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Operational Paths Towards Sustainability Reconsidered: Changes in Social Metabolism and Colonization of Nature*)

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7 Text-Figures

Sustainability
Social Metabolism
Colonization

Contents

1. The Concepts "Metabolism" and "Colonization"

The emergence of "sustainable development" as a key concept in the debate surrounding environmental issues has stimulated an interdisciplinary dialogue which, increasingly, has brought together scientists from most divergent fields as well as conflicting political and social groups. The concepts we will present below, and the attempts at their operationalization, have been generated by such dialogues and are interdisciplinary, bridging natural and social sciences.

Human societies may be conceptualized as subsystems of the biosphere***). 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 with respect to both matter and energy (DALY, 1994). A description and analysis of society – nature interaction, therefore, 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 & SIMONIS, 1994a; FISCHER-KOWALSKI & HABERL, 1994).

Essentially, metabolism is a biological concept which refers to 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 (cf. AYRES, 1994; AYRES & SIMONIS, 1994b).

The analysis of society's metabolism provides a kind of framework to distinguish cultures, societies or regions according to their characteristic relationship with nature. First you can just look at the overall "size" of this metabolism.

1) Materials flow: The social metabolism may be measured as mass throughput (kg a^{-1}) for nutrition, shelter, clothing, buildings etc. Every society has at least the metabolism that corresponds to the sum of the metabolisms of its population.
2) Energy: 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. Input per capita and year is largely determined by the mode of production, which can only be sustained if the necessary natural 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.

And here comes in a second distinction outlined in Text-Fig. 1. A society may live from the "renewable" resources it can draw from the biosphere (or, even more nar-

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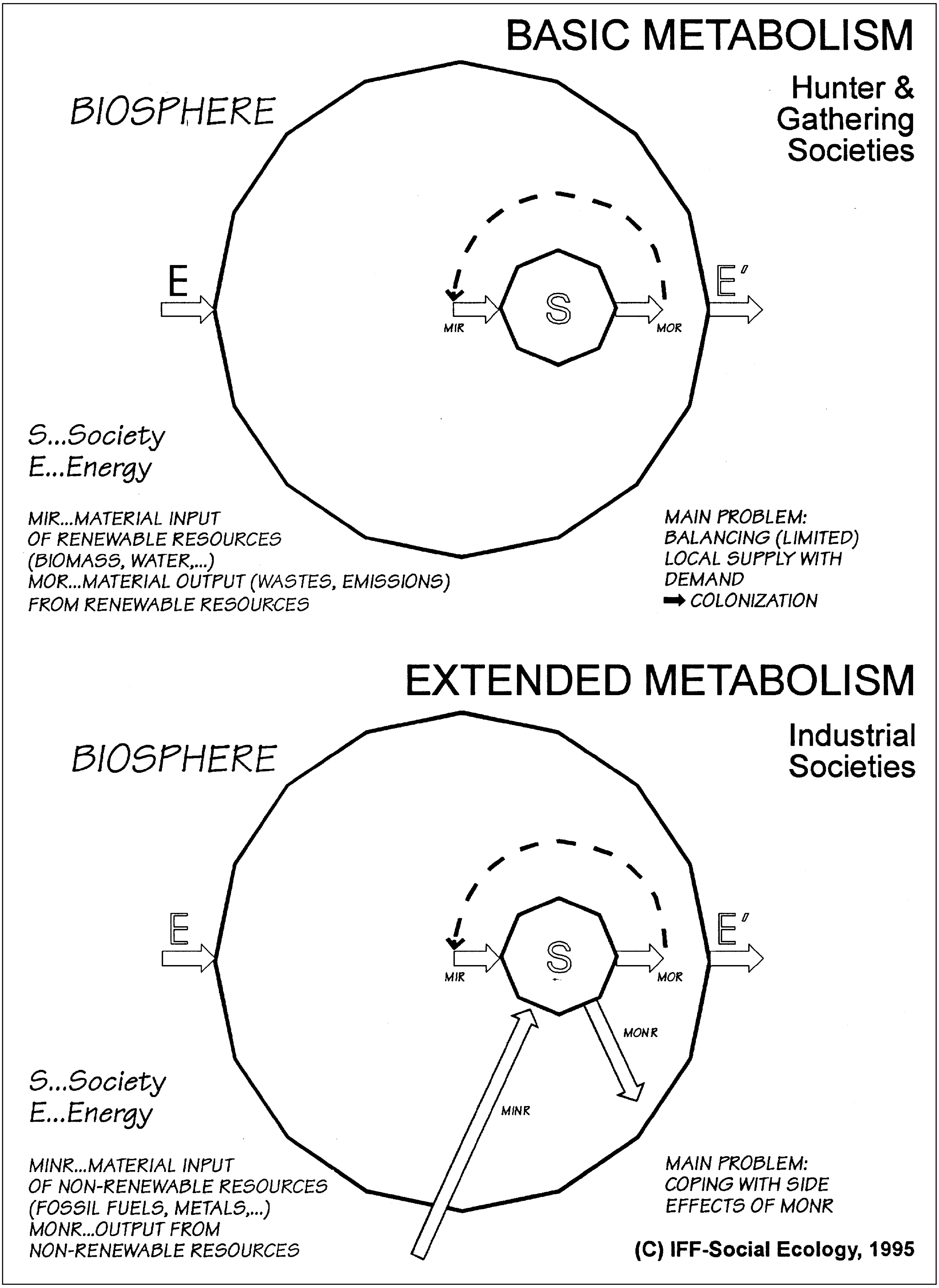
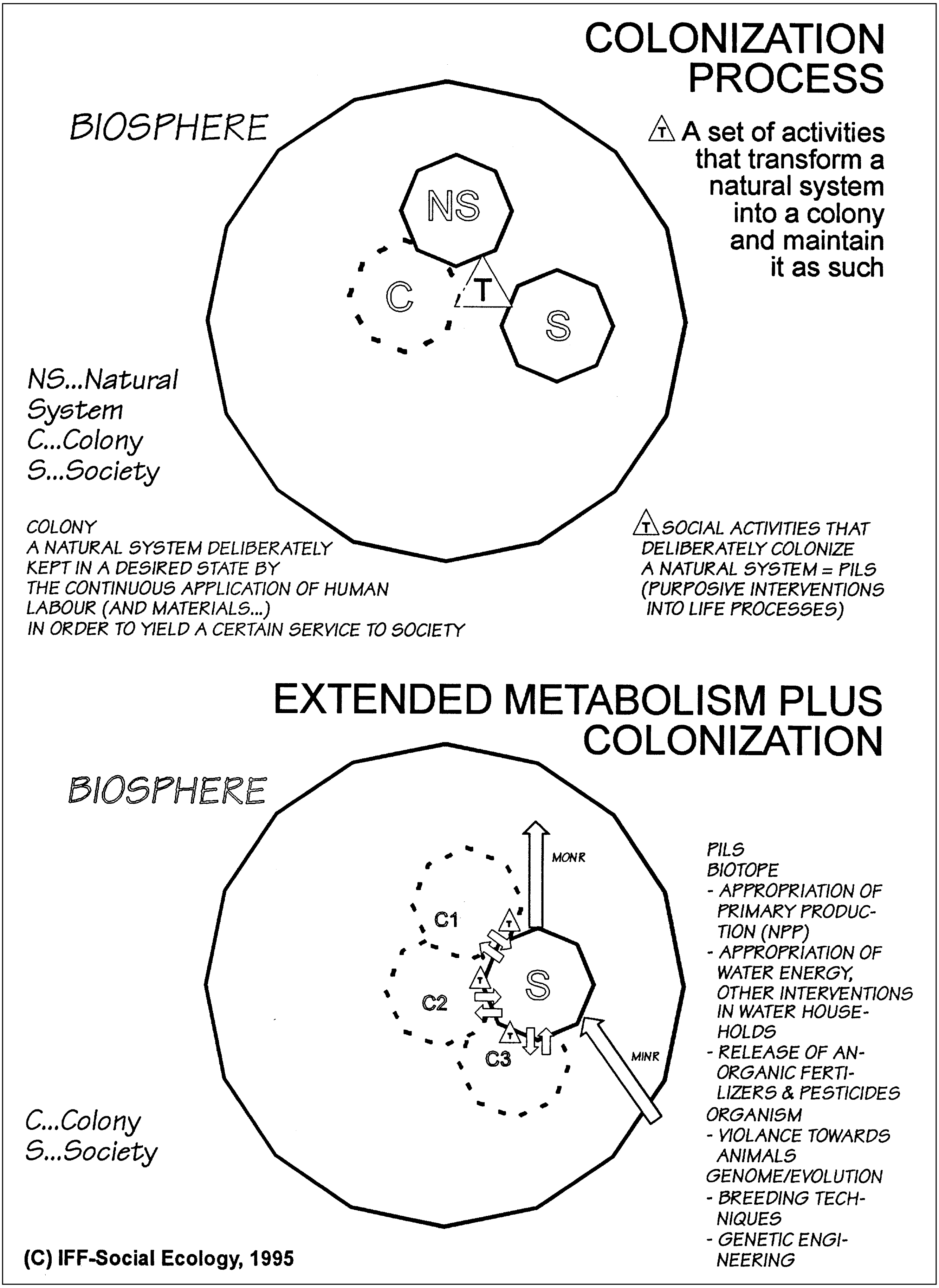
***) Such a conception, of course, does not fit within what CATTON & DUNLAP (1978) have identified as the paradigm of "human exceptionalism" predominating within the social sciences.



Text-Fig. 1.
Basic and extended social metabolism.



Text-Fig. 2.
Colonization and metabolism.

rowly, from the local or regional biosphere). This "basic metabolism" relies on the natural reproduction of resources: biomass growing again, and using the offproducts (emissions) from previous consumption. Most societies in human history had nothing but this basic metabolism. They could deplete their environment of resources, if the rate of consumption exceeded the rate of reproduction, of course. This is where "colonization" comes in, as we will explain further below.

Industrial societies, though, largely rely on resources from outside the biosphere, so called "non-renewable resources" such as fossil fuels, metals and other minerals – they rely on an "extended metabolism" (Text-Fig. 1), and on materials agricultural societies used, if at all, only in very small amounts. In view of the constant scarcity of life-sustaining resources of the agricultural era, this may be looked upon as a socially and environmentally beneficial 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 depleting the base of human nutrition.

Unfortunately, however, this induces new problems which, in the long run, may certainly affect inputs, yet become manifest more immediately with respect to the output of social metabolism. The mobilization of huge amounts*) 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; cf. BOWLUS, 1988), but global and long term consequences will be felt for centuries to come. Thus, intermediate "bottlenecks" checking population growth and/or the scale of metabolism, e.g. the scarcity of energy based on current biomass, have been overcome within industrial societies, only to be substituted by an environmental "bottleneck" induced by "output" or off-products resulting from industrial processes. (Of course, resource scarcity will once again raise "input bottlenecks" with the depletion of some "non-renewable resources").

There is no easy cure in returning to the exclusive use of "renewable" resources, though, at least not if they depend upon biomass – even if social "colonization" technologies would again vastly improve.

What is "colonization" then? In order to maintain their metabolism, societies transform natural systems in a way that tends to maximize their usefulness for social purposes: natural ecosystems are replaced by agricultural ecosystems (meadows, fields) designed to produce as much usable biomass as possible, or are converted into built-up space, genetic codes of species are altered to increase their resistance against pests or pesticides, or to produce pharmaceuticals. We refer to this mode of intervention into natural systems as "colonization" (FISCHER-KOWALSKI & HABERL, 1993) and define it as the conundrum of social activities which deliberately induce disequilibrium into natural systems and maintain them in that state (see Text-Fig. 2).

Historically "colonization" was the response to increasing scarcity of natural resources, mainly of food – and these strategies were not adopted with great joy, since they meant a considerable increase in human labor. To raise and maintain that amount of labor, elaborate social hierarchies had to be constructed.

We think it useful to have a sufficiently abstract notion of "colonization". Social activities which deliberately transform (induce disequilibrium into) natural systems can intervene on different levels. The most traditional interventions take place on the level of biotopes: agriculture and forestry deliberately transform biotopes in order to make them more productive for types of biomass ("renewable resources") society needs, and less productive for other biomass. Similarly transformations of the water household (construction of dams, draining, irrigation, etc.) intervene on this level. But the interventions may also take place on levels below, such as the level of organisms or even the level of genomes, which means an intervention into natural evolution (such as traditional breeding or modern biotechniques). We have tried to define indicators for the quality and quantity of "colonization" (FISCHER-KOWALSKI et al., 1994) – but we think a lot of research still has to be done to clarify and operationalize this concept. We think it could prove very useful for historical, anthropological and cultural comparisons, and there should be many links between the social organisation of societies and their colonization strategies. Historically it seems obvious that societies increasingly draw all their "renewable" resources from colonized environments. The proportion of nutrition from non-colonized environments (i.e. "exploitation" such as fishing, hunting and gathering) seems to decrease continuously**), as does for example the proportion of water utilized from "wild" sources (as compared to water from technical structures).

2. The Size of the Industrial Metabolism

As we already mentioned, one can think of two reasonable ways to look at the "size" of the metabolism of a society:

1) The metabolism can be operationalized as "materials flow" (raw materials enter society, are processed internally and "released" in form of emissions) and
2) as "energy flow".

Of course, the same material can be part of both flows (e.g. oil), but some will only be relevant in the materials flow (e.g. water, gravel, sand).

Let us first look at the amount of materials processed by an industrial 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 & 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.

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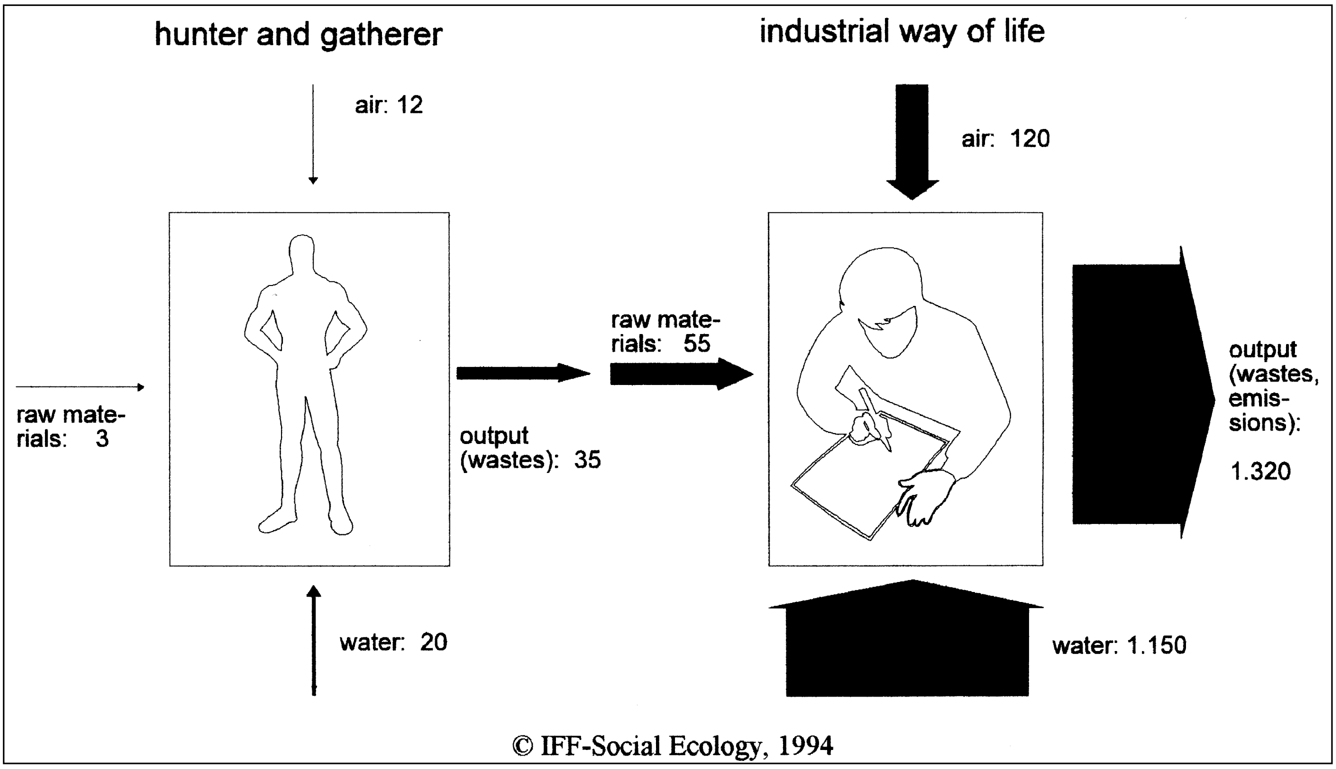
*) AYRES (1991), for example, demonstrates that the amount of carbon, nitrogen, sulfur & phosphor mobilized by the social metabolism of industrial societies ranges from 5 % to several hundred percent of natural processes.

**) One of the more recent developments being the expansion of "aquaculture" in fishing.



Text-Fig. 3.
The social metabolism of hunters and gatherers compared with members of an industrialized society (in kg per capita and day).

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 Text-Fig. 1. Austrians or Germans currently maintain a metabolism which is about 40 times larger in scale than the metabolism of people who inhabited the same region some 4000 years ago. They use about 10 times as much air, 20 times as much solid "raw materials" and 60 times as much water (see Text-Fig. 3). Accordingly, they put an amount of stress upon their natural environment which is several times larger compared to 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*) 10, disregarding population growth.

The numbers given in Text-Fig. 3 are valid for Austria, but comparable countries are very similar (see SCHÜTZ & BRINGEZU, 1993 for Germany, JÄNICKE, 1994 for a comparison of Austria, Germany and Japan). It appears that approximately 88 % of the socio-economic metabolism of industrial societies is water, 8 % air and 4 % "raw materials", which means solid materials (ores, gravels, sand, coal, biomass etc.) and liquid/gazeous energy carriers (oil, natural gas).

If we distinguish between "renewable" (mainly: biomass and water) and "non-renewable" (mainly: fossil fuels, minerals and metals) inputs, the major characteristic of industrial society of course consists in the enormous increase of the latter fraction: Among the raw materials (disregarding water and air) of contemporary industrial societies "non-renewable resources" make up for about two thirds of input**) in terms of mass. Tentative estimates for agricultural societies (based on NETTING [1981]; analyses for 6th century Byzanz and 15th century Venice are in preparation, WINIWARTER [1994]) show that metals and minerals amounted to certainly less than 10 % of their input. Nevertheless industrial development obviously also increases the amount of per-capita-input of "renewable resources", i.e. biomass, by more than 50 %.

Thus it seems there exists a per capita level of material input/output typical for highly developed industrial societies, far above the level for agricultural societies. Interestingly enough, as judged from the case of Austria, this enlarged metabolism still mainly consists in the extraction of raw materials from national territory. 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 raw materials input of 157 million tons not more than 40 million tons (25 %) were imported from abroad***) – with more than half of it being fossil energy resources.

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 goods in the economic sense. 27 million tons****) (i.e.17 % of raw material input) are discharged

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*) We do not yet have good estimates for the size of metabolism in agricultural societies, although we are currently working at the reconstruction of typical examples. Scales are difficult to establish since regional and temporal variance is substantial.

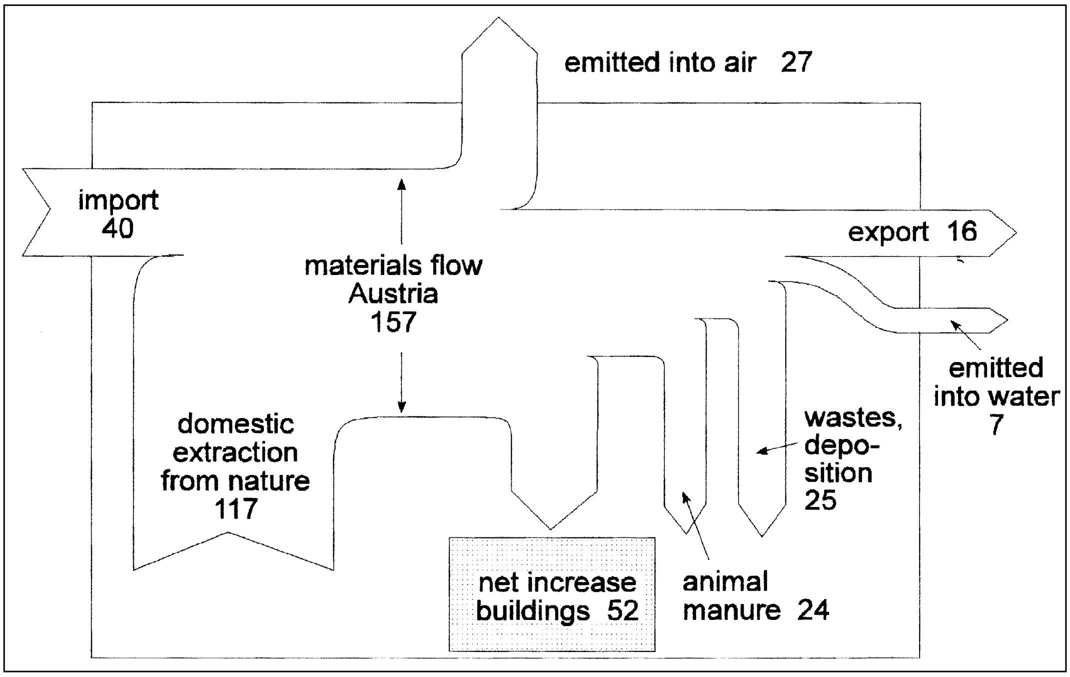
**) The results of this calculation strongly depend upon the definition of "biomass", i.e. wether its weight is calculated including natural water content or by dry substance. Here we used Austrian data (STEURER, 1993), natural water content. A pecularity of the German calculations (both from the Statistical Office and the Wuppertal Institute) is the exclusion of green fodder consumed by livestock, which reduces their proportion of biomass to 18 % of the total of raw materials (KUHN et al., 1994).

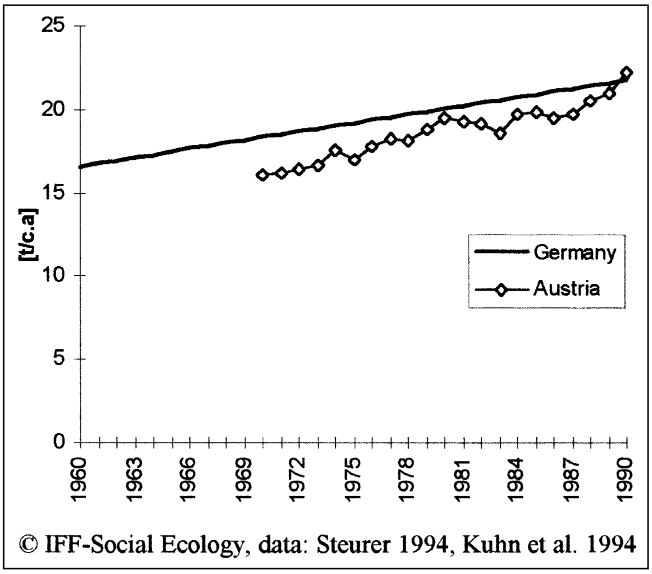
***) This calculation is not quite fair, though, since imported materials are only computed by the weight they have when they cross the national border. In their country of origin and by transportation they have accumulated an additional material "rucksack" not included here. Symmetrically, however, the "rucksack" of exports is included here.

****) Counted as C, S, H ..., not as CO_2, H_2O, SO_2, ...(CO_2-emissions are approx. 60 mio.t).

Text-Fig. 4.
Raw materials flow with reference to the national territory (in Mio. t/a).

into the atmosphere, mainly in the form of CO_2, and another 7 million tons (4 %) of residuals are discharged into the countries 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 (10 %) are rather trivial (see Text-Fig. 4).





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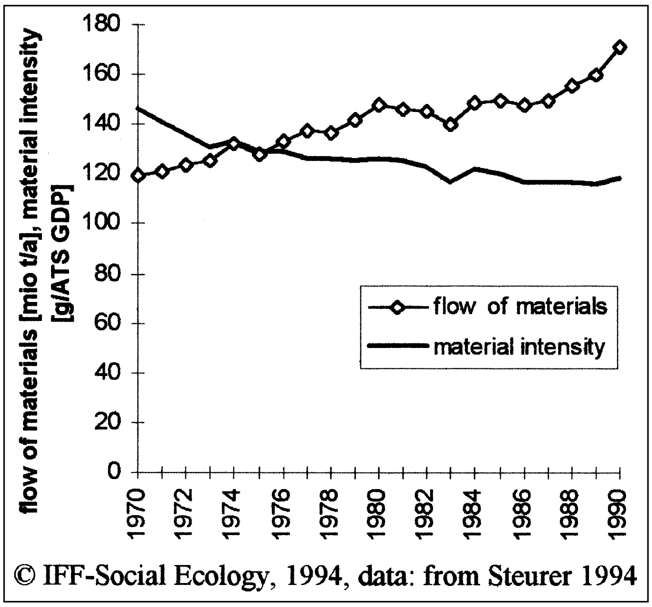
Text-Fig. 5.
Comparison of the per-capita raw materials flow in Germany and Austria (1960–1990).

In Text-Fig. 5 we present a comparison of the raw materials flow of Austria and Germany (ex-FRG only), which shows that the differences between the two countries are rather small. The total per capita raw materials flow in Japan is also very similar (Jänicke, 1994). But what is even more interesting to note in Text-Fig. 3 is the similarity in growth rates. Whereas in Austria the raw materials flow has increased by a third within two decades, this happened in Germany within three decades.

Thus we may conclude that even in rich industrial countries economic growth still also means growth in the consumption of raw materials (and emissions resp. waste). Whichever mechanisms may be at work to reduce material growth (such as increases in the material and energy efficiency, miniaturization of products or an increase in the relative importance of services) don't serve to stop material growth altogether.

But as may be judged from Text-Fig. 6, we can observe a decrease in material intensity: Economic growth in terms of monetary values (i.e. Austrian Shillings at constant prices) during the last two decades has surpassed growth in terms of material tons. Material intensity (i.e. tons/Shillings) has decreased by approximately one third.

A second way is to look at the size of the metabolism of a society in terms of energy. Text-Fig. 7 shows a comparison of the energy input of hunter-and-gathering societies, an example from an agrarian society (Törbel 1875) and an industrial society (Austria 1990). Törbel, a small village in Switzerland, has been investigated in an in-depth study by Netting (1981), which allows extrapolations of the total energy and materials flows. The per-capita energy use of this agrarian village turns out to be about four times higher than our estimates for hunter-and-gathering societies. Industrial societies again use about 3,5 times more energy than agrarian societies per capita. Interestingly enough, biomass use remained nearly stable (65 GJ/c.a in Törbel, 75 GJ/c.a in Austria 1990). This may be specific for



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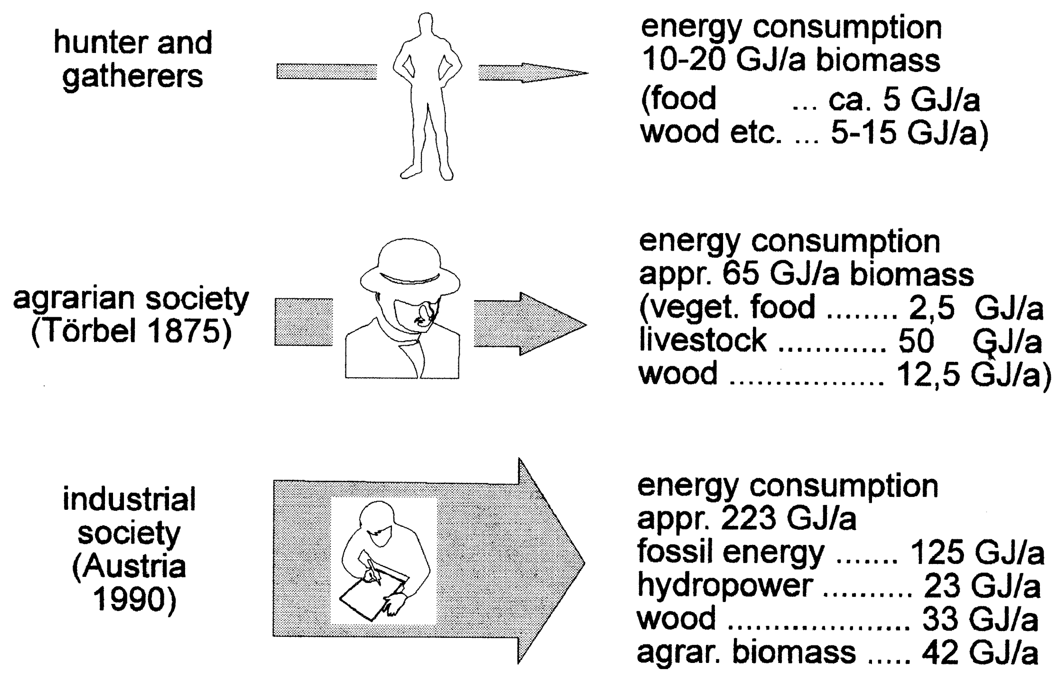
Text-Fig. 6.
Flow of raw materials in Austria related to GDP (1970–1990).

Text-Fig. 7.
Per-capita energy flow of hunters and gatherers, an agrarian society and an industrial society.



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Austria, since Austria's use of biomass is extraordinarily high compared to other industrialized countries. However, it is obvious that the enormous increase of per-capita energy use was only possible by a shift to fossil fuels as new energy carriers.

As far as the total energy "income" from the sun is concerned, the energy inputs of social systems, even under industrial conditions, are very low. What is more relevant as a limit to natural "income" 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*). The proportion of this NPP that is appropriated by human societies**) is, therefore, a good indicator 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 40 % of the NPP on its territory***). Whichever way one prefers to look at it, the scale of the industrial metabolism is both excessive compared 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 base of all animal species taken together, it clearly competes the rest to extinction****). A similar argument applies to the relation between the industrialized countries of the North and the – mainly agrarian and industrializing – countries of the South. By their excessive metabolism the industrialized countries just do not leave enough environmental "space" (be it in terms of raw materials or natural absorption capacity for emissions) for the South to develop along the same paths.

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*) 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).

**) 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 the built-up environment. 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.

***) "Sustainability" originally implied not to exploit forests beyond their reproduction rates – harvest rates are not supposed to exceed reproduction rates, wich certainly does 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 & 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.

****) For an in-depth case study of the scale at which the industrial metabolism of Austria is operating cf. Fischer-Kowalski & Haberl (1994), Steurer (1994).

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