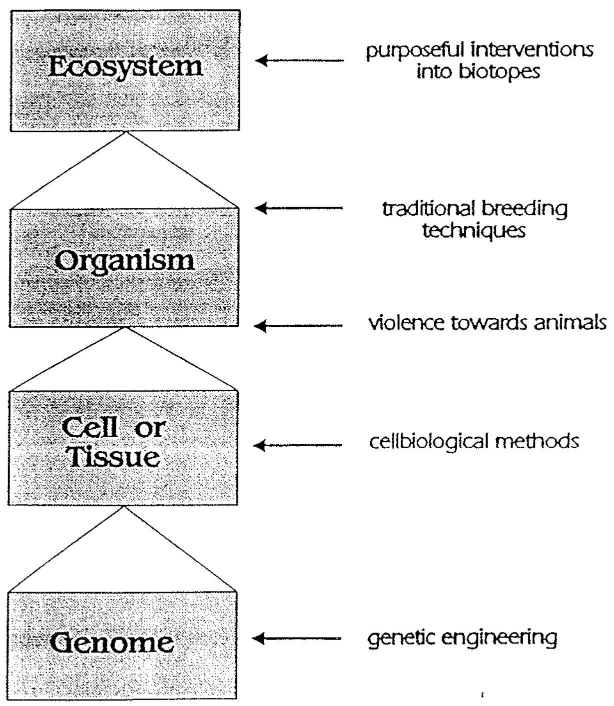
1) **Interventions into biotopes:** Indicators for socio-economic efforts to change the structure of natural ecosystems. The most important efforts of this kind are interventions into water systems, the appropriation of photosynthetically fixed energy (see below), and the input of technically produced substances (fertilizers, pesticides).

2) **Violence towards animals:** Indicators for social activities that cause suffering and pain of animals. This subset contains two indicators, one for the circumstances of keeping animals (long-term aspect), and one for short-term aspects, killing animals, and animal experiments.

3) **Interventions into evolution:** Indicators for direct (genetic engineering) and indirect (breeding techniques) influences on the gene pool (see Wenzl/Zangerl-Weisz 1991).

This systematisation is based upon the different biological hierarchical levels on which these interventions take place (Figure 6).

PILS ACCORDING TO THE LEVEL OF INTERVENTION



Source: Fischer-Kowalski et al. 1991b

Figure 6

5.1. Interventions into biotopes. An empirical example of the socio-economic appropriation of photosynthetically fixed energy

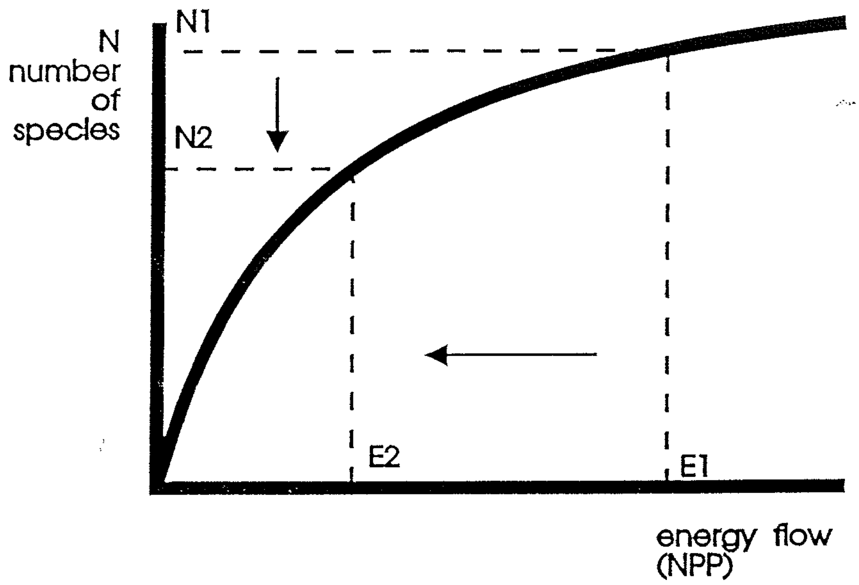
Energy not only is the "motor" for industrial metabolism, but also for natural systems. Ecosystems can be conceptualized with compartment models, in which (more or less closed) materials' circles between the compartments are driven by a flow of energy. In fact, the development of ecology as a theoretically integrated discipline of the natural sciences began with the investigation of energy flows by Eugene P. and Howard T. Odum (see Odum 1983, 1991).

Today, the following concept - reported in rather simplified terms - is broadly accepted: The green plants convert radiant energy of the sun into chemical energy in the process of photosynthesis. The accumulated energy - the net primary production (NPP) - is available to all other (heterotrophic) organisms. Consequently, "photosynthetically fixed energy ultimately supports the great diversity of species that inhabit the world's ecosystems." (Wright 1990, p.189).

NPP is the photosynthetically fixed energy, accumulated by green plants in a certain period of time (usually one year). It is an important figure because of several reasons. First, empirical studies show that "energy flow can be related to numbers of species with species-energy curves." (Wright 1990, p. 189) This means that if the amount of energy remaining in the ecosystem is reduced, the number of species living in this ecosystem will diminish (see Figure 7). Secondly, there are limits to the fraction of NPP which can be used in a sustainable manner. The human appropriation of the NPP currently is estimated to lie between 20 and 40% of the total terrestrial global NPP (Wright 1990, Max-Neef 1991). Even if it is not clear at which percentage of human appropriation of NPP the limits of sustainability are reached, the current amount already is considerable, and obviously cannot be increased without further speeding up the dieout of many other species.

We therefore propose to use the appropriation of NPP by the socio-ecoomic system as (one of three) indicators for purposeful interventions into biotopes (Haberl 1991). The indicator is formulated as the difference between the hypothetical NPP of the undisturbed eco-system and the actual NPP.

THE RELATIONSHIP BETWEEN NUMBER OF SPECIES AND ENERGY FLOW IN BIOTOPES



Source: Wright 1990, p. 190

Figure 7

What does this mean? The hypothetical NPP_h (per space unit and year) depends upon morphological and climatic circumstances. Under Austrian conditions it may vary from about 5 TJ/km^2*a (alpine grasslands) to 50TJ/km^2*a (floodplains)[13]. Would man not intervene, this biological energetic basis would be available to all other species. Man, or speaking more technically, the socio-economic system, may intervene in qualitatively different forms, but they can basically be boiled down to two strategies: (a) It may build structures (such as highways or buildings) that prevent or reduce the NPP in a certain area drastically (the very same road prevents a certain NPP_h each year by its very existence[14]). (b) Consumption: Certain amounts of NPP are harvested (or grazed off by cattle) and serve as inputs to the socio-economic system, thereby being no more available to the ecosystem. What is shown in Table 3 as NPP_a appropriated by the socio-economic system is therefore the sum of "prevented" NPP and "consumed" NPP.

TABLE 3: APPROPRIATION OF NET PRIMARY PRODUCTION IN AUSTRIA (1988, FIRST ESTIMATION)

socio-economic uses	area concerned	photosynthet. fixed energy[1]		distribution
		hypothetical	appropriated by man	of approp.
	km²	NPP_h (PJ/a)	NPP_a (PJ/a)	NPP (%)
agriculture[2]	15.900	370	250	40,4
grassland, alpine pastures	21.000	280	180	29,0
forests (logging)	34.300	580	110	17,7
gardens	1.700	40	20	3,2
traffic zones	1.600	40	40	6,5
buildings	700	20	20	3,2
other[3]	8.000	40	0	0,0
total	83.200	1.370	620	100,0

[1] first estimates based on international literature
[2] including wine
[3] indcluding waters and wasteland

Sources: Bundesamt für Eich- und Vermessungswesen 1989; BMLF 1989a; BMLF 1989b; ÖSTAT 1990; own calculations

The hypothetical NPP on Austrian territory is estimated to be around 1.370 PJ/a. Thus the socio-economic appropriation of the products of photosynthesis in Austria (with 620 PJ/a) amounts to about 45% of the total production[15].

This means that the socio-economic system produces and reproduces environmental structures that permit little more than half of the current photosynthetically fixed energy for all other species but human beings. This certainly is highly relevant both from the viewpoint of the "natural balances paradigm" and from the "conviviality paradigm".

6. Conclusions

The concept of "metabolism" is a very useful approach to direct attention to the physical exchange processes between industrial economy (or as we prefer to call it, the socio-economic system) and its natural environment. As we have tried to exemplify empirically for Austria, a description of such exchange processes links well to standard economic statistics, and in a way mirrors some of the logics of the monetary SNA on a physical level.

Which aspects of this metabolism should be described requires a careful selection process. This selection process may be guided by four basic paradigms for the relationship between the socio-economic system and its natural environment. We have described these as "poison paradigm", "entropy paradigm", "natural balances paradigm", and "conviviality paradigm". These paradigms draw attention to very different ways in which the socio-economic system causes damages in its natural environment, thereby possibly threatening its own survival. This calls for an information system on "metabolism", sophisticated enough to catch a variety of aspects - without expanding beyond reach. We have proposed the outlines of such an information system at another occasion[16].

One of the examples we demonstrated empirically was the calculation of "material balances" and "material intensities" for selected branches of the economy. How much material input (in terms of weight) the economy needs, be it as direct extraction from the environment or from other parts of the economy, and how much material output it produces either as goods for further use or as wastage put out into the environment, are very crucial elements of the description of its metabolism. Empirically it is interesting to note that in the socio-economic system water obviously plays a just as central role as for ecosystems.

Nevertheless, the concept of "metabolism" in its organismic analogy does not take into account a type of interaction between system and environment that is very specific for and very typical of the socio-economic system. It does not just consume certain outputs of its environment (resources), and deposits used up elements as its own output (emissions, wastes), but it purposively intervenes in the structures of this environment, it "colonizes" its environment. This implies a basic asymmetry between the socio-economic system and natural ecosystems. Natural ecosystems may interfere with the socio-economic system (which they do all the time, even strongly so), but they cannot intervene or colonize the socio-economic system in order ot make it more useful to them. Under the circumstances of industrial economy that is as impossible as it is for a monkey to keep a human child as a pet.

So the concept of "metabolism" should be stretched in order to come to grips with this asymmetrical process, but without betraying its methodological qualities which consist in its concentration upon flows (rather than stocks). This is what we attempted by suggesting (and empirically exemplifying) a measure for the socio-economic intake of photosynthetically fixed energy, which is the basis of most of the life on this planet, as a result of such interventions (or colonization). The stunning proportions of this intake demonstrate as much as other indicators the gigantic size of the industrial metabolism vis a vis its natural environment. Obviously, the socio-economic system is a very dominant competitor to all natural ecosystems. But it may be doubted that it is able to completely push them out of existence but for the prize of its own destruction.

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1. This chapter is based upon a two-years study on "causer-related environmental indicators", partly financed within a programme for "new paths towards measuring the National Product" ran by the Austrian Ministry for the Environment. Its content is - to a large extent - product of the cooperation of the whole team, which contained, besides the authors: René Dell'Mour, Peter Fleissner, Anton Steurer, Karl Turetschek, Rudolf Vymazal, Peter Wenzl and Helga Zangerl-Weisz.

2. Attempts in this direction are becoming somewhat more common now, see for example Pearce et al.1990, and the international examples given there,. or Ayres 1991.

3. The notion of "sustainability" claims to be such a "grand" paradigm. But inspite of its generality we think it cannot embrace all aspects these 4 paradigms encompass. It excludes the "conviviality"-reasoning (paradigm 4) completely, and it would rule out some of the more short-term processes in the "poison"-paradigm. It seems a close relative to the "entropy"-paradigm, also sharing its unspecificity.

4. This term can also be used on levels below, i.e. the cell, or even parts of cells.

5. One of the main difficulties for finding a biological analogy comes from the fact that is does not have topographical or physical, but functional boundaries. For operational purposes a topographical boundary may be defined (such as we do here by analyzing the Austrian socio-economic system), but nevertheless physically it shares its space with all other physical systems.

6. This information system was developed for the Austrian Ministry of Environment in order to be integrated into an environmental satellite system to the SNA. It is designed to work not only on the level of the national economy, but on the level of branches of economic activities in terms of standard economic statistics (particularly input-output statistics).

7. This means, for example, that no indicator such as "growing monocultures" would be included since this would be on such a low level of abstraction that no other actor but agriculture could be characterized.

8. Using a funcional basis is very common in energy statistics, for example: "traffic". We differentiate into "transport industry", and in addition to this, each branch of the economy causes its own traffic. Intermediary services by the transport industry may then be distributed among the other branches by input-output techniques; see Dell'Mour et al. 1991.

9. We have calculated the amount of transport (in tons*kilometers and persons*kilometers per year) and the transport intensities of the Austrian economy on a 10-sector level by means of input-output-analysis (see Dell'Mour et al. 1991). The empirical calculation of energy-consumption and -intensities (seperated into renewable/nonrenewable and transport/non-transport) by 40 branches of economic activity is standard statistics in Austria.

10. However, that doesn't supply any information on specific environmental impacts such as the toxicologic risk potential by using matter. That is the explicit function of information on emissions, and indicators for purposeful interventions into life processes.

11. The need for a supplementary system of physical accounting connected to the traditional SNA has gained understanding during the last years. Ambitious attempts have been started by the Norwegian, the French and the Canadian governments (see Corniere 1986, Friend 1988, OECD 1988). The model of material balances and intensities as represented below is a contribution to that discussion in progress.

12. The data bases to do so would be sufficient, if confined to processes of combustion (which makes for the major share of the total).

13. 1 TJ = 10^{12} J; 1 PJ = 10^{15} J

14. There may also be cases in which the intervention causes an increase of NPP above the "natural" level, such as by growing maize instead of wood. But in practically all such cases this surplus NPP is then extracted from the ecosystem by harvesting.

15. It is interesting to note that the amount of appropriated photosynthetically fixed energy corresponds quantitatively to the end use of (technical) energy, which for Austria is around 750 PJ/a.

16. For more detail on this information system as a whole, see Fischer-Kowalski et al.(1991a).