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On the cultural Evolution of social Metabolism with Nature

Sustainability Problems Quantified

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On The Cultural Evolution of Social Metabolism With Nature: Sustainability Problems Quantified

Abstract

The paper seeks to determine the concept of "sustainable development" in operational terms, looking at the way in which various societies handled their „sustainability problems". There are two aspects which we consider essential for: On one hand, it is the particular form in which societies establish and maintain their material input from and output to nature, i.e., their "social metabolism": The mode in which they organize the exchange of matter and energy with their natural environment. On the other hand, it is the social strategies employed to transform parts of their natural environment: This we prefer to call "colonization". Part 1 of the paper is concerned with an exploration of the long term cultural evolution of sustainability problems from hunter and gathering societies to agricultural societies and, finally, industrial societies. Part 2 presents the results of an empirical analysis of the structure and dynamics of social metabolism of industrial societies. The final part is devoted to strategies which might permit industrial societies to reduce and transform their metabolism in a way which renders it a process that may justly be conceived as "sustainable development".

1. Introduction

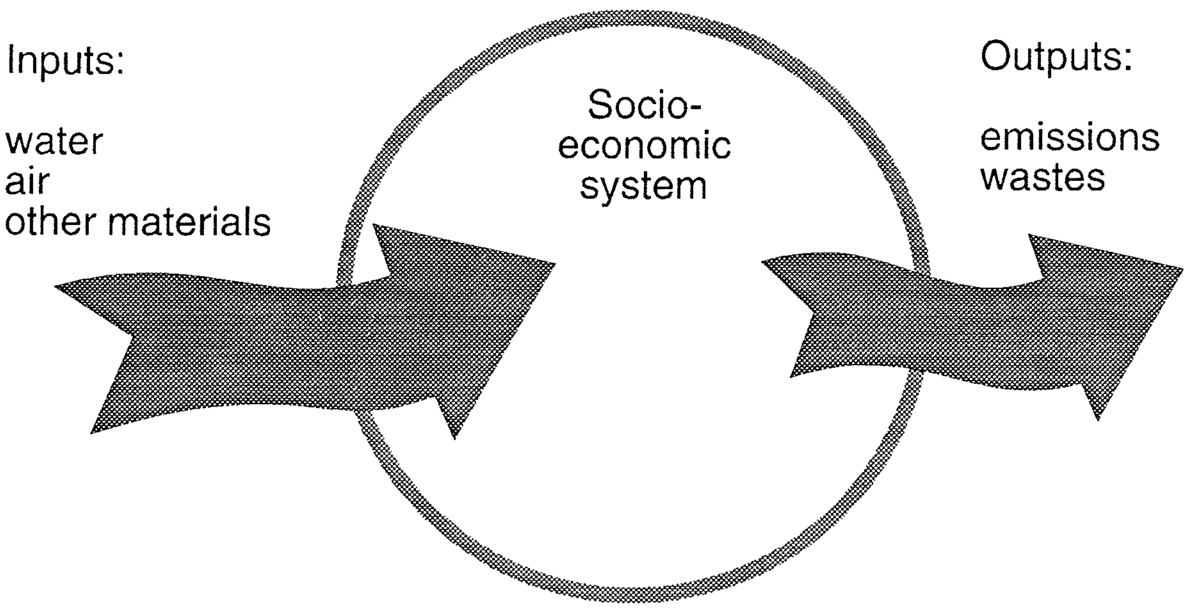
The debate concerning environmental problems has witnessed profound changes in recent years. In particular, it was the emergence of "sustainable development" as a key concept that has proved to be extremely fruitful in stimulating and provoking a dialogue integrating various scientific disciplines (from the natural to the social sciences) as well as conflicting political and social groups (from top-level managers to NGO-representatives). In the course of the discussion a wide variety of conceptions concerning sustainability has emerged. Therefore, the concept of "sustainable development" needs to be operationalized if it is to be relevant in terms of political and economic strategies.

To do so, we think that it is useful to conceptualize societies as subsystems of the biosphere.[1] Whereas the biosphere, i.e. the global eco-system, is closed materially yet an open system with respect to energy, societies are subsystems which are open both with respect to matter and energy (Daly, 1994). From this point of view, strategies for sustainable development must be vitally concerned with the organization of flows of materials and energy between society and nature or, in other words, with social metabolism (Ayres and Simonis, 1994a; Fischer-Kowalski and Haberl, 1994).

[1] Such a conception, of course, does not fit within what Catton and Dunlap (1978) have identified as the paradigm of "human exceptionalism" predominating within the social sciences.

Essentially, metabolism is a biological concept connoting the internal processes of a living organism. Organisms maintain a continuous flow of materials and energy with their environment to provide for their own functions, for growth and/or reproduction. In an analogous way, social systems convert raw materials into manufactured products, services and, finally, into wastes - processes which economists describe as production and consumption (see figure 1; Ayres, 1994; Ayres and Simonis, 1994b).

Figure 1.: Social Metabolism



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Environmental problems arise on both sides of this metabolism: With respect to their "inputs", societies take in minerals, fossil fuels, uranium, biomass, oxygen, etc. Of course, human societies have always been beset by problems of resource scarcity related to this process of "productive consumption". Societies have traditionally attempted to cope with these problems by migrating to more fertile regions, reducing procreation, changing nutritional habits or established modes of production, by means of trade, expelling other peoples, and by many other measures. On the "output"-side, environmental problems arise if the waste materials of societies cannot be absorbed and integrated in the natural environment in a useful or, at least, innocuous way. This type of environmental problems is historically old - even in classical antiquity the problem of safely removing the faeces from densely populated cities had to be solved. Gone are the times, however, when these problems used to be, more or less, local phenomena which could be solved by fairly restricted measures. They have evolved into global threats as a result of the development of industrial societies which, to a great extent, rely on inputs extracted not from current biological cycles but - like fossil fuels, mineral resources, metals and the like - are removed from global deposits or sinks (Fischer-Kowalski and Payer, 1993).

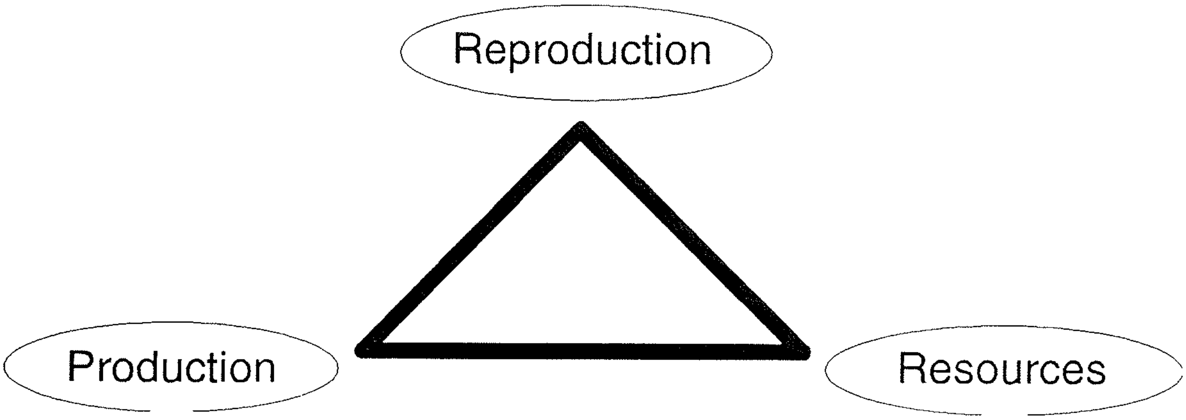
To identify the specific relationships between societies and nature, however, it does not suffice to look at their metabolism. In order to maintain their metabolism, societies transform natural systems in a way that tends to maximize their usefulness for social purposes. For example, natural ecosystems are replaced by agricultural ecosystems (meadows, fields) designed to produce as much usable biomass as possible, or they are covered with concrete or asphalt to provide even surfaces which greatly enhance the joy of riding a car. The genetic code of species is altered in order to increase their resistance against pests or pesticides, or in order to produce pharmaceutics. We have called this type of intervention into natural systems "colonization" (Fischer-Kowalski and Haberl, 1993). Colonization may be defined as social activities which deliberately induce disequilibrium into natural systems and maintain them in that state.

Since we want to analyze the history of sustainability problems in this article, we consider it useful to characterize past societies according to the differences in the way in which they have organized their metabolism and colonized their natural environment. To our knowledge the best guideline for such an analysis is the approach of materialist cultural anthropology outlined by Harris (1989, 1990).

From the point of view of materialist cultural anthropology societies are considered as forms of organization that are expected to serve but one ultimate purpose, i.e. to sustain mankind as a species. These societies have evolved from rather small, egalitarian groups of hunters and gatherers to the highly specialized industrial societies.

The culture of each society may be characterized as a specific balance of elements which Harris arranges in a "magic triangle": Reproduction, production, and resources (see Figure 2). All three elements run into sustainability problems, and cultural evolution may be viewed as a continuing struggle of societies trying to solve these problems. If, for example, people reproduce too fast, traditional resources will not suffice to provide enough food - as a consequence, new resources must be found and/or new production techniques have to be developed - otherwise people will starve to death. Whereas Harris (1990) focuses on the explanation of cultural traits like food taboos sustained by ecological necessities, we will use his triangle to describe the cultural evolution of sustainability problems in a more general manner.

Figure 2.: Harris' Triangle



© IFF-Social Ecology, after Harris (1989, 1990)

The cultural evolution of societies may be interpreted as a story of sustainability problems and, therefore, may serve to explain dramatic changes in the mode of production, in the resources utilized, in the forms of population control, and in the complex interrelations between the elements of the triangle. This interpretation may likewise be expected to cast some light on the question why some cultures broke down while others proved to be "superior". This analysis provides a kind of framework to distinguish types of cultures according to their characteristic relationship with nature. These sustainability problems may be viewed as problems of maintaining the social metabolism under given environmental circumstances. This metabolism has two important aspects:

1. The materials flow aspect: The social metabolism may be measured as mass throughput [kg.a^{-1}] for nutrition, shelter, clothing, buildings etc. From this point of view, societies are complex material systems, ingesting various resources and emitting diverse waste substances.
2. The energy aspect: Like any other dynamic system of material stocks and flows, social systems are driven by a flow of free energy. Every society has at least the biological energy turnover of its members. Nowadays, in industrial societies the energy input per capita is at least 40 times the biological energy requirement of humans.

The metabolism of a human society at a certain time in a certain region may be characterized by its mass and energy input. Obviously, the three elements of Harris' triangle determine these key figures: Input per capita and year is largely determined by the mode of production, which can only be sustained if the necessary resources are available in sufficient quantity and quality. It is the size of the population, then, that determines the overall input of both energy and mass. On the other hand, the sustainable population density is determined by the mode of production and society's ability to exploit certain key resources.

In what follows, we will first outline the major steps in the evolution of sustainability problems by analyzing the metabolism and colonization strategies of various societies using a broad classification of societies; in a second step we will take a closer look at specific developments in recent decades and substantiate the analysis by contemporary empirical data.

2. Sustainability Problems: From Hunters and Gatherers to Industrial Societies

As each human being has a metabolism, the metabolism of a society has to be at least the sum of the metabolisms of its members. The history of mankind is a history of the expansion of social metabolism far beyond this sum total of individual metabolisms. Simultaneously, societies colonized more and more natural systems for their own purposes, and the intensity of intervention into natural processes has increased.

The history of the relations of societies with their natural environment may be classified into three main stages (Sieferle, 1993): (1) hunter-and-gathering societies, (2) agrarian societies,[2] (3) industrial societies.

2.1 Hunter and Gathering Societies

99% of the time since the emergence of the human species mankind has lived as hunters and gatherers. Hunters and gatherers lived in bands of 20 to 50 people. The metabolism of hunters and gatherers did not very much exceed their biological metabolism. Their lifestyle was essentially migratory and they probably did not have a lot of heavy goods to carry. Nutrition was provided by gathering fruits and other edible parts of plants, by hunting and fishing. To a great extent, the ratio of vegetarian food to meat and fish depended on the environment. Whereas Inuit almost exclusively live on meat and fish, !Kung bushmen meet 70-80% of their energy demand by means of vegetarian food. Their tools were made of stone, wood and bones. Fire was used for cooking, warmth, protection against carnivores, and driving game animals over cliffs or into ambushes. It seems that in hunter and gathering societies there was a lot of leisure time, since they were able to make a living with about 3 or 4 hours of work per day (Harris, 1991; Ponting, 1991; Wing and Brown, 1979). Hunters and

[2] Sieferle (1993, p. 14) distinguishes "simple agrarian societies" and "agrarian high cultures". For simplification we do not draw this - otherwise very reasonable - distinction here.

gatherers did not colonize nature in the sense that they deliberately modified natural systems in order to make them more productive or convenient for their needs.[3]

It is very likely that the major sustainability-problem for hunter-and-gathering-societies was the acquisition of sufficient amounts of food. Since the food supply was regulated by nature, each ecosystem had a rather invariable carrying capacity for humans. Whenever the number of people exceeded the critical level, there were two possibilities: Migration to new places with sufficient food supply or starvation. It appears that hunter-and-gathering societies had a lot of regulatory mechanisms which kept population growth at very low levels (Harris, 1991). Nervertheless, they managed to populate all continents and all climate zones within a span of approximately 50 millenia.

This mode of production came to its limits when these mechanisms failed to keep population numbers small enough. There is evidence that hunters and gatherers where involved in the extinction of many big animal species: Following data given by Ponting (1991), 86% of the big animal species in Australia became extinct in the past 40.000 years, most likely because of hunting activities of the aboriginals. In South America 80% of the bigger animal species became extinct, in North America 73%. The "invention of agriculture" - the neolithic revolution - seems to have happened because it was impossible to feed the grown number of people.[4]

2.2 Agricultural Societies

In terms of our theoretical approach the major innovation of agricultural societies compared to hunter and gathering societies consists in the fact that most of their metabolism is based upon "colonization". As elaborated above, colonization implies the deliberate transformation of natural ecosystems by means of the continuous application of human labour. In the course of this process, ecosystems are thrown into a state which is far from their natural balance but, at the same time, they yield more of those products which society's metabolism needs[5].

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[3] There is one exception: It seems that fire was used to burn down forests in order to promote herbaceous plants, which are usable for prey animals to a greater extent than woody species (Butzer, 1984; Harris, 1991).

[4] This change in the mode of production coincides with a major climatic turn - the end of the last glacial period. The increased temperature changed forests to grasslands. This promoted the invention of the domestication of animals rather than hunting them. Harris (1990) argues that it was not the lack of technological abilities which retarded an earlier development of agriculture, since hunter and gathering-societies knew some agricultural technologies long before they where used on a broad basis. They did not use them simply because agriculture is a much less convenient way of food production than the one they were used to.

[5] As soon as the investment of human labor stops, these ecosystems become re-naturalized: domestic animals reconvert into wild ones (and regain those traits successful in natural selection), gardens and fields are reconverted into forests or grasslands. Some of this renaturalization has to be permitted periodically in order to maintain the regenerative qualities of the ecosystems - wild species have to be

What does the metabolism of agrarian societies look like? Of course, it is still based on biomass for nutrition. Compared to hunter and gathering societies, however, the necessary amount per capita will have multiplied: Now it must not only contain food for humans but also for their domestic animals. Firewood will not only be needed for heating and cooking, but also to melt metals, produce metal goods, support mining shafts sunk for the removal of salt and metals (Bieler, 1992), for the construction of houses, ships and carriages[6]. To an ever increasing extent, the biomass required for nutrition (grains, animal milk and meat) must be extracted from the "colonized environments". Specific natural cycles need to be supported by human labour, and social wastes (in particular, human and animal faeces) must be applied in order to retain soil fertility. This, in turn, must be supported by a "colonization" of local and regional water households. Irrigation systems need to be established, the water supply of larger settlements must be organized, wet areas need to be drained and cities protected from flooding. Forests - formerly an abundant resource - are mostly just exploited in much the same way as the sea is harvested for fish, with society relying completely on the self-regenerating capacities of nature.

A new large fraction of the social metabolism emerges as a consequence of the sedentary way of life, i.e. mineral materials used for construction. Storehouses, harbour and city walls, dams, roads, fortresses and other buildings require an enormous amount of stones to be moved and heaped up. And, of course, resources like metals and salt are introduced which account for a small but crucial fraction of the social metabolism (salt is a key prerequisite for the domestication of animals).

If now we relate these changes to the initial "triangle" of the cultural balance as outlined by Harris, we may reach the following conclusions:

(1)Initially, the "sustainablity problem" was registered and experienced as a chronic shortage of nutrition. The problem had emerged as a result of a very slow but steady population growth and, at least regionally, was aggravated by a major climatic change.

(2)A new mode of production was "invented" which led to the "colonization" of parts of the natural environment instead of its mere exploitation. This implied a significant change in the function of human labour: Increasing the amount of labour put into those "colonies" permitted a multiplication of returns yet, at the same time, did not result in the depletion of the natural base. Much of this labour was, indeed, invested in upgrading the carrying

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crossed in with domesticated plants and animals, forests have to be given time to grow again in slash-and-burn agriculture in tropical zones, fallow periods have to be established in rainforest agriculture.

[6] According to Farb (1988, p. 49), Shoshone hunters produced two calories per one calory spent on hunting; Maya peasants harvested 33 calories per calory invested. This, of course, refers only to the hunters' respectively farmers' labor and is not calculated on a per capita basis for the whole population. But it still is indicative of the enormous increase of biomass appropriated by human societies with the transition from one mode of production to another. One local example may serve as an illustration: In order to stabilize St.Marc's Plaza in Venice 1 million of oaks from Istria were driven into the ground of the lagoon during the 12th century. The continuous demand for wood during the ancient empires resulted in the deforestation of the whole Mediterranean region - with the accompanying climatic changes.

capacity of natural systems (such als ploughing, fertilizing, flooding and irrigating, or feeding of animals). This intensification of labour and the seeming increase in labour productivity both induced and permitted an excess population to profit from it, to organize it - and to avoid it. Thus, much larger societies with an elaborate social hierarchy and division of labour could develop and exist in the same environments at a much higher population density.

(3)This change was accompanied by a change in the cultural regulation of reproduction. The sedentary mode of living and the new value of child labour stimulated population growth. Although practically all agrarian societies also apply some kind of birth control (and, therefore, have population growth rates much below the rates that are biologically possible), the population during the ancient empires, e.g., grew at rates of approximately 0.5% annually (compared to about 0.001% in hunter and gathering cultures; Hassan, 1981; cited in Harris, 1991; p. 96). Thus, human populations tend to outgrow their nutritional base.

(4)One way to respond to this was to culturally regulate what should legitimately be considered a "resource". Duby (1984; p. 70) for example, reports that during the 6th century strong taboos predominated in Europe against the cutting of trees - taboos which the Church had difficulties to overcome despite an abundance of undernourished people. Harris (1990) provides a wide range of examples referring to food regulation, such as the prohibition of eating pork (3rd book Mose) or the institutionalization of the "Holy Cow" in India[7]. As is well known, all forms of vegetarianism require less (by a factor of approximately 10 less) plant biomass than eating animal products or animal meat (which have to be fed on plants before); thus, religious prescriptions of vegetarianism may be found in many agrarian cultures. Other ways to respond are migration, the colonization or conquest of new territories[8], or civil wars which decimate the population. Finally, it may be left to nature herself to regulate by means of positive checks, i.e. by famines and epidemics. Each agrarian culture has used a varying assembly of these means throughout the centuries, and for most of them malnutrition of the majority of the population was as common as childbirth, hard labour and cruelty.

Thus, agricultural societies - despite the fact that they lasted for a few millenia and gradually colonized most parts of the earth that could easily be settled - did not develop a way of life that was "sustainable" in the long run - they depleted many of the natural resources they depended upon, such as forests and arable soil, and they eventually rendered no more than a fairly miserable, hard-working and badly nourished life for most of their members. Improvements in technology such as the use of iron ploughs and horses brought only temporary relief that was soon compensated by population growth. The "natural limits to

[7] He analyzes that the prohibition of eating pork in the Middle East corresponded to pigs becoming direct nutritional competitors of humans as a consequence of deforestation in this region - before, pigs had been able to feed on themselves in the woods. Had there not been established a general religious taboo, the further breeding of pigs would have required sacrificing the grains and other increasingly scarce resources like shadow and water pools needed for the direct supply of humans (Harris 1990, p. 180).

[8] The importing of slaves as in Ancient Rome has a similar effect: It "externalizes" the biological costs of child bearing and rearing to a different territory.

growth" were set by the amount of available land and its capacity for food production; the margin of soil productivity increases which were amenable to technological manipulation was not very substantial.

2.3 Industrial Societies

Parallel to this colonial expansion of agrarian cultures a new mode of production developed gradually within Europe, for which this expansion and the accompanying improvements in the means of transportation (and increased possibilities of trading) were of key importance. We are not going to discuss the reasons for this transition to industrialism here in detail, but only position this new mode of production in the framework of the above triangle.

However slowly the new mode of production, its technical inventions, its reorganization of the division and organization of labour came into being, its final breakthrough depended on the use of a qualitatively new resource, i.e. fossil fuels. First, and for a long time, this involved only coal, with oil and gas becoming ever more important. In view of the constant scarcity of life-sustaining resources of the agricultural era (the supply of animal labour always competed with humans for nutrition), this may be looked upon as an environmentally benefactory innovation: There is no other living system that human societies might depend upon that is vitally interested in fossil fuels or in the many other subterrestrial resources which - with the help of fossil fuels - may now be effectively utilized. Thus, the social metabolism can be greatly increased without decimating the base of human nutrition.

Unfortunately, however, this induces new problems. Although these problems may, in the long run, certainly affect inputs, they become manifest more immediately with respect to the output of social metabolism The mobilization of huge amounts[9] of materials stowed away for geological periods in subterrestrial sinks and their eventual deposition in the biosphere kicks off biochemical processes on a planetary scale and at a speed beyond the reach of gradual evolutionary adaptation. Local and regional consequences of this were felt quickly (e.g. fogs detrimental to human health and agricultural productivity in 19th century England, see Bowlus, 1988), but global and long term consequences will be felt for centuries to come. Thus, the intermediate "bottleneck" of human growth (whether it be growth of population and/or of metabolism), e.g. the scarcity of energy based on current biomass, has been overcome (at least within industrial societies) and substituted for an environmental "bottleneck" on the side of the "outputs" or off-products resulting from industrial processes. (Of course, there is another "input bottleneck" about to come, when the so-called "non-renewable resources" come to an end, one after another.)

At the other corner of the triangle - reproduction - industrialism seems to have had beneficial effects in the end. During the transition to the industrial mode of production (historically in

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[9] Ayres (1991), for example, demonstrates that the amount of carbon, nitrogen, sulfur & phosphor mobilized by social metabolism involves a share ranging from 5% up to several hundred percent of natural processes.

Europe, North America and Japan, and currently in many parts of the rest of the world) the traditional cultural regulations of population growth broke down. However insufficient they had been, what followed was a veritable population explosion. In the early phases of industrial development theories like that of Malthus made it seem inevitable that most members of industrial societies would have to be kept just at a minimum level of income, else they would bear more children than the labour market could absorb and the soil could feed (Sieferle, 1990, p. 90). In later stages the mechanism proved to be different: The industrial mode of living changed the cost-benefit ratio of having children, i.e. lowered the benefits and increased the costs, so that it became culturally established to have very few children or even no children at all (Heinsohn et al., 1979). This cultural change became effective even before the invention of elegant technologies of birth control. Thus, in the centres of industrialism the population does not grow any more except by immigration. This, of course, is not the case at the "peripheries"[10], and there it is still a matter of hope whether a "demografic transition" will take place.

The "sustainability problem" of industrial societies, therefore, is squarely rooted in the size and quality of their excessive metabolism - and this is what we are going to analyze in our next paragraph.

3. Industrial Metabolism

3.1 The size of the industrial metabolism

One can think of two reasonable ways to look at the "size" of the metabolism of a society:

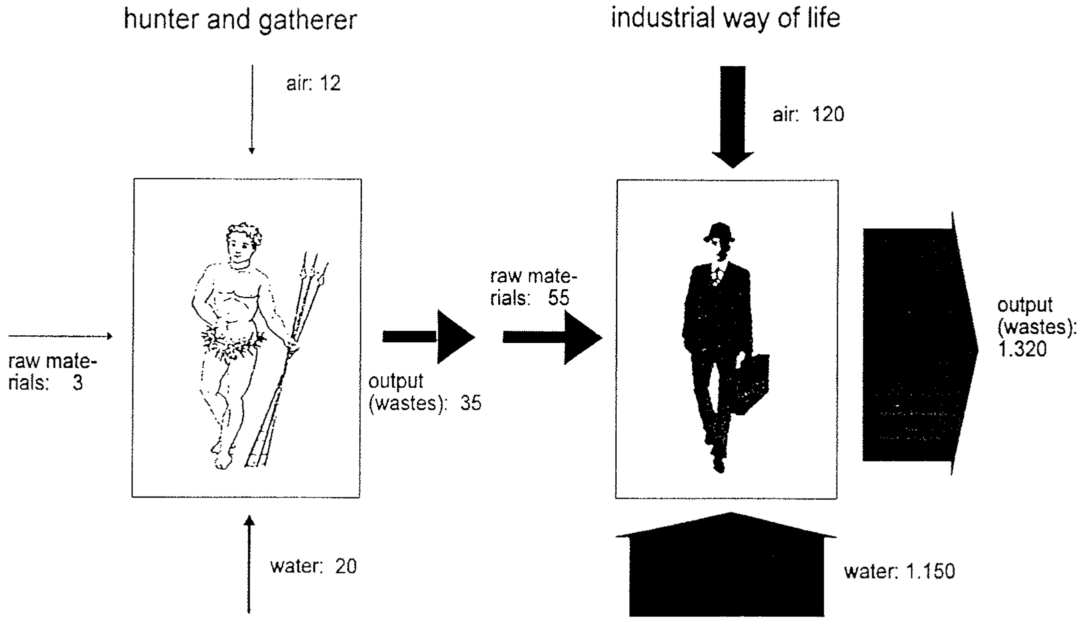
1) One way is to look at the amount of materials processed by a society. These materials are extracted from nature, used and transformed in one way or another within society, and are eventually returned into natural cycles as wastes or emissions. This is a more or less simple input-output calculation in material units (e.g. tons) which may be computed - on the basis of some methodological assumptions and conventions that are gradually being agreed upon internationally (Ayres and Simonis, 1994) - from standard economic statistics. This results in a kind of material "national product", with tons rather than particular currencies serving as accounting units. Divided by the size of the population, this figure provides the per capita metabolism of the average member of a society. Interestingly enough, these per capita values are very similar internationally for highly industrialized countries (Jänicke, 1994).

This per capita metabolism may be compared to the metabolism which - using historical and anthropological data - can be estimated for hunter and gathering societies, as shown in Figure 3. Accordingly, contemporary Austrians or Germans have about 50 times the metabolism of people who inhabited the same region some 4000 years ago. They use about

[10] In several African countries, for example, population growth rates at present amount to an annual 3,5% to 6%.

10 times as much air, 20 times as much solid "raw materials" and 60 times as much water (see figure 3). Roughly speaking, they therefore weigh upon their natural environment 50 times as much as their predecessors. (If the 70% of the world population now living under more or less agrarian circumstances changed to an industrial mode of living, the stresses upon the environment, judged by this crude measure, would multiply by a factor of approximately[11] 10, disregarding population growth).

Figure 3: Comparison of the Social Metabolism of Hunters and Gatherers Compared with Members of an Industrialized Society (in kg per capita and day)



[11] We do not yet have good estimates for the size of metabolism in agricultural societies. They are difficult to establish since there is a great regional and temporal variance. But we are currently working at the reconstruction of typical examples.

2) A second way is to look at the size of the metabolism of society in terms of energy. As far as the total energy "income" from the sun is concerned, the energy inputs of social systems, even under industrial circumstances, are very low. But what is more relevant is the annual energetic net primary production of plants - sun energy incorporated into plant biomass within a given period of time. This energy is the nutritional base of all heterotrophic life on this planet. Humans live on this energy as well as all animals and all microorganisms that are not capable of photosynthesis. The amount of this net primary production (NPP) of plants depends on climate, soil quality and the availability of water, and on a planetary scale can only be marginally increased by human techniques[12]. The proportion of this NPP that is appropriated by human societies[13] is, therefore, a good indication of the "size" of social metabolism visavis its natural environment. As soon as societies appropriate more than 100% of NPP, they "consume more than what is growing" and very quickly deplete their own and only nutritional base. According to Vitousek et al. (1986), human societies appropriate about one third of world-wide terrestrial NPP and - as a result of population growth alone - this percentage may be expected to double within the next 35 years (Daly, 1992). According to our calculations for Austria, this industrial society appropriates more than 50% of the NPP on its territory.[14]

Thus, according to both ways of looking at it, the size of the industrial metabolism is both excessive in comparison to other modes of production and very large in relation to the natural environment that it feeds upon. If one single species (together with its domesticated animals) needs half of the nutritional basis of all animal species taken together, it clearly competes the rest to extinction.

Is there any chance for industrial societies to scale down their metabolism, either in terms of materials or in terms of energy, or both? Before we approach this question more closely, we have to look at the structure of an industrial country's metabolism.

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[12] More easily it can be - and is being - reduced through overuse of land and consequent desertification, through toxic emissions etc. Most anthropogenic biotopes (such as corn fields or orchards) are less productive than the natural ones that would grow in the same place (such as natural forests).

[13] Society may "appropriate" this energy in two different ways: a) By preventing its generation or reducing the quantity of energy being generated. Buildings or roads, for example, prevent the growth of plants in this area and thereby reduce the NPP that can be generated. In Austria almost 10% of potential NPP is prevented by built constructions. Another way of preventing NPP is planting biotopes that are less productive than the natural biotopes that would evolve there in the absence of intervention - such as grasslands, gardens or fields (instead of woods). b) By harvesting the plants (or part of the plants) growing in an area. In Austria the harvest of wood accounts for almost 29% of NPP-appropriation.

[14] Not to exploit forests beyond their reproduction rates was the original definition of "sustainability". Even for forests this just means that there is growing as much wood as you harvest. To harvest wood to this extend does certainly not mean to harvest a hundred percent NPP on this territory, but 50 percent at best. Still, this does not take into account the living conditions of all the other species for which forests provide. They were disregarded and successively extinguished by the application of this "sustainability rule". According to Weterings and Opschoor (1992), sustainable amounts of social NPP-appropriation should not exceed 20% in each territory if a reasonable degree of biodiversity is to be maintained.

3.2 The Structure and Dynamics of Industrial Metabolism - the Case of Austria[15]

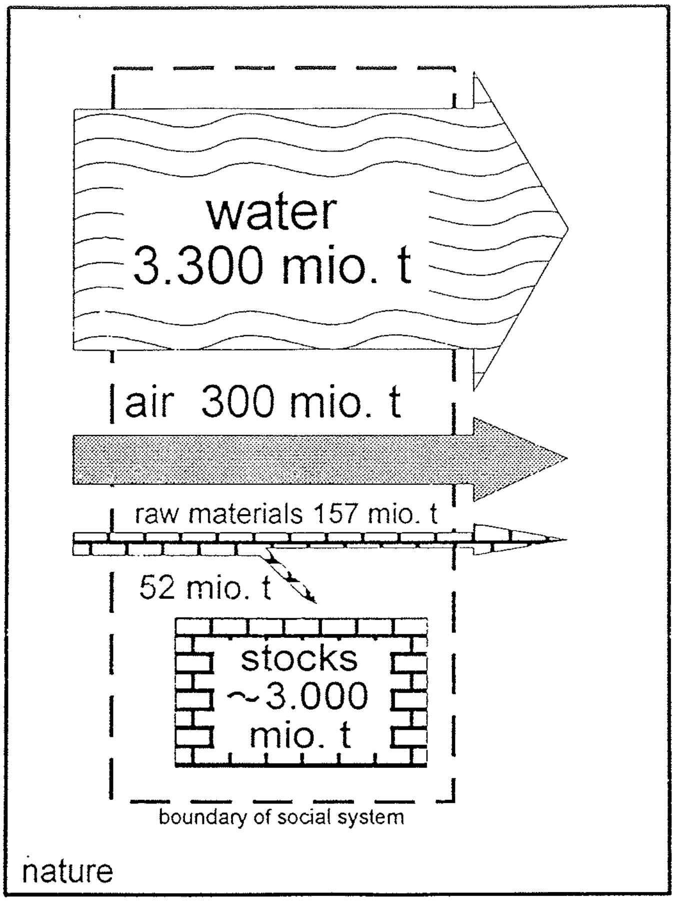
In terms of quantity and mass, it is water that by far holds the largest share (88%!) in the metabolism of Austrian society. It uses a total volume of 3,3 billion tons of water annually (1150 litres per inhabitant per day) - not including a multiple of that amount currently used to drive the turbines of electric power plants. With an annual average precipitation in Austria of 1,2 cubic meters per square meter (Katzmann et al., 1989) total precipitation amounts to about 100 billion tons annually. This implies that already as much as 3% of the annual amount of precipitation is diverted, heated up and polluted by society. About half of this water is needed for cooling purposes in industrial energy production.

The next largest segment of the metabolism (8% of the total) is air. 300 million tons of air per year (or 105 kg per inhabitant and day) are needed to extract its oxygen part for combustion and technical processing.

Only a small fraction (4% of the total) of industrial metabolism consists of solid matter - 160 million tons of "raw materials" in the narrow sense of the word are absorbed into the economy annually (55 kg per inhabitant per day). From these solid materials roughly 60 million tons (about one third) are put on stock (mainly buildings, roads and the like), more than 100 tons are annual throughput, issued into the environment as wastes and emissions (see Figure 4).

[15] We use Austrian data for this analysis but - as comparisons with data for Germany (Schütz and Bringezu, 1993) and Japan (Statistical Yearbook, 1992, quoted in Jänicke, 1994) have shown, they can be regarded as quite representative for highly industrialized countries.

Figure 4: Overall Structure of the Industrial Metabolism



© IFF Social Ecology, Data for Austria 1988 in mio. metric tons, source: Steurer (1992)

Interestingly enough, even under industrial conditions and in terms of mass it is the direct extraction of raw materials from nature that accounts for the largest part of inputs into the economy on a national level, and it is the national territory that provides the space where most of it is extracted. With respect to water and air, of course, this involves the local utilization of a good that is truly transnational by nature. But with respect to the raw materials input of 157 million tons not more than 40 million tons (25%) were imported from abroad[16] - with more than half of it being fossil energy resources.

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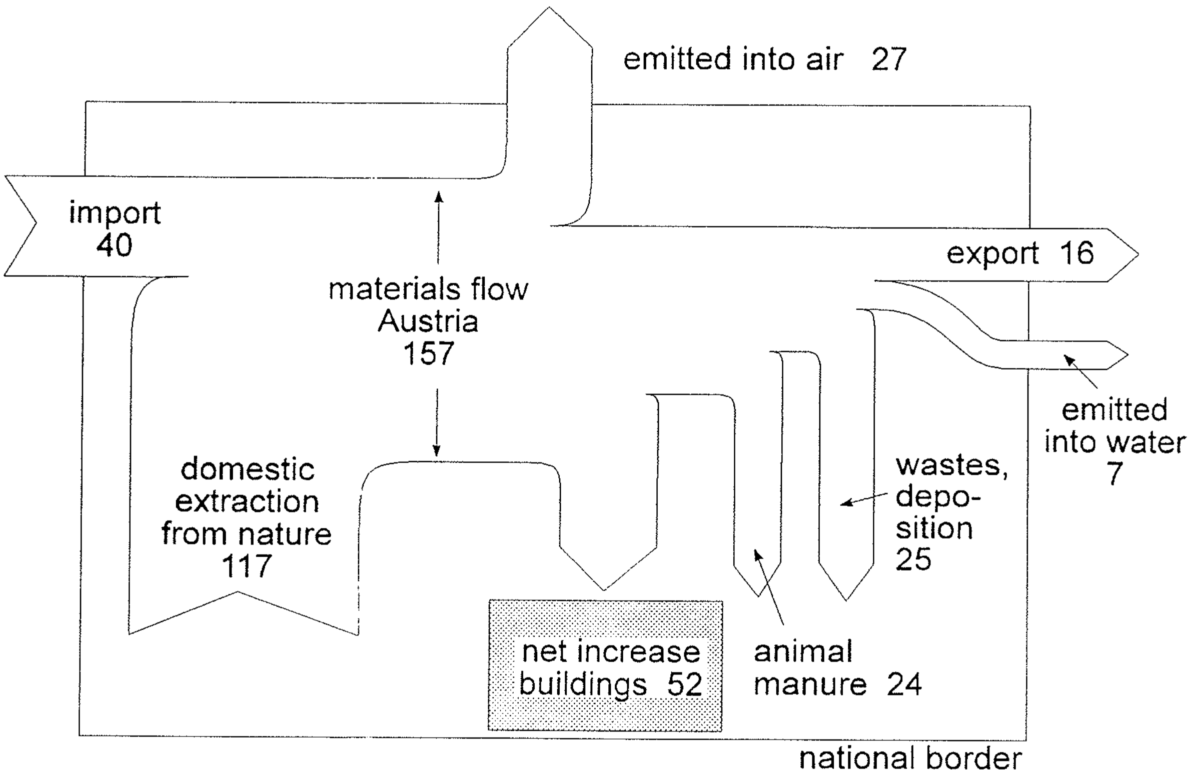
[16] This calculation is not quite fair, though, since imported materials are only computed by the weight they have when they cross the national border. In their country of origin they have accumulated an additional material "rucksack" such as wastes produced during production, transport fuels etc. which is not included here, but which is to be included in case they are extracted and processed within the national territory. Symmetrically, however, this is valid for exports as well.

Outputs originating from solid raw materials are more likely to be emitted as wastes to the transnational mediums like the atmosphere and the water system than to be "exported" as products in an economic sense. 27 million tons are discharged into the atmosphere, mainly in the form of CO_2, and another 7 million tons of residuals are discharged into the country's rivers (and part of it finally to the sea). Compared to this "export of emissions", commodity exports amounting to a total volume of about 16 million tons are rather trivial, indeed (see figure 5).

Figure 5: Raw Materials Flow with Reference to the National Territory



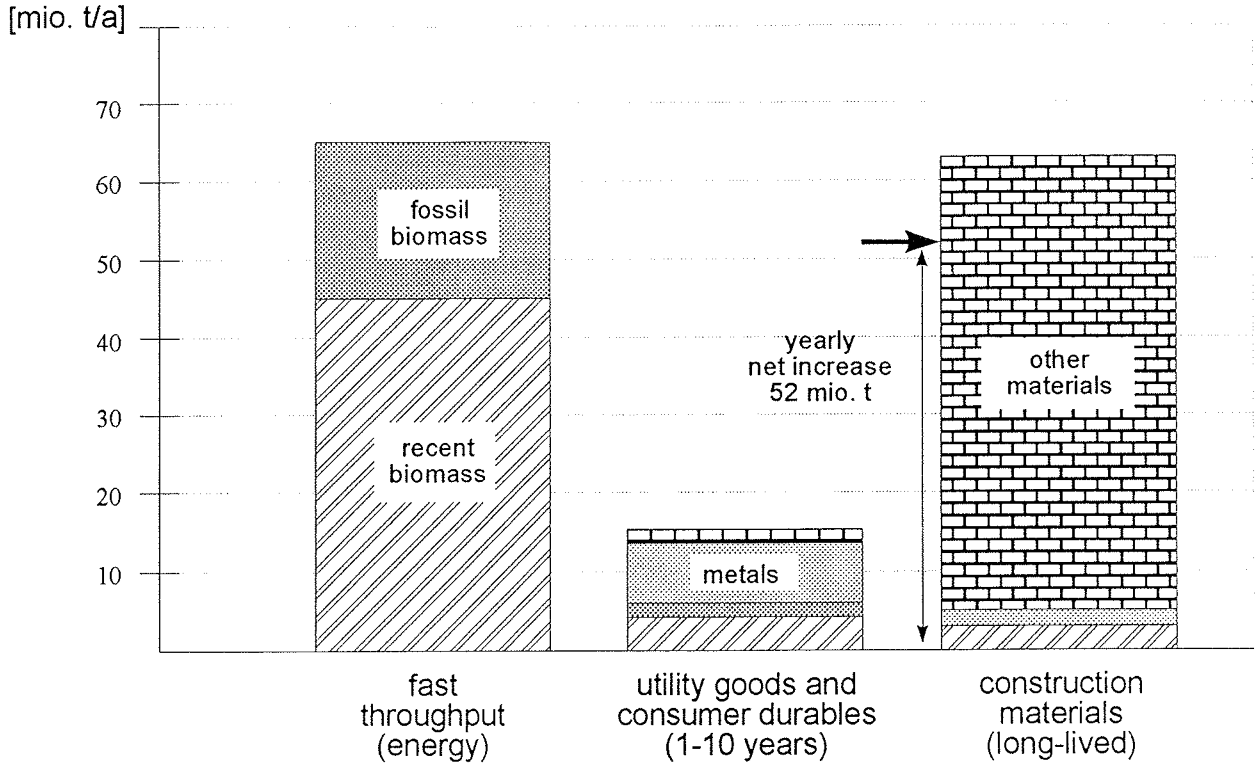
© IFF Social Ecology, Data for Austria 1988 in mio. metric tons, source: Steurer (1992)

Let us now take a look at what these (solid) raw materials consist of and what they are used for. Figure 6 groups them according to the time span for which they are used as a commodity within the social system before they are reverted to the natural environment as wastes or emissions. Clearly, energy carriers (in the wider sense of the term, i.e. fossil as well as recent biomass) are used up most rapidly[17] - they amount to approximately 40% of total raw materials input. Consumer- and durable goods with a typical lifespan of between a

[17] The dominant role of recent biomass compared to fossil fuels is due to its high water content; converted into dry mass, its relevance drops by 50%.

week and ten years hold a share of approximately 15% of turnover and, therefore, are quantitatively much less significant. Building materials (mainly gravel and sand), on the other hand, are about as important as energy sources - every year sees the relentless completion of another 52 million tons of buildings and structures that are added to the tentative volume of 3000 million tons already „beautifying“ the landscape.

Figure 6: Raw Materials Flow with Reference to Turnover Time and Quality



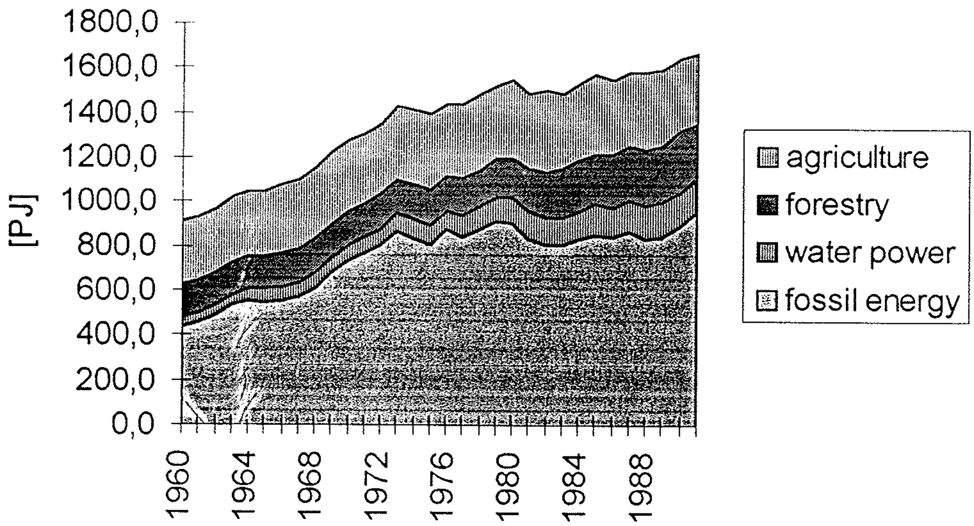
 Data for Austria (excluding exports), source: Steurer (1992)

As we can learn from this, the supply of energy and the supply of materials for construction by far dominate the industrial metabolism. For both of them there is still a strong growth mechanism at work. Let us look at this more closely for the case of energy.

In figure 6 above we grouped "energy carriers" from an ecological point of view, that is, we included foodstuffs required to feed both people and their working animals, the technical utilization of energy as well as the so-called "non-energetic utilization" of energy carriers (i.e. the use of recent or fossil biomass for chemical syntheses). Such a definition is well compatible both with the energy balances of natural ecosystems and with historical modes of social production. But if we look at this in terms of energy rather than mass, we have to include part of another item which, in the figure above, is not contained within the column labelled "energy" but rather in the one denoted "construction materials" - it is the construction materials required to build the facilities which serve to produce electricity from water power.

Over the last 30 years total energy input[18] in Austria has increased by almost 70%. The utilization of water power[19] has roughly tripled, while fossil energy inputs have doubled over the period in question. The utilization of recent biomass, however, has also increased by 34%, though less in the form of agricultural products than - by a disproportionately large extent - in terms of wood being used.

Figure 7: Domestic Energy Consumption in Austria 1960-1991



© IFF-Social Ecology, Data including nutrition and „non-energetic use" calculated as calorific values, source: Haberl 1994

With a view towards sustainable development this increase in the social consumption of energy is alarming in several respects. Environmental problems associated with the utilization of fossil energy sources (global warming, toxic emissions, etc.) are well known by now and need not be elaborated here. But what can be learned from this overall view on energy consumption is that the common technocratic recipe of substituting fossil energy by "renewable energy sources" is no path towards sustainability either - certainly not at this high level of consumption.

18 Data concerning energy flows are converted to calorific values. Data concerning "technical" energy flows, therefore, differ from official energy statistics data which are based on heating values.

19 including imported electricity.

Interventions in nature associated with the procurement of water power are substantial. The largest 18 Austrian rivers have a total length of 1884 kilometers of which 698 km have already been transformed into reservoirs. A large part of the remaining sections has been severely affected by power plants, leaving a mere 652 km (roughly 35%) that so far have not yet been subjected to damming, diversions or flooding-operations. The previous leas and meads have been reduced to a mere 10% of their former extension (Muhar, 1992). All this has had (and still has) severe repercussions in terms of reducing biodiversity. Moreover, as can be learned from Figure 5, rivers are being used as sewerage systems for about 7 million tons of residual materials per year - if at the same time their self-cleaning capacity is reduced by dams, lasting effects for the quality of water are going to be likely results.

Similar limitations exist for the possible increase in the energetic use of biomass. It was necessary to enforce a radical transformation of the landscape to facilitate the generation of more than 690 PJ of energy annually from biomass, which already amounts to more than half of the potential biomass energy on Austrian territory (NPP), as was shown above. It is for a very long time, indeed, that the majority of the land in Austria has been used, in one way or another, for agricultural purposes and forestry. But the amount of energy Austria uses at present (1670 PJ/year) is more than the amount of energy that would be generated by biomass on Austrian territory if one allowed everything to grow according to its natural potential (1370 PJ/year).[20]

What about the other fractions of the social metabolism? Is there also still a dynamics at work that results in a continuous increase in material throughput? Some international analyses imply that during the last decades - despite continuing economic growth in monetary terms - materials flows have tended to stagnate (Jänicke, 1994). We have tested this empirically for the total of material throughputs in the Austrian economy during the last two decades (Steurer, 1994). So far, however, the empirical data base is preliminary and needs further statistical corroboration. Taking into account the reservations that are warranted, we may still argue that there has been another increase in the throughput of solid ("raw") materials[21] by roughly one third between 1970 and 1990. The population has also increased slightly over the same period, but throughput in terms of quantities per capita also has risen from about 16 tons per capita and year in 1970 to approximately 21 tons by 1990 - which corresponds to an increase of 30% over twenty years. (see Figure 8)[22].

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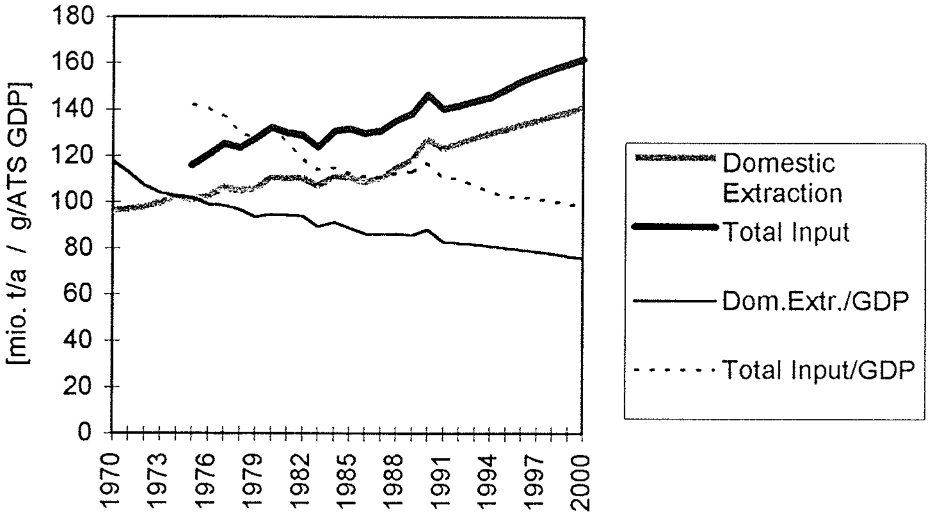
[20] 1 PJ = 10^{15} J, 1 PJ = 278.000.000 kWh.

[21] Quantities are measured in tons of solid material throughput (excluding soil excavation). Agricultural biomass is standardized to 15% water content, which corresponds to the average water content of cereals in trade. In Figures 3 and 6 animal fodder was entered on the basis of its actual water content - with animal feed containing, at least in part, water up to 85%. Compared to these figures, therefore, values in Figure 9 are somewhat lower.

[22] Figures for the end of the 1980s are identical with per capita figures for (the Federal Republic of) Germany calculated by Schütz/Bringezu (1993) (cf. Steurer, 1994:19f.). As far as we know, there is as yet no other country for which figures concerning solid materials throughput have been calculated for an extended period of time. International comparisons concerning trends for particular fractions of materials

Figure 8: Raw Materials Flow 1970 to 2000 in Relation to the GDP



© IFF-Social Ecology, Solid materials only, Source: Steurer 1994, own calculations

An increase in the volume of material metabolism, however, does not seem to be immediately related to "economic growth" (in terms of GDP at constant prices). As can be seen from Figure 8, materials throughput per ATS (Austrian Schilling) of GDP has continuously decreased since the 1970s. These last twenty years, therefore, have seen a markedly stronger growth of the "economy" compared to the increase in materials throughput. Picture an Austrian Schilling of 1970 (at constant prices 1983) as weighing 140 grammes, then this same Austrian Schilling would not have weighed more than 100 grammes in 1990. Our data, therefore, do in fact empirically support the hope we expressed at the beginning - i.e., that the links between monetary and material flows become less significant. This does not prove the possibility, however, that materials and monetary flows may change in opposite directions - which would imply an economy that grows but, simultaneously, reduces the volume of its material metabolism. Still, it must be considered as proven that materials flows, over a long period of time, may grow slower than the economy as such.

What kind of dynamics may be expected to emerge from this process of development in the future? Will the growth rate of the volume of metabolism decrease, approach linearity, or even increase?

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by Jänicke et al. (1991), however, suggest conclusions which are similar to those derived from Austrian data.

Figure 8 shows an extrapolation from figures illustrating the changes from 1970-1990 (domestic extraction) and, respectively, from 1975-1990 (total throughput); based upon these figures, the per capita materials flow was forecasted until the year 2000. The forecast was based upon a "no-policy"-scenario and carried out by means of regression analysis (least-square-fit) using the following hyperbolic function[23] :

$$f(t) = 1/(A+B.t)$$

A second step involved forecasting the total throughput of solid materials to be expected, given the population forecast of the Austrian Statistical Office.

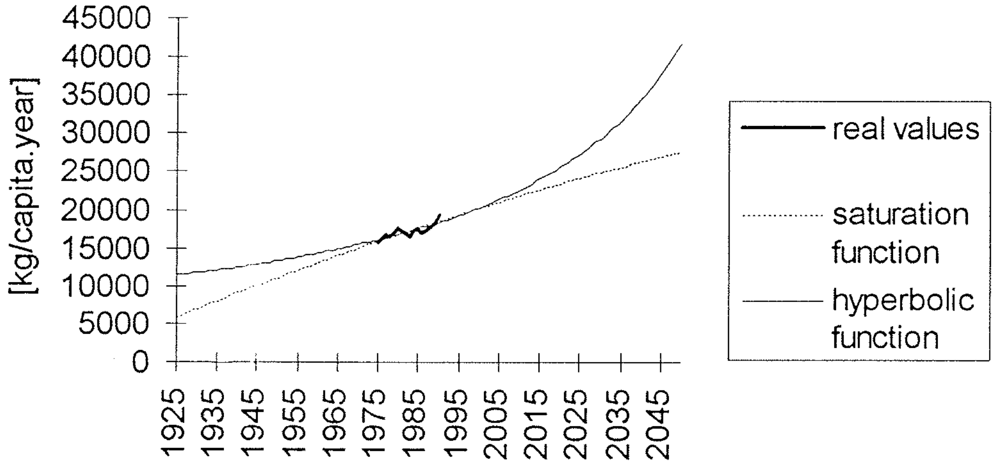
The specification and the coefficients of this function suggest that, currently, the annual rates of increase of materials throughput are roughly constant, but may be expected to increase even further in the future. It is possible to use a linear function which has a virtually identical fit with respect to the data observed. A reasonable fit may also be achieved with a saturation function of the type:

$$f(t) = k(1-e^{-a.t})$$

It is remarkable, however, that with this function saturation will only be reached after current throughput will have increased fivefold, and that this process will take far more than 100 years to mature. Figure 9 displays the results of model calculations for a more extended period of time.

[23] The fit of the regression was very good (r^2 = 0,868 for extraction from nature in Austria, r^2 = 0,695 for total throughput).

Figure 9: Modeling the Total Raw Materials Flow in Austria 1925-2050



Of course, one needs to be aware of the limited degree to which this "forecast by extrapolation" is meaningful and reliable. A quick glance at the graphs suggests that there is a whole bundle of functions which is perfectly compatible with the data observed. One thing, however, needs to be taken serious: There is nothing that suggests that one may expect an immediate slowdown of the increase of material flows - neither in terms of total volume nor on a per capita basis. Even if volume or mass per unit of money - and even volume or mass per "service-unit" (as Schmidt-Bleek (1993) has calculated on the basis of his "MIPS") - decrease, it seems that this is more than compensated by the growth of national income and of the volume of goods consumed. Ecologically speaking, the number of grammes that a Schilling weighs, or the number of kilogrammes turned over for a particular consumer good are not immediately relevant. It is the total volume of throughput that is of prime importance for the possibilities of a sustainable development - and this volume continues to increase relentlessly.

4. How Can Industrial Society Perceive its own Sustainability Problems and Respond to Them?

Let us assume the diagnosis is correct that industrial society is well on its way to change the functioning of natural systems that it vitally depends upon (such as the atmosphere) by excessively emitting substances which are either transferred from long-term planetary sinks or alien to the biosphere altogether (like FCKWs); let us assume it strains the natural energy household to the extent of severely reducing biodiversity; let us assume it does run into a threatening shortage of non-renewable resources. Although all of this may be true, and even many people may be convinced of this truth - this still remains an intellectual exercise in obvious contradiction to most of society's everyday experience.

Hunter and gathering societies could experience that they hunted or harvested too much or too effectively - they then had to wander about ever more in order to find appropriate nutrition. They could find out that there were too many mouths to be fed for a given environment, and therefore culturally regulate their procreation.

It is similar with agricultural societies: They were able to learn what the consequences were when they exploited the soil too much, or had too many animals to feed on, and - accordingly - were capable of improving their balance. With respect to procreation, however, this was more difficult: They discovered that child labour improved their conditions of living, and that children increased survival rates in old age. There was a dilemma, then, between the need for labour and the excess of mouths to be fed - a dilemma that could not be resolved in a sustainable way.

But what do industrial societies experience? Their experience tells them that

- raw materials are becoming cheaper and cheaper
- agriculture is producing an excess of goods that cannot be sold on regular markets for regular prices
- inhabitants of industrial societies live ever longer, maybe even healthier and more comfortably
- they do not depend on their territories but, on the contrary, gain a lot by far-reaching exchange and transport
- they better keep their growing labour forces busy most of the time, although it may be hard to procure a sufficient amount of work
- they can resolve or at least moderate their internal social problems by stimulating economic growth and, finally,
- most parts of the world strive to imitate the industrial mode of production and living.

Why, then, should they believe in intellectual, scientific insights rather than in their reinforcing day-to-day experience?

The real problem, therefore, of taking a turn towards a more sustainable mode of production and living is to create conditions that provide the subsystems of society, particularly the economic subsystem, with different experience[24] - with kinds of experience that make the right alarms ring. To find out how this could be done is a genuine task for the social sciences and, among them, for environmental sociology.

We will proceed by checking some measures within the range of political feasibility as to whether they qualify in the light of this reasoning.

4.1 Social-Ecological Tax Reform

The international division of labour, notwithstanding increasing scarcity, consistently cheapens raw materials while, at the same time, it raises the price of industrial labour. Therefore, there is a strong tendency to curb expenditures on industrial labour, instead of employing its intelligence to develop more elegant forms of utilizing natural resources. Moreover, this process of economizing aggravates the redundancy of human labour and eliminates an ever increasing number of people from productive processes. The situation is made even worse as a result of economic policy agreements like EU, NAFTA or GATT, with national policies multiplying this effect.

It is not only the costs of the market economy but also a relevant margin of "political costs" that increases gross wages by about 50% (taxes, social insurance, etc.). Social-ecological wage reform implies a gradual shift from taxing wages to taxing energy and raw materials. If one pursues this course of action, labour intensive forms of production, e.g. services, will become cheaper, whereas energy- and raw materials intensive forms of production will become more expensive. Reform policies may be expected to promote the development of technologies which, by employing labour power, economizes on natural resources. With respect to its effects on society, pursuing this course of action increases the demand for labour and, therefore, is also socially advantageous.

A recent study by the German Institute for Economic Research (DIW, 1994), financed by Greenpeace Germany, has tried to develop an econometric model of the economic effects of taxing energy and repaying the extra tax income to employers via a reduction of their share in social security payments for employees, and to households by means of what is called an "eco-bonus" (a fixed monthly sum per person) - the results were very reassuring for both a five- and a ten-year interval: There was no reduction of economic growth, a slight increase in employment and a degressive effect on household incomes. According to the model, the tax would induce a reduction of energy consumption of about 20%. One may hope, therefore, that this study is going to stimulate national efforts and back up the ongoing international efforts to introduce energy taxing.

[24] This type of reasoning, although put in different terms, very much resembles what Luhmann (1986) has called the problems of environmental communication.

Energy taxing is one thing - taxing of other raw materials is another. As far as we know, no comprehensive models have as yet been developed to estimate the effects ensuing from corresponding measures. What seems to be particularly complicated is the handling of raw materials from agriculture; currently, there does not even exists a consensus among environmental scientists, since many of them still consider the substitution of "non-renewable" by "renewable resources" a useful strategy, which - as far as biomass is concerned - we doubt very much in the light of the argument elaborated above. Provided a reasonable amount of social science intelligence is invested, however, taxing agricultural raw materials might prove to be beneficial both with regard to the existing inequity in the international division of labour and with respect to the dilemmas associated with agricultural subsidies in industrial societies.

4.2 Reduction of Regular Working Time

Reducing the "regular number of hours worked" promises to be another measure with similar far-reaching effects. As, e.g., Marin (European Centre, 1993) has well documented, it is only a minority (of one, rather than two thirds) of predominantly middle-aged males that work these "normal hours". It is this group of employees, however, that staffs highly influential positions when it comes to determine the standards of "normality" with respect to ways of living. Their cultural position is causally related to the high and increasing degree of energy- and resource consumption. Whoever works that hard claims for the right to indulge in luxury and comfort, is eager to avoid the chores of everyday life and usually does not even have enough time to provide for his well-being in any other ways than those provided by material goods, i.e. commodities.

If this dominant model of allocating time gradually turned out to be less obligatory, a good many forms of material compensations employed to reach a state of satisfaction might become redundant; eventually, they might be substituted by services which are more effective to achieve the satisfaction of needs and wants: It is rarely effective to buy a new skirt if one is lovesick, to bet one's luck on a sportscar for fear of being impotent, or to try and substitute lack of affection by lavishing ever new toys on children. Moreover, it may be reasonable to assume that a substantial part of excessive consumption of materials is caused by the fact that consumers are short of time: This involves the whole range of gadgets from hiring taxis to ready-made meals, from energy used for driers to countless decisions in favour of replacement instead of repair. It would be a rewarding objective of research and social experimentation to explore the room to manoevre available in this respect.

A strategy that seems well worth exploring is to pay for productivity increases by means of time rather than with money. With an average productivity increase of, e.g., 2% per year this would imply an annual reduction of four working days. This also would have a degressive effect on the income structure: One can hardly offer eight extra days to a manager and one to a labourer. Of course, productivity gains are not distributed equally across the economy - but this problem has to be resolved with respect to wages as well. It is also a matter of research to what extent, nowadays, productivity gains are being achieved by "technization" (applying mainly to industry) and to what extent by "improvements in organization" (which applies at least as much to services as well).[25]

Historically speaking, it is interesting to note that the lower class culture of "hard labour" that was established in the agricultural era - where it was quite neccessary considering ecological conditions - has been generalized for all classes in industrial society where this patently seems to be ecological nonsense.

4.3 Cultural Variety

Finally: There must be room for social and cultural experience to try out new and different ways of life. Once again, we are considering several problems simultaneously: The gradual dissolution of traditional family structures and regional communities, migration movements, the omnipresence of markets, bureaucracies and the media, and the lack of affection and social recognition - i.e. the deficiency in "positional goods" associated with that - are phenomena which frustrate an ever-increasing number of people in their endeavour to gain recognition within their social environment. As a result of that, more and more energy is spent to achieve this by means of spectacular expenditure on energy as well as on resources, or by means of intimidation and violence. It is impossible to create "communities" by means of policy measures - and even the mere attempt to pretend doing so is bound to face terrible consequences - but it is possible to grant them the space that they need to unfold, to try out ways of life that are better sustainable with respect to ecological concerns.

5. Conclusions

We have tried to demonstrate that human societies have been producing "sustainability problems" for themselves since the beginnings of their very existence. They have been trying to cope with them by the cultural regulation of population growth (and its spacial distribution), and by the cultural evolution of new modes of production. Each mode of production corresponds to specific exchange-relations between societies and their natural environments. We have distinguished two types of exchange-relations that we denoted, respectively, as "metabolism" and "colonization".

Metabolism refers to physical input-transformation-output processes between societies and their natural environments: Natural resources are "ingested", processed internally and released into the environment. This metabolism can be described both in terms of mass (tons) and in terms of energy (joule). Society's metabolism can be related to a biological minimum that equals the sum of the metabolisms of the human beings that make up society.

[25] This classic distinction advanced by Lutz (1969) might prove very useful when one analyzes the potential means available to reduce material metabolism on the level of single working processes or firms.

History may be interpreted as an enormous increase in this metabolism: On a per-capita basis, members of an industrial society, as empirically exemplified for Austria, maintain a metabolism which is 50 times the metabolism of (well nourished) members of a hunter and gathering society. Members of an industrial society consume 20 times the amount of biomass, 60 times the amount of water and about 10 times the amount of air which their individual metabolism would in fact require. This, of course, puts an enormous pressure upon the environment. In the course of human history changes in the mode of production never reduced, but always enhanced, the metabolism per capita (despite the fact that the average living conditions resulting from this were occasionally more miserable than before). The metabolism has changed in quality, however. Environmentally speaking, the great invention of the industrial mode of production consisted in using subterrestrial resources (such as fossil fuels, in addition to metal ores) which were far beyond the vital interests of other species; the process, therefore, did not compete these species out of existence and did not deplete the base of human nutrition in the short run. The restraints which this mode of production has eventually been forced to acknowledge, however, are not only the limited amounts of such resources (which will be heavily felt for generations to come), but the fact that releasing residual products of transformation processes into the "wrong" natural cycles causes disturbances in the self-regulatory processes of natural systems which societies so far have relied upon.

"Colonization" refers to another type of exchange relation between societies and their natural environments. This exchange relation is a prerequisite to metabolism; it cannot be described within the logic of input-output-models, but needs to be explicated rather within the logic of domination. It encompasses a set of deliberate interventions into living systems that change some aspects of their functioning (but still relies upon their self-regulatory properties) in order to make them more exploitable for social needs. Colonization strategies were the very invention of the neolithic revolution and have also undergone changes with each new mode of production. Within the industrial mode of production innovations in colonization were neglected for a long time - and are rapidly becoming one of the most advanced fields of scientific development (bio-technologies). All colonization techniques act within the framework of competition with other living species and intentionally influence biological evolution. The most basic of these interventions is the appropriation of the energy accumulated by green plants by either harvesting it for nutritional and other purposes, or by artificially reducing its production (for example by built structures). We were able to show empirically that an industrial society like Austria at the time being appropriates almost half of the bioenergetic resources on its territorry and channels them into social uses: Per inhabitant this amounts to about twenty times the neccessary caloric intake of a human being.

An empirical analysis of the dynamics of the metabolism of the national economy of Austria in terms of mass and energy shows that there still is a strong growth mechanism at work: Per capita amounts of material and energy throughput have increased by almost a third over the past twenty years. A regression model of this process of development shows a good fit for linear increase. This increase is slower than economic growth during this period in monetary terms (at constant prices) - a certain disjuncture between "economic" and "material" growth may be registered, therefore. Obviously, however, there is no way that the current dynamics underlying this process will lead to an absolute reduction in social metabolism, let alone reductions in the dimension of 8:1 as Meadows et al. (1992) demand, or a reduction by roughly 60% as Friends of the Earth have calculated as targets for "sustainable Netherlands" (Institut für sozial-ökologische Forschung, 1993).

The final part of the paper has taken a closer look at these dynamics in the light of common social and economic experience in industrial societies. In striking contrast to previous cultures, however, industrial societies are as yet unable to perceive their sustainability problems except by means of scientific reasoning. This contradicts standard everyday experience such as raw materials which become ever cheaper, people who live ever longer, and most other societies that strive to imitate the industrial way of life. Finally, we have sketched three strategies which we consider crucial to enhance new social experience that is more in line with what we consider factual problems of sustainability: Socio-ecological tax reform, rewards for productivity gains in terms of time rather than in the form of monetary remuneration, and the promotion of opportunities for (sub)cultural settings to try out other ways of life within industrial society.

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