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The Concept of Environmental Space

John Hille

Implications for Policies, Environmental Reporting and Assessments

European Environment Agency

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In order to provide possible inputs to the developing work programme of the EEA, and to stimulate debate on issues that may contribute to the identification, framing and evaluation of environmental policy measures, the EEA, from time to time, asks independent experts to summarise their views on topical or upcoming issues, so that the EEA can consider publishing them as "Experts' Corner" reports.

Experts' Corner Reports do not necessarily reflect the views of the EEA, or of any other EU institution: they are the opinions of the author only. However, they are intended to facilitate the broader dissemination of more recent environmental information that may provide useful inputs into the developing environmental agenda. The EEA hopes, therefore, that they will be of interest to the Community, Member States and other environmental stakeholders, whose comments on the contents it would welcome.

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Foreword

The concept of environmental space is in one sense simple, yet potentially radical in its implications. It tells us something "we all know" - that there are limits to rate at which we can exploit the Earth's resources. And: that there are even tighter limits to the amounts we can consume in Europe, if we are to share fairly with other parts of the world.

But it is not equally simple to quantify those limits. Nor, if we do so and find that we are currently living in excess of our environmental space, will it be a simple task to design policies capable of bringing us back within it.

The debate on these issues is still at an early stage, though gaining momentum.

Introduced as an academic concept in the 1980's, the notion of environmental space was taken up by environmental NGOs in the early 1990's. The first major effort to quantify environmental space at the European level was carried out in 1994 by the Wuppertal Institute in Germany, at the instigation of Friends of the Earth (FoE) Europe. Today, some national governments, including those of the Netherlands and Denmark, are studying how the concept of environmental space may inform their policy-making.

This paper has been commissioned by the European Environment Agency with the objective of clarifying the implications of the environmental space concept for sustainable development policies, as well as for environmental reporting and assessments - two fields in which the EEA is charged with special responsibilities. Hopefully, it will also be found useful by a wider audience, including those with corresponding responsibilities at the national level in European countries.

A draft version of the paper was presented for discussion at a Roundtable on Indicators for Sustainability, arranged by the EEA in co-operation with FoE Europe in Copenhagen in March 1996. The Roundtable was attended by some 40 participants including researchers, senior government officials, politicians and NGO representatives. The author is indebted to the convenors and participants for stimulating discussions and constructive criticism.

Throughout the process of writing the paper, I have had the benefit of close co-operation with an expert group including Maria Buitenkamp and Philippe Spapens of FoE Netherlands, Joachim Spangenberg of the Wuppertal Institute, Prof. Michael Carley of the University of Edinburgh and Andrzej Kassenberg of the Institute for Sustainable Development, Warsaw. Sincere thanks are due to them and to Peter Bosch of the EEA for fruitful discussions, contributions and comments on successive draft versions of the paper. They share no responsibility for any errors or weaknesses the reader may find in the present report.

Oslo, August 1996

John Hille

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1. The Environmental Space Concept

> *"If 7 billion people were to consume as much energy and resources as we do in the West today we would need10 worlds, not one, to satisfy all our needs"*
>
> - Gro Harlem Brundtland

1.1 Background

1.1.1 Definition of the concept

The term "environmental space" - or more precisely the Dutch *milieugebruiks-ruimte* (literally: "environmental utilisation space"), is commonly credited to J.B. Opschoor (1987), although Opschoor himself has pointed to an earlier source (Siebert 1982). In the words of Opschoor and F. Weterings (1994 a, b), the concept "reflects that at any given point in time, there are limits to the amount of environmental pressure that the Earth's ecosystems can handle without irreversible damage to these systems or to the life support processes that they enable". The services provided by the Earth's ecosystems, and for which there is a limited space, include both *stocks* (of renewable, semi-renewable and non-renewable resources) and *sinks* (i.e. capacities to absorb waste, pollution and encroachment).

The "society" for which the biosphere provides services is of course global. As defined by Weterings and Opschoor, environmental space similarly means the space available to *humanity as a whole* for utilisation of stocks and sinks. At least, this applies to stocks that are globally tradeable, and sinks that are global in extent. However, the same authors point out that the recognition of global limits forces us to face the issue of how environmental space is to be *allocated* between nations and regions.

Following its introduction by Opschoor, the concept of environmental space became the subject not only of considerable academic discussion, but also of political interest in his native country (Netherlands Council for the Environment 1994; Milieu 1994). The term gained much broader international currency with the publication in English of the **Action Plan for a Sustainable Netherlands** (Buitenkamp et al. 1993) by Friends of the Earth (FoE) Netherlands.

The Action Plan is an effort to actually quantify the amount of environmental space for some major resources, that will be available to each Dutchman in 2010. In so doing, the authors impart a new meaning to the term "environmental space" itself. It is used not only of the space available to all of humanity, but also of the *share* in this space that will accrue to the Netherlands (or to the average Dutchman), *if the global space is to be distributed on what the authors regard as a fair basis.*[1]

"Sustainable Netherlands" gave the cue to similar efforts in other countries, and most significantly to a study with a pan-European perspective, "**Towards sustainable Europe**" (Spangenberg 1994), carried out by the Wuppertal Institute in co-operation with Friends of the Earth Europe.

In "Towards Sustainable Europe" (TSE), environmental space is defined as "the quantity of energy, water, land, non-renewable raw materials and wood that we can use in a sustainable fashion". It is furthermore made clear that "sustainability", at least with respect to energy and materials resources, is intended to include *global equity*. In other words, we are exceeding our environmental space for these resources if our use-rates cannot be reconciled with ecological sustainability *and* equity. (The understanding of "equity" in TSE, as well as some alternative interpretations, are discussed in section 1.2 below. Suffice it for the moment to say that equity is *not* regarded as compatible with the present great North-South disparity in per capita access to resources).

The definition given in TSE thus departs from Opschoor's usage on at least two points. The first is that the distributive aspect is incorporated into the concept as such. The other is that environmental space is defined in terms of resources - Opschoor's "stocks" - only, i.e. of *inputs* to the human economy. Further, TSE introduces the notion of a *minimum* sustainable use-rate of resources, so that environmental space has a "floor" as well as a "ceiling".

[1] *This author has suggested elsewhere (Hille 1995) that ambiguity might be avoided by using the term "environmental share" for the fraction of environmental space accruing to a nation, region or individual. However, the present paper follows the more widespread usage whereby "environmental space" may refer either to the whole or the part.*

In the present paper, "environmental space" will be used in a sense that accords fairly closely with the usage in TSE, namely: *The maximum amounts of natural resources that we can use sustainably and without violating global equity*. ("We" may, depending on the context, refer to the population of a country or of a group of countries, such as the EU).

However, the possible existence of *minimum* sustainable use-rates of natural resources will not be considered in this paper.

1.1.2 Why an input-oriented concept of environmental space?

Clearly, the concept of environmental space, as just defined, becomes of most immediate importance if we believe

- that the present global use-rate of some resources at least is unsustainable, or
- that the present share-out of some resources at least is inequitable, and that sustainability combined with equitable distribution will mean that some people at least must reduce their resource consumption.

Equally clearly, the evolution of the (resource-oriented) environmental space concept in the 1990's reflects growing concern on both scores. At first glance, this concern may appear to hark back to the formative years of the modern environmental movement - those which led up to the Stockholm Conference in 1972. The classic "Limits to Growth", published in the same year, saw the exhaustion of energy or mineral resources or the insufficiency of agricultural resources as likely causes of a global catastrophe in the next century - much more so than over-pollution.

In the late 70s and early 80s, however, the question of resource consumption lost ground in the Northern public awareness to those of pollution and other forms of environmental disturbance. This was also reflected in political priorities as Departments of Environment and the like were established: "cleaning up" - often at the end of the pipe - took precedence over reducing the level of inputs to the economy. To the extent that *energy* consumption was of major concern, this was as much on account of price increases and worries about short-term security of supply, as for ecological reasons.

The reasons for this shift of emphasis are complex and beyond the scope of this paper. However, it is fair to suggest that some of the more alarmist literature of a quarter-century ago may actually have contributed to it. The case for resource scarcity was often based on rather simplistic interpretations of fact.

The new focus on resource consumption in the nineties does not, however, simply mean that the debate over the human ecological predicament has come full circle. An upward spiral turn would definitely be a better image.

There are at least two important differences between the thinking that underlies the environmental space concept, and that which was common in the early 1970s.

The first is that we have moved beyond the static notions concerning resource limits. It is generally recognised that improved technology can increase the exploitable potential of most resources (geological, geophysical or biotic) and even on occasion "invent" entirely new resources. However, these possibilities are not *infinite*. The fact that some people in the 1970's mistook mineral reserves for ultimately exploitable resources, and falsely predicted the exhaustion of the latter within decades, does not mean that we can go on extracting any amounts of minerals forever. And the fact that 6 billion people today are eating, on average, slightly better than 4 billion were in the 1970's, does not necessarily mean that it will ever be physically possible to feed 10 billion an American diet. In fact, an increasing number of leading agronomists appear strongly to doubt it.

At the same time, there is a much greater awareness today that the *environmental effects* of exploiting resources set limits to the acceptable rate of exploitation, which may be *more* stringent than those which physical availability alone would impose. This applies both to energy (with impacts such as CO_2 emissions and radioactive waste), to non-fuel minerals (destructive effects of extraction as well as processing and eventual disposal or dissipation) and to biotic resources (negative impacts of intensive agriculture and forestry on biodiversity, erosion, physical hydrology, CH_4, N_20 and NH_3 emissions, nutrient loss to water etc.) Some of these effects are impossible to delink from the rate of resource exploitation, while in other cases this is possible only to a limited extent and with difficulty.

Now, if negative environmental effects (e.g. exceedance of sink capacities) are major reasons for limiting resource consumption, we may ask why environmental space should be defined in terms of resource consumption only. The first reason is that it simplifies matters. The major inputs to a modern economy, each of which is associated with a host of environmental problems, can be considered under relatively few headings. If indeed many of the environmental problems are difficult to delink from the rate of resource exploitation, or if reducing the latter is simply the surest and most cost-efficient way of reducing the former, then a concept which focuses on inputs is in itself cost-efficient.

The other reason is linked to the global equity aspect of the environmental space concept. Most sinks are in fact regional or local in extent (major exceptions being those for greenhouse gases, ozone depleting substances and persistent toxins which can be globally distributed through ocean waters or food chains). By contrast, most resources are globally tradeable. The disturbances to which their extraction, harnessing and / or processing give rise consume sink capacities where these processes take place, not (necessarily) where the resources are ultimately consumed. In other words, *our consumption of sink capacities is largely mediated via our consumption of resources*.

If we are to talk of a globally fair distribution of rights to put pressures on the environment, then we must begin by talking about the distribution of resource consumption.[2]

The second important point about the environmental space concept, compared to much previous thinking about resource limits, is - precisely - the emphasis it places on global equity. “Limits to Growth”, for instance, skirted the issue of distribution entirely, and other major futures studies of the seventies assumed that a large consumption gap between North and South would persist for as long as it was worthwhile thinking about. Even the Brundtland Commission envisaged, in its favoured energy scenario, that the North after 40 years would still be consuming three times more per capita than the South.

By contrast, the environmental space concept, as defined above, involves the principle that access to resources should (as a rule with some unavoidable exceptions) be equitably shared among people in all countries. This is of course an ethical ideal, which will become a political and ecological reality only when people in the now-poor countries have the purchasing power to actually claim their fair share of environmental space.

However, there is much to suggest that it may not merely be just, but also wise to plan for such a situation within the first half of the next century. If, for instance, the countries of East Asia sustain their recent growth rates of around 10% p.a., the whole region will in one generation have about the same per capita GDP as the OECD today - and twice the population of the OECD and CEE countries taken together. It is difficult enough to imagine that one billion people might *sustainably* consume resources at the present European rate, but quite another thing to imagine that 10-12 billion may be doing so in 2050.

1.2 Quantification of environmental space - The example of “Towards Sustainable Europe”

It follows from the discussion above that the amount of environmental space for any given resource that is available to the citizens of a country or region, will depend on

a) the amount that one estimates can be sustainably exploited at the global level, if the resource is considered globally tradeable, or at some lower geographical level if not;

b) the understanding one has of “equity”, and the particular consequences this may have for the country or region in question.

In this section, we shall first see how these two sets of problems have been addressed in the “Towards Sustainable Europe” study, and what conclusions it yields regarding environmental space for European countries. TSE is the most ambitious effort so far at roughly quantifying the environmental space for *most* major inputs to the European economy, and therefore a natural point of departure. Afterwards, we shall consider how the conclusions of that study might be modified through other possible approaches to questions (a) and (b).

1.2.1 Equity principles in “Towards Sustainable Europe”

The main premise in TSE is that a country’s environmental space, or fair share in the resources which can be sustainably exploited globally, should be determined by its share

[2] A similar point is made by Weterings and Opschoor (1994 c): “...a country’s performance in terms of sustainability depends on the environmental pressure it generates through what is consumed, irrespective of where the environmental impacts occur, and hence access should be established on the basis of consumption rather than production”.

in global population. There are, however, some important modifications.

The first is that *changes in population shares after the year 2010 should not affect countries' environmental space*. In other words, countries whose population goes on growing after that date will see their *per capita* environmental space decreasing, whereas it will remain constant in countries whose population is constant and increase if population declines.

Apart from this modification, TSE upholds the principle of equal per capita shares for all countries in the cases of **energy** and **non-fuel minerals**, which (with some qualifications in the case of renewable energy sources and low value-to-weight minerals) may be regarded as globally tradeable.

In the cases of **timber** and **agricultural land**, however, TSE defines environmental space on the basis of *continental* resources. The premise is that Europe should be self-sufficient, not in an absolute sense, but in the sense that the amount of land used in other continents to produce for export to Europe should not exceed the amount used in Europe to produce for others. On this point, the modification of the environmental space concept accords with the thinking behind the concept of the "ecological footprint" (Wackernagel 1993).

In TSE**, water** is for obvious reasons defined as a *regional* resource. It is impracticable (and can be ecologically undesirable) to transport very large quantities of it over very long distances. Therefore, people's environmental space for water use will depend on what can be sustainably extracted in the region or drainage basin they live in.

Similarly, the sustainable use-rate of **land for construction and other non-agricultural purposes** must be determined at a sub-continental level, depending inter alia on population density. However, TSE suggests an approximate guideline value for the EU as a whole.

TSE contains no explicit judgements on how environmental space should be distributed *within* countries, beyond the "floor" principle: that everyone's basic needs should be satisfied. The reason given for not discussing ntra-national distribution is that people's judgements regarding distributive justice vary as between countries; therefore, these issues must be left to the political process within each country.

1.2.2 Limits to resource exploitation in "Towards Sustainable Europe"

To quantify the sustainable use-rate of resources, knowledge is needed both of their physical availability and the environmental effects of exploiting them. If precise and complete knowledge is not available, estimates must be made.

In addition to scientific facts or estimates, however, such quantification must necessarily incorporate value judgements about the degree of environmental degradation or risk that we are willing to accept, and also about obligations towards future generations.
In TSE, the sustainable use-rate of major resources is estimated as follows:

Energy: The space for *fossil fuel* consumption is limited by the need to reduce CO_2 emissions enough to avoid a global temperature increase of more than 0.1 degree per decade, or an ultimate increase of more than 2 degrees. Based on IPCC estimates, this means halving global emissions by 2050, to a per capita level 77% lower than the present European average. The reduction in fossil energy use could be slightly less, as indicated in Table 1 below, if some coal is replaced by gas. However, *nuclear* energy is ruled out as being associated with unacceptable risks.

The availability of *renewable* energy is based on an assessment of European resources. In principle, solar energy could be globally traded as hydrogen or possibly super-conducted electricity. However, the main constraint on solar energy development according to TSE is not absolute physical availability - be it at the European or the global level - but the amounts of materials required to construct solar energy systems.

Non-fuel minerals: TSE takes an unconventional approach to the question of non-renewable raw materials. The problem is not seen as one of limits to the amounts of specific raw materials that may be consumed. Instead, it is seen as one of limits to the aggregate "material input" to the economy, defined as the total amount of materials *moved* in the course of economic activity (see box). According to assessments by Prof. F. Schmidt-Bleek and co-workers at the Wuppertal Institute, the total material input to the world economy must be halved if the environmental impacts of movement, extraction, processing and dissipation of materials are to be reduced to acceptable levels.

Timber: It is a requirement in TSE that 10 per cent of total land area, and the same proportion of forest land, must be set aside for conservation. This is in accordance with IUCN recommendations, as the minimum necessary to preserve or re-establish natural eco-systems of sufficient diversity (IUCN 1991). In remaining forest areas, forestry must be based on endemic species, with natural regeneration and selective felling. This will limit annual increment. If the whole of the increment is harvested, it is estimated that annual *yield* in Europe will nevertheless be about equal to current production. At present, harvest is much less than increment in most countries in Europe.

Agricultural products: The availability of land for agriculture is limited by the requirement that 10% of total land area be set aside for nature conservation. Availability of agricultural products will be further limited by the requirement that agriculture should be on *organic principles*, and that there should be *no net appropriation of foreign land to supply Europe*. Calculations in TSE nevertheless suggest that it will be possible to provide Europeans with an acceptable diet from only 70% of the present agricultural land area. However, this presupposes a drastic two-thirds reduction in meat consumption.

Land for construction: The environmental space for built-up land is not analysed in detail and per region. As a first approximation, the space is assumed equal to present consumption (the size of which is itself uncertain in some countries).

Water: As a regional resource, per capita environmental space for water consumption will vary widely.

Marine resources are not explicitly discussed in the TSE study. However, it is quite clear that the environmental space for these is also limited and that, for many of them, current rates of exploitation already exceed the environmental space.

Table 1 shows the reductions in per capita resource consumption that will be required for compliance with environmental space in the EU, according to TSE. The study suggests that these goals should be reached by the year 2050. The table also shows goals for the year 2010, by which year TSE suggests as a main rule that 25% of the necessary reductions should be achieved. Exceptions are nuclear energy (to be phased out by 2010) and targets for land use, which should also be achieved faster.

"MATERIAL INPUT" AND "RUCKSACKS"

The concept of "material input" (MI) is a conceptually radical way of simplifying the problem of material-resource consumption.

The concept reflects the idea that the sum of problems associated with materials consumption (physical disturbance, pollution through dissipation, waste disposal and so on) can be roughly related to the **total amount** of materials **moved in the course of economic activity**. If this amount can be reduced, then so will the overall impact of materials consumption. In other words, the assumption is that, in practice, shifts as between the kinds of materials moved are likely to mean less than changes in the total quantity.

Materials **moved** not only include those actually **extracted** with a view to making products out of them (e.g. limestone extracted to make cement and then buildings, or bauxite extracted to make aluminium products). They also include the earth or rock overburden that must be **re**moved (albeit only a short distance) in order to get at the economically valuable material. Also, they include the economically worthless materials that have to be moved in the course of construction activities, and materials **unintentionally** moved in the course of economic activity, e.g. by accelerated erosion.

Associated with the concept of MI is that of "rucksacks". The rucksack is the amount of "invisible" MI - moved materials - behind our consumption of a specific material, e.g. aluminium.

To make one ton of aluminium takes about 4.8 tons of bauxite. In order to extract one ton of bauxite, however, some 0.6 tons of topsoil must typically be removed. So far, this makes for a "rucksack" of (4.8 x 1.6) -1 = 6.8 tons of moved material per ton of aluminium. To make the aluminium, however, various other materials are also required as auxiliary inputs. The total "rucksack", counting these materials but not the materials moved to provide energy for the processes, has been estimated by at Wuppertal Institute researchers at some 8.6 tons per ton of aluminium.

Virgin steel has a smaller relative "rucksack" (requires less MI per ton), partly because iron ore grades are typically around 50-60%, so less ore is moved per ton of metal. Copper, on the other hand, has a very large "rucksack", because the average ore grade today is only 0.7%. Therefore, 140 tons of rock must be blasted to make one ton of copper.

1.2.3 Discussion

"Towards Sustainable Europe" represents one approach to the quantification of environmental space, and so far the internationally most prominent one. This attempt clearly rests on a number of judgements and assumptions which can be contested. The question is not whether other approaches are possible, but whether other at least equally reasonable approaches might yield very different results.

Let us first consider the question of international equity. A copious literature already exists, if not exactly on the subject of equity in access to all natural resources, then certainly on rights to GHG emissions, which are closely linked to fossil energy consumption. The main ethical view-points advanced in this debate may be transferable to consumption of other resources as well.

The simplest possible viewpoint is that equitable distribution is the same as *equal* per capita distribution. Important modifications to this principle that have been proposed in the GHG debate are :

1) That national quotas should be distributed on a "once-off" basis, taking no account of differences in population growth after they have been distributed;

2) That national quotas should be adjusted to compensate for historical emissions (e.g. Agarwal and Narain 1991);

3) That quotas should take account of natural conditions which affect objective "needs" for fossil energy (such as climate, population density or availability of renewable energy sources) (e.g. Benestad 1994).

Table 1

Per capita environmental space for major resources in the EU and required reductions in consumption from 1990 levels, according to "Towards Sustainable Europe"

Resource	Environmental space per capita (2050)	Reduction required from 1990	Suggested reduction goal for 2010
Total primary energy	60 GJ/a	50%	12.5%
-fossil energy	25 GJ/a	75%	19%
-nuclear energy	0	100%	100%
Timber*	0.56 m3/a	15%	4%
Cement	80 kg/a	85%	21%
Iron	36 kg/a	87%	22%
Aluminium	1.2 kg/a	90%	22.5%
Copper	0.75 kg/a	88%	22%
Lead	0.39 kg/a	83%	21%
Chlorine**	0	100%	
N, P, K fertilizer**	0	100%	
Built-up land	0.0513 ha	3.2%	3.2%
Agricultural land***	0.281 ha	30%	30%
"Imported" land (net)	0	100%	50%

* Based on self-sufficiency in Western and Central Europe. Environmental space increases to 1.0 m3/a if the resource base is extended to include the European part of the former Soviet Union.

** Based on the premise that the use of chlorine and chemical fertilizers is to be phased out. Sustainable Europe also gives other figures based on resource limitations only.

*** Estimated amount required to cover nutritional requirements with organic agriculture. If agricultural area were limited only by the requirement that 10% should be set aside for conservation, availability would be 0.36 ha/capita.

Source: Spangenberg 1994.

The first modification is adopted by TSE in the cases of energy resources and non-renewable raw materials. Its ethical justification rests on the idea that the citizens of states can be held collectively responsible for their reproductive behaviour. The obvious counter-argument is that yet unborn children can neither be held responsible for their place of birth, nor for the reproductive behaviour of their own or their neighbours' parents.

If one assumes that world population will grow to 10-11 billion by 2050 - in accordance with UN mid-range estimates - and also holds that environmental space should at all times be distributed on the basis of *current* population, then per capita availability of global resources, in Europe as elsewhere, will be *reduced by one-third* from the figures one arrives at by applying the principles in TSE.

The idea that rights to (non-renewable) resources should be adjusted to take account of *countries' historical consumption*, may also be read as "visiting the sins of the fathers upon the sons". In this case, however, it is possible to argue that countries which have consumed large amounts of resources in the past have not only gained an economic head start by doing so, but also built up physical stocks of recyclable materials, including in-place infrastructure. Allowing less developed countries greater per capita rights to virgin raw materials and / or fossil energy, may therefore be seen as a compensatory mechanism. However, it would obviously not be easy to decide the appropriate rates of compensation. What is certain, is that any scheme of "historical compensation" would allow Europeans less and not more environmental space.

The idea that *differences in natural conditions create different objective needs* for particular resources is most obviously relevant to energy. It has been discussed elsewhere by the author (Hille 1995) with specific reference to Norway, a country which on several counts (climate, topography, population density) might appear at first glance to have greater energy needs - for heating as well as transport - than most others. The conclusion, however, is that while objective differences do exist, they are minor in relation to total energy consumption in a modern industrial society. If this is true of the relationship between world-average conditions and those of an "extreme case" such as Norway, then it is all the more likely to be true of the relationship between world-average and European-average conditions.

So far, the suggestion is that applying alternative principles of equity would, if anything, give Europeans *less* environmental space than suggested in TSE.

With regard to agricultural land and timber, TSE departs from the principle of global equity, giving priority to that of continental self-sufficiency. In the case of agricultural land, this has very important consequences. At present Europe (including European Russia, Belarus and Ukraine) has some 0.4 hectares of agricultural land per capita, compared to a global average of only 0.24. Excluding the three countries mentioned, Europe has only 0.27 ha / cap., but these are, on average, more productive than the world average. By 2050, Europe (broadly defined) is likely to have almost three times more arable land per capita than the world average. (Given a world population of 10 billion, and assuming that 10% of presently cultivated area is to be set aside for conservation, while losses to built-up land will be roughly balanced by new cultivation, global per capita availability of arable land in 2050 will be only 0.13 ha.)

In other words, continental self-sufficiency means allowing Europeans a very much better diet than Africans or Asians. Conversely, an equitable global share-out of agricultural resources would put Europe in the position of a net exporter, with much less meat left on the table for home consumption.[3]

With regard to timber, it is a moot point whether a global share-out would leave Europeans with more or less per head than would self-sufficiency. On a global average, annual gross increment in presently standing forests (uncertainly estimated at 7-8 bn m^3) is probably slightly higher per head of population than it is in Europe. However, this relationship is likely to be reversed by 2050. With more intensive management of tropical forests and some allowance for plantation forestry, global-average per capita timber yield could still be somewhat greater than the European. To what extent logging of presently virgin tropical forests and / or short-rotation plantations can be made sustainable in the long term, however, are still matters open to debate.

Alternative interpretations of equity, then, could make environmental space for some or all resources in Europe significantly smaller than TSE suggests; none of those mentioned would make it *much* larger.

[3] TSE actually broaches the possibility of a more global approach to agricultural resources (on p. 65, it is suggested that Europe might export food in exchange for energy or other resources). But the thought is not carried to its logical conclusion in quantifying environmental space.

The other set of questions that may be raised, concern the global (or continental) limits to resource exploitation. Space does not permit anything like a thorough discussion of all the data and judgements underlying the conclusions on these limits in TSE, only a few comments on major points.

Global space for energy. The view taken of *fossil fuels* in TSE is only moderately "precautionary", in that the study accepts consumption levels which are *likely* to lead to global warming by 0.1 degree per decade, and *could* lead to more rapid warming. To increase the space for fossil fuels significantly through the second half of next century, however, we would in fact have to accept much *greater* environmental risks than this. At present rates of world consumption (never mind present European per capita rates!) oil and gas resources would be largely exhausted by 2100. If the world's population were to go on consuming fossil fuels at much more than the rate suggested in TSE, it would by that time be relying heavily on coal. Unless we are willing to face such a scenario, the only possible question is whether the reduction in fossil fuel consumption that TSE advocates should be advanced, or could be delayed, by some decades.

By contrast, the view TSE takes of nuclear energy is strongly precautionary, and a straight matter of judgement about acceptable risks. Some EU countries concur with this judgement as a matter of policy; others do not.

The area in which differences in *purely scientific* opinion could make a substantial difference to the sums, is that of renewable energy. If one compares available estimates of the potentials of renewable energy sources at the global level, it seems probable that they would suffice to provide a population of not just 7, but even 10 billion with the 35 GJ / capita that TSE suggests for Europe.

This is true even after one applies substantial reduction factors on account of the negative environmental effects of utilising these energy sources. The question remains of whether we might achieve significantly more - the main "joker" in the picture being solar energy, whose purely theoretical potential is vastly greater than that of all other renewable sources combined.

As TSE points out, the long-term physical constraint on solar energy utilisation will be the amounts of materials required to construct the systems. Any conclusions on this point therefore depend on one's view of the sustainable use-rate of materials (below). But they also depend on the extent to which one believes that future technologies will be able to improve the efficiency of materials utilisation in solar-energy conversion. Because the technologies are still young and strongly evolving, the plausible range of conjecture about what will be achieved in the next 50 years is broad. However, it is also worth noting that if renewable energy is to substitute entirely for fossil fuels (as it ultimately must), then we shall need not 35, but 60 GJ each from these sources to fill the overall energy "allowance" of TSE. This would mean 600 EJ annually for a global population of 10 billion, which is already in the optimistic part of the range of estimated potentials, cf. Table 2; and to provide everyone with the present European per capita consumption, 1200 EJ would be needed.

Global space for materials. TSE makes two basic and controversial assumptions about the environmental space for non-renewable materials. The first is that it is relevant to

Table 2.
Some estimates of potential availability of renewable energy in the 21st century

Source	Global renewable energy potential* (exajoules/year)
Greenpeace/Stockholm Environment Institute (Lazarus et al. 1993)	239 (2030) 987 (2100)
Worldwatch Institute (Flavin and Lenssen 1994) van Ettinger (1994)	c. 300 (2050)** c. 500 (2100)** 248 (2050)
IPCC (Biomass-intensive LESS scenario, 1995)	c. 300 (2050)** c. 600 (2100)**
Shell Oil ("Sustained growth" scenario, 1995)	c. 1000 (2060)**
Johansson et al. (1993)	318 (2050)

* None of the estimates pretend to represent the absolute technical potential of renewable energy sources; in general, both environmental and economic limitations have been taken into account. However, the nature, strength and relative weight given to requirements for profitability and for environmental compatibility vary considerably between the sources.
** Figures are approximate because the sources present estimates in diagram form only.

consider all humanly induced movement of materials ("material input") under one heading - and, by implication, that the size of this aggregate (in tons) is likely to be roughly correlated with the overall ecological impacts. The other is that the permissible global level of MI is 0.5 (rather than 0.1, or 1, or 5) times the present (1990) level.

One possible objection to the MI approach is obviously that not all movement of materials *has* equal ecological impact. The movement of one ton of common soil or rock in connection with construction activity is not the same as the movement of one ton of an ore with a high sulphur and heavy metal content, capable of polluting water and atmosphere. Nor is the extraction of one ton of mercury ore, combined with the use and eventual dissipation of the mercury, necessarily equivalent to the extraction of one ton of iron ore, combined with use and dissipation of the iron content.

TSE makes some allowance for this by presenting the 50% global reduction of material input as a *minimum* requirement, which will need to be supplemented by a "systematic detoxification of production", i.e. greater reductions in forms of MI that involve especially serious pollution or health risks. If indeed some kinds of MI need to be reduced more than others, however, the question remains of whether one ought not to specify a separate environmental space for each.

It is also important to note that MI is an entirely flow-based concept, taking no account of the *scarcity* of non-renewable materials. In this, TSE differs from the approach taken by Weterings and Opschoor (1994 b) and also from the "Action Plan for a Sustainable Netherlands". A main reason why TSE avoids incorporating stock depletion as a factor limiting environmental space, is that this is regarded as an *economic*, rather than a strictly *environmental* problem.

However, the depletion of non-renewable resources is certainly a potential *sustainability* problem, and thus falls within our (and TSE's) initial definition of environmental space. If one does choose to take account of scarcity in quantifying environmental space, then clearly this may lead to the conclusion that environmental space for some resources is *less* than environmental considerations alone would dictate. The reverse does not apply (if the flow of a resource needs to be limited on environmental grounds, abundant stocks will not alter the fact).

In practice, stock-depletion considerations would be little likely to affect the environmental space for *geochemically abundant metals*, such as iron and aluminium. On the other hand, their environmental effects are certainly severe enough to warrant reductions in consumption. For instance, Wuppertal institute researchers estimate that tailings from iron ore mining alone release as much sulphur dioxide into the atmosphere as all combustion of fossil fuels.

Most other metals are *geochemically scarce*, which means that there are quite clear limits to the amounts present in ore mineral form in the Earth's upper crust, and that these would in most cases be exhausted in centuries or a few millenia at current rates of extraction.

For these metals, a case could certainly be made that extraction should be restricted on the grounds of scarcity. On the environmental side, many scarce metals are toxic in themselves. Coupled with the fact that, as elements, they are non-degradeable, this is a strong argument for approaching closed-loop recycling, i.e. minimising new input and throughput.

Many *non-metal minerals* occur only in surficial deposits which would also be exhausted in centuries at current rates of extraction. Some of these are being regenerated under present geophysical conditions - usually at rates well below those of current extraction - while others are not. Where they are, one might suggest that the sustainable use-rate at most equals the rate of regeneration. Where they are not, a similar problem arises as in the case of scarce metals - though with the added complication that most non-metal minerals are difficult or impossible to recycle.

As in the case of metals, the purely environmental case for reducing throughput of non-metal minerals in the global economy is strong. For instance, three of the four minerals that are used in highest volume (excepting aggregates) are limestone, phosphate rock and common salt. The first is used to make cement and lime, which inevitably leads to large CO_2 emissions; all major uses of the second contribute to eutrophication; and the most important uses of the third include deicing and chlorine production, both of which entail severe environmental problems.

In short, there is a lot to support the postulate in TSE that overall consumption of non-renewable raw materials at the global level should be *reduced*, be it by 50% or more or less. A more refined approach, whereby environmental space is defined separately for individual (classes of) materials, taking account of their specific toxicity and / or scarcity, may be desirable.

However, this would not alter the directional conclusion. Rather, it would raise the possibility that the ceiling on consumption of some materials should be set at considerably *less* than half the current rate.

Environmental space for land use. TSE proposes three main kinds of limits to the use-"rate" of land for economic purposes: that 10% should be set aside for conservation, that built-up area (in Europe) should be frozen, and that agricultural as well as forest land should be subject to certain management practices.

The requirements concerning the percentage of land which should be set aside for conservation and the limits to built-up land will not be discussed further here. Clearly, it would be possible to argue for higher or lower figures in each case (meaning, in the case of built-up land, that one could opine that there is too much of it already - be it from the point of view of landscape aesthetics, biodiversity or conservation of agricultural resources).

The requirement that agriculture should be "organic" raises more problems of definition and principle. In the popular conception, organic agriculture is negatively defined: no pesticides, no chemical fertilisers. This is most obviously a pair of restrictions on *materials* consumption, rather than on the use of *land* as an input.

However, agriculture does in fact consume land in two senses or dimensions. It consumes land-in-depth, i.e. soil, by accelerating erosion; and it consumes land area, or landscape, by converting it into (increasingly homogenised) cropland or pasture. TSE would limit the latter kind of land consumption by putting 10% of land area *altogether* out of bounds for agriculture (and the latter by retiring "severely degraded" land from production, which is a very small fraction of land in Europe). However, there are strong grounds for also limiting the *degree* to which the remaining *agricultural* landscape may be "monocultured"; that is, for preserving or re-establishing such features as hedgerows, shelterbelts, open watercourses and other natural boundaries between fields, as well as for more diversified crop rotations and the (re-)integration of cropping and animal hubandry. A claim could be made that agriculture is exceeding its environmental space, if either the rate of erosion exceeds that of soil formation, or the landscape is homogenised beyond a certain point.

Many practitioners of organic farming would concur that considerations such as these are as much a part of the concept as the avoidance of chemical fertilisers and pesticides. Practitioners of so-called "integrated" farming might claim that *limited* use of fertilisers and pesticides, combined with other measures to conserve soil, landscape and biodiversity, is getting closer to sustainability than 100% avoidance of the former and nothing of the latter.

Defining environmental space for land use in their terms might make food availability somewhat larger than if the requirement is 100% organic agriculture as conventionally defined. On the other hand, one should note that TSE makes an optimistic estimate of food availability from organic agriculture; while quoting research that suggests it will reduce yields by 10-30% from current levels, the study uses the minimum figure (10%) as a basis for calculations[4]. So a slightly more "liberal" definition of the environmental space for exploitation of agricultural land, might not lead to very different conclusions regarding food availability from those drawn in TSE.

1.2.4 Quantification of environmental space - concluding remarks

Environmental space is a young concept. "Towards Sustainable Europe" is the first systematic effort to quantify it at the European level. It is quite possible to contest the conclusions of TSE on the grounds that other principles of equity should have been applied; that there is a need to differentiate more between categories of resources; and / or that the estimates of sustainable availability for some resources are off the mark. In this author's view, alternative approaches, if motivated by a genuine concern for sustainability, would be at least as likely to make the environmental space for most resources *smaller* than TSE suggests, as to make it larger.

The point of departure for the remainder of this paper is therefore that the level of inputs to the European econonomy, including both

[4] This optimism is motivated by the view that a reorientation of plant breeding, towards the development of varieties suited to organic agriculture, would be likely to improve "organic" yields. (Joachim Spangenberg, personal communication).

energy, materials and land, must be significantly reduced. Reference will sometimes be made to the reductions proposed in “Towards Sustainable Europe”. As the reader will have gathered, this does not mean that the study should be regarded as the last word on quantification of environmental space, but that its conclusions may be indicative of the *order of magnitude* of necessary reductions in resource consumption (which is all they claim to be).

1.3 Environmental space, efficiency and economic growth

The environmental space concept as such implies no judgements about the possibilities for continued growth in the GDP in now-rich countries. The message for Europe is simply that the levels of inputs to the economy must be reduced, in some cases drastically so. If it is possible to increase GDP while staying within these limits - which according to “Towards Sustainable Europe” means reducing energy intensity by a factor of *more than* 50%, the intensity of many primary materials by *more than* 90%, and delinking growth entirely from the expansion of built-up area - then such growth may be sustainable.

Achieving sustainable growth, however, presents a formidable challenge at best. Although materials as well as energy efficiency has in fact improved greatly in the EU in the past quarter-century, this has not been sufficient, at average GDP growth rates of just over 2%, to prevent an absolute *increase* in consumption of many resources. Since 1970, energy consumption in Western Europe has increased by 40%. Although steel consumption has stabilised or even declined slightly, copper consumption has grown by 20% and aluminium consumption by over 100%. Many industrial minerals have also shown strong growth rates. And the extent of built-up land in some countries has virtually doubled.

The corollary is that we must either *drastically* increase the rate of improvement in the resource efficiency of the economy, or reduce or even stop growth in final consumption of goods and services. (“Resource efficiency” is a function both of technology and of the mix of goods and services that are consumed).

The size of the challenge may also be expressed in these terms: If we need to reduce consumption of virgin raw materials by 90 per cent, then at constant rates of final consumption, this means increasing the efficiency with which they are used by a factor of 10. At 2% annual growth, however, we would need to improve efficiency by a factor of 80 by the end of next century; and at 3% annual growth, by a factor of 200!

However, it is important to note that there are ways of getting more welfare out of a given level as well as mix of consumption (or the same welfare out of less consumption, of goods in particular). This can be done, for example, by increasing the lifetime of goods or by more people’s sharing goods which are otherwise used for only a few hours per day, week or year. To take account of such possibilities, it has been suggested that consumption of goods should be measured in terms of “service units”, i.e. the amount of utility or want satisfaction they actually provide, rather than simply in terms of money (Bringezu 1994a).

1.4 Implications for policy-making and reporting

Taken seriously, it is clear that a commitment to observe environmental space must affect policy-making at all institutional levels (EU, national, regional, local) and in all sectors, though in some more than others.

Besides authorities with general responsibility for environment (at the EU level: DG XI), both the EU (DG XVII) and most national governments have ministries and / or agencies with special responsibility for *energy* policy. *Land use* strongly involves authorities responsible for agriculture and forestry (EU: DG VI). Also, local authorities in most countries have an important statutory role in land-use planning. By contrast, neither the EU nor many national governments have created authorities with particular responsibility for management (as opposed to extraction) of *materials* resources. Waste management (at the national or local level) is only a partial exception.

While the creation of authorities with special responsibility for resource policy, or the empowerment and “rebriefing” of existing ones, may be a necessary step on the way to policy-making for sustainability, it will not be enough. Others needing to be involved include the authorities responsible for economic sectors that create *pressures* on environmental space (including transport, industry, construction, tourism and once again agriculture). Equally important will be those responsible for *cross-sectoral instruments*, including finance, science and technology and consumer policy. Since it is very probable that neither technology alone, nor such changes in the *pattern* of consumption as may be induced by financial or other (dis)incentives, will be enough to bring the economy within its environmental space, the question may arise of restructuring the economy to cope with less or no *overall growth*. This of course involves macroeconomics policy-making at the highest level and questions such as employment, with shorter working hours and changes in the organisation of work being possible parts of the solution.

Just as the observance of environmental space has wide-ranging implications for policy-making, a wide range of indicators will be required to measure progress in the various fields and a wide range of planning tools adapted to give better guidance as to which options are more sustainable.

This paper discusses a selection only of these issues. Chapter 2 discusses implications for policy-making within two sectors, namely **transport** and **agriculture**. Chapter 3 concerns implications for what is currently termed environmental **reporting** (but should perhaps be called sustainability reporting) at the EU and national levels. Finally, Chapter 4 discusses the implications of the environmental space concept for environmental **assessments**.

2. Environmental Space and Sectoral Policies - The Cases of Transport and Agriculture

2.1 Introduction

The concept of environmental space demands a radical shift in the focus of environmental policies: from symptoms to causes, from outputs to inputs, from local to global challenges. Thereby, it affects much more than what has traditionally been labelled "environmental" policymaking. To live within our environmental space, we will need both to radically restructure our economies and to rethink our ways of living, eating and moving about.

All economic and policy-making sectors will need to contribute to these changes. A reasonable starting-point for the thought process on how this should occur, is that each sector should contribute proportionately, i.e. reduce its consumption of resources by the same percentages as are required for the total economy. Obviously, this should not be regarded as a dogma, but a proposition which may need to be adjusted - upwards for some sectors and downwards for others - in the light of experience. A useful aspect of further research on the subject of environmental space would be scenario studies to illuminate the most cost-efficient ways of distributing reductions in resource consumption between sectors.

In this chapter, we shall focus on transport and agriculture - two sectors whose contributions are bound to be of crucial importance, because each of them is responsible for very large shares of our consumption of some or all resources.

2.2 Transport

> "Present trends in road and air transport are all leading towards even greater inefficiency, congestion, pollution, wastage of time and value, damage to health, danger to life and general economic loss..."
>
> *5th EU Environmental Action Programme*

2.2.1 Background

For almost a generation, transport has been widely recognised as a major source of environmental as well as social problems. This has not prevented them from steadily increasing.

In the light of environmental space, three objections may be raised against the environmentally motivated policies towards the transport sector that have hitherto been conducted in EU countries.

- Firstly, policies have focused strongly on outputs (vehicle emissions, noise, congestion) rather than on inputs (consumption of energy, materials and land).
- Secondly, policies have focused on local, and to a lesser extent regional impacts of transport, while omitting the global level.
- Thirdly, policies have been too weak and/or misdirected even to solve many of the problems on which attention *has* been focused.

Limited successes have been scored - in decreasing order of degree - in

- reducing lead pollution (by substitution of unleaded for leaded petrol)
- reducing carbon monoxide and hydrocarbon pollution (by requiring, or giving tax concessions for, catalytic converters in new cars)
- containing NOx emissions (by the same means)
- in some places reducing noise disturbance (partly by imposing noise limits on vehicles, partly by the materials-intensive method of erecting barriers), while in other places disturbance goes on increasing.

Congestion has been countered *mainly* by building more and broader roads. In general, this has had few lasting positive effects, as new roads have rapidly been filled with the number of vehicles they are able to accommodate.

Meanwhile, the resource consumption and globally important emissions associated with transport have gone on growing without respite.

In recent years, some of the limitations of traditional thinking about transport and the environment have, at least verbally, been recognised by policy makers at the highest levels. At the EU level, this is expressed in the White Paper: **The Future Development of the Common Transport Policy, COM(92) 494** (Commission 1992), delivered shortly after the inauguration of the 5EAP.

The White Paper highlights the well known problems of energy consumption and operational pollution, congestion, land use and risks stemming from the transport of dangerous goods. Moreover, it recognises that technical fixes alone will not solve these problems if transport volumes go on increasing. The White Paper pays considerable attention to charging the full external costs of transport to users, to favour those forms of transport that impose fewer external costs or even to avoid unnecessary movements (p. 38). However only a stepwise approach to this initiative is proposed.

The White paper states:

> "…the risk of the development of the transport sector being unsustainable in the medium to long term due to its environmental impact remains real." (p.15).

Technical and fiscal measures will need to be supplemented with measures to limit the overall need for mobility and encourage shifts towards more environmentally friendly modes:

> "...Promotion of collective transport is a vital component of efforts to integrate environmental objectives into transport policy especially with regards to improving the urban environment. Public and private investment will be essential to promote collective transport as an alternative to the private car. …" (p.62).

and

> "….Improvement of environmental efficiency of transport infrastructure requires careful assessment of the environmental impact at the planning stage of transport infrastructure, according to common criteria, with the possibility of other options. …" (p.64).

However, the environmental message is qualified by others, especially the concern that "…imbalances and inefficiencies… threaten to damage the Community's development, slowing the process of economic integration and adversely affecting its international competitiveness. …" (p.31).

And while the White Paper does recognise a number of important environmental problems, among which energy and land consumption, no mention is made of materials consumption by the transport sector.

Above all, there are no quantitative targets, be it for the reduction of transport volumes, of resource consumption or even of outputs. Even verbally, the level of ambition is to "correct environmental inefficiencies and improve the environmental performance of the transport sector" (p.59), whereas the need is quite clearly to *drastically* reduce inputs as well as outputs.

More importantly, the call for a reorientation of transport policies, aimed at limiting transport volumes and encouraging large-scale modal shifts towards more environmentally friendly modes, has still to be followed up in practice. Billions of ECU are still being poured into the expansion of road and air transport infrastructure. Concern over energy consumption and CO_2 emissions has not led to significant increases in taxes on car fuels. (Of the 10 countries that were members of the EU in 1980, three had *lower* petrol taxes in real terms in 1995 than 15 years previously. Only in two countries: Germany and the UK, did real taxes increase by more than 30% over the period. Since the pre-tax price of petrol dropped in the meantime, its real selling price was less throughout the EU in 1995 than in 1980. (Eurostat 1996)). And aviation fuels are altogether exempt from tax.

Hitherto, the clearest examples of implemented policies directed at *driving forces* behind traffic congestion and pollution have come from the local level of government, rather than the national or EU level. Such measures have included the development of alternative infrastructure (from cycle lanes to new rail links), pricing of roads and of parking, closing of streets or districts to car traffic, subsidies for and improve-ments to public transport.

Locally, such policies have sometimes been successful in *dampening* the growth in urban car traffic. Perhaps the most impressive single example of this comes from Freiburg in Germany, where car traffic has not grown at all since 1976, while it has grown by some 70 percent in western Germany as a whole. However, as the same example illustrates, such local and partial successes have been scored against a backdrop of steady reverses.

2.2.2 Transport and environmental space

Transport policies that are designed to ensure compliance with environmental space will need to be different from those which have been designed mainly to relieve local environmental pressures. This does not only apply to the strength of measures that need to be implemented. In some cases, it will mean a reordering of policy options and priorities.

Today, transport is, together with buildings, one of the two largest "consumers" of all three major cate-gories of resources: energy, materials and (built-up) land. A few figures may serve to illustrate this.

- In 1970, transport accounted for 17% of final energy consumption in EU-15. In 1995, this had increased to 29% (IEA). Over the period, transport energy consumption doubled, while consumption for non-transport purposes grew by slightly more than 10%. These figures refer to direct energy consumption only. In Norway, for instance, it has been estimated that the energy required to supply the country with transport equipment and to construct and maintain infrastructure, equals one-quarter of direct energy consumption by transport (Hille 1995).
- Production of transport equipment and infrastructure typically accounts for between 20 and 40 percent of consumption of major materials, including aggregates, cement, steel and aluminium.
- In 1990 road and rail networks alone claimed 1.3% of the land area of the EU-12. This is an absolute minimum estimate, including only carriageways and not, for instance, parking space. More inclusive figures for transport systems in Germany (Statistisches Bundesamt 1994) and France (Casagrande and Piveteau 1994) are much higher, viz. 4.6% and 2.5% respectively - which still does not include areas subject to noise and other disturbance by transport. In both countries, transport networks represent some 30 to 40 percent of the total built-up area, and in both, it has grown by close to 1% annually since 1980.

There is also a close dialectic relationship between growth in transport and in consumption of land, materials and energy for construction and operation of buildings. This is especially true in urban areas. More (auto)mobility permits urban sprawl; conversely, as dwellings and services spread out, the need for mobility increases further.

From 1982 to 1994, the amount of land devoted to dwellings and services in France grew by 30%; in Germany, land devoted to buildings and gardens grew by 25% from 1979-93. Behind such trends is not only the growth of actual building space, but also a growing preference in many countries for detached or semi-detached houses. Both factors lead to more materials and energy consumption. This partly explains why, despite better weather-proofing, residential and commercial energy consumption in the EU grew by over 40% from 1970 to 1993. In Germany, construction and maintenance of dwellings alone is estimated to account for one-sixth of total "material input" (Behrensmeier and Bringezu 1995 a, cf. fig. 3). Such figures highlight the need for coherent policies, targeting transport and building construction at once, if we are to live within our environmental space. In particular, they point to an enhanced role for urban planning.

2.2.3 Factors influencing transport's claim on environmental space

In Chapter 1, we concluded that the estimates of environmental space given in "Towards Sustainable Europe" may be taken as indicative of the order of magnitude of reductions in resource consumption that are required in the EU. This means reducing per capita energy consumption by the order of 50%, consumption of mineral resources by the order of 90%, and calling a halt to the expansion of built-up land.

From the figures quoted in the last paragraphs, it is evident that none of these goals is likely to be achieved, unless there are substantial reductions in resource consumption by transport. We have chosen, as a starting-point, to assume that the reductions in this sector should be proportionate to those in the economy as a whole.

A central implication is that future policies towards the transport sector must aim to reduce consumption of *all* categories of resources (i.e. not just energy, which has hitherto attracted most attention - closely linked as it is to direct emissions by transport). Taking account of land and materials consumption may in some cases lead to other policy choices than would follow from assessments based on energy alone.

The factors that directly govern resource consumption by transport, and which may therefore be targeted by environmental space policies, include:

- total transport volumes (passenger and ton-kilometres)
- the modes of transport chosen
- the inherent resource efficiency of vehicles and infrastructure within each mode
- the capacity utilisation of vehicles and infrastructure
- the operating speeds of vehicles within each mode.

We shall briefly consider each of these factors in turn.

2.2.4 Transport volumes

From 1970 to 1990, goods transport volumes in Western Europe grew at an estimated average rate of 2.5% per year - almost exactly in tandem with GDP. Passenger transport grew even faster, at 3.1% (ECMT 1993). In per capita terms, this translates into growth of 1.9% and 2.5% respectively.

If these trends should continue through the first half of the next century, then by 2050 per capita goods and passenger transport volumes will have reached three and four times present levels respectively. There is no conceivable way in which this can be reconciled with environmental space. The first requirement, therefore, is to limit transport volumes.

Policies leading to compliance with environmental space in other fields, would automatically lead to some reduction in *goods* transport volumes, since there would be less consumption of primary materials as well as fossil energy sources. Bulk transport of ores, concentrates, quarry products, timber, pulp, coal, oil etc. account for a large proportion of total goods transport volumes today, much of which would disappear if the targets in Table 1 were to be reached.[5] Policies aimed at reducing primary resource consumption in general, will thus be an important contribution to sustainable transport policies.

On the other hand, short- and medium-range transport of food and piece goods leads to much higher energy and materials expenditure *per ton-kilometre* than does long-range bulk transport, particularly if the latter is by ship. Also, the observed rapid growth in freight transport since 1970 has occurred in spite of considerably slower overall growth in consumption of bulk materials and fossil fuels. In other words, it has been largely due to other factors, such as the increasing geographical separation of production steps and of finished-goods producers from their markets. Therefore, future policies must also be aimed at *shortening distances* in goods transport. In the context of the Single Market, this can best be achieved by general increases in the cost of transport - whether directly through taxation, or by reducing investments in infrastructure.

However, limiting motorised *passenger* transport volumes is of even greater concern. Passenger transport already typically accounts for two-thirds of total transport energy consumption - and probably similar proportions of land and materials consumption - and is growing faster than goods transport. Along with containing urban growth, measures to limit motorised passenger transport may include

- encouraging *non*-motorized transport
- encouraging a degree of “multi-centrism” in cities which have already sprawled (so that people can find workplaces and services closer to home)
- encouraging tourism / holidays closer to home (admittedly the most difficult for policy-makers to influence)
- encouraging the use of telecommunications as an alternative to business travel.

2.2.5 Transport modes

The rapid growth in passenger and goods transport volumes in Western Europe over the past four decades has been accompanied by dramatic changes in the modal mix of both. Simply summarized, the trend has been from ship and rail to road transport of goods and from public (as well as non-motorized) transport of passengers, to car and air travel. In Northwestern Europe (UK,

[5] Of the total tonnage of goods entering into cross-border trade within the EU in 1991, fuels made up 26%; ores, metals, minerals and building materials 33%; and other raw materials and semi-manufactures 22%. The remaining 19% was evenly split between manufactured articles and foodstuffs (EUROSTAT 1995, Table 14-2).

Benelux, Germany, Scandinavia) per capita use of the “old” modes has been roughly constant since the 1960s, so that almost the entire growth in transport volumes has been shared between lorries, cars and aircraft. In Southern Europe, there has still been some growth in rail freight and public transport, but much less than in car and lorry transport.

From the point of view of *energy* consumption, these modal shifts have been unequivocally negative. At equal capacity utilisation, passenger transport by car demands 2-3 times as much energy as bus or rail transport, while air transport demands 8-10 times more than trains running at 150 km / h, if capacity factors are equal. The energy efficiency of ship and road goods transport depends heavily on vehicle size.

However, for similar kinds of goods, heavy lorries typically require about 50 percent more energy per effective tkm than trains. Small coasters or barges may only be about as efficient as goods trains, whereas larger coasters (5-10.000 dwt) can be up to five times more efficient.

So far, this suggests that policies should be directed at

- moving passenger traffic from private cars to public transport (bus or rail)
- moving freight traffic from roads to railways, ships or barges
- bringing air travellers down to earth.

Are these conclusions still valid, if we take account of land and materials consumption?

The case is most clear-cut, and simplest in the case of cars vs. buses. The amount of materials required to build a 40-seater bus is about 10 times that for a passenger car, but so is its seating capacity. Since the bus will typically have an operating life (in km driven) 2-3 times longer than that of the car, this means that, with equal capacity factors (which is a conservative assumption in urban traffic) the bus is, at a first approximation, 2-3 times more efficient with respect to materials entering into the vehicle. Also, a bus requires only about one-third of the road space taken up by 10 cars, which means that it is more efficient with respect to land as well as materials for infrastructure.

Comparisons between road (car or lorry) and **rail** transport create more difficulties because the infrastructure, in both cases, must be “split” between freight and passengers. Nevertheless, there is much to suggest that rail transport is superior both to cars and lorries in terms of land use. According to the first-order estimates in the Green Paper on transport, the rail network in the EU-12 occupies only 2.5% of the land taken up by roads. Yet the railways still carried out 17% of all land goods transport in 1991, and 7.5% of land passenger transport in 1988. Without regard to differences in capacity utilisation, this suggests that rail transport in current European practice is 4-5 times more land-efficient than road transport.

There is also no doubt that railway rolling stock consumes less materials (in tons) per passenger-kilometre than private cars (taking account of the lifetime of both). If we still aggregate materials in tons, the materials intensity of railway freight wagons is comparable to that of heavy articulated lorries. Both have a tare weight equal to about half of their maximum payload, and operating lifetimes (in km travelled) are similar. Compared to *light* road goods vehicles, trains are decidedly more efficient. The few available comparisons of materials consumption for road and rail *infrastructure*, however, give very divergent results. Here, assumptions about life-times, maintenance needs and capacity utilisation are decisive.

Ships in coastal and ocean traffic are land- as well as energy-efficient; the amount of land taken up by harbours is small by comparison with the volume of goods transported by sea. Inland waterways can be quite another matter. The ratio of “tare” weight to payload is poorer for very small ships or barges than for goods trains or heavy lorries - about 1:1 for ships of 500 t - but improves with size, to the order of 1:2 in the 5-10.000 t range. Taking account of operating lifetime (km sailed), however, even small ships are probably more materials-efficient than lorries or freight wagons. (Kordi 1979, Stiller 1995).

Air travel, on the other hand, shows up considerably better with respect to land and materials than to energy. The main reason is simply that aircraft need only runways and terminals at either end of their route, and no infrastructure in between. Certainly, air travel is more land-efficient than car travel, and probably even more land-efficient than railways, although the evidence is patchy. For instance, the total area occupied by airports in France has been estimated at about one-quarter of that occupied by railways (Casagrande and Piveteau 1994) and in Norway at about one-third of that occupied by railways (Aall 1994). Assuming that one-half of the railway infrastructure in both countries can be ascribed to passenger traffic, and that half of the air traffic between these countries and others can be ascribed to their own airports, then land consumption per passenger-km for air travel appears to be about one-third of that for rail in France and one-sixth in Norway. Admittedly, this does not allow for the fact that capacity utilisation of the rail network in both countries is probably lower than of airports.

What applies to land consumption, is also likely to apply to materials consumption for infrastructure. As for vehicles, an aircraft seating 200 passengers and weighing some 30-40 t may perform some 6-7 billion pkm of transport work during its operating life (Assumptions: 50 million km flown, capacity factor 65%.) This is at least 4-5 times more than can be expected of a passenger train of twice the capacity (locomotive + 7 wagons) weighing ten times as much.

A closer analysis of the relative materials intensity of different modes of transport, which is much to be desired, would need to take account of the relative environmental loads of the specific materials entering into the different kinds of vehicle and related infra-structure. It is nevertheless likely that the *broad* relationships above would be confirmed, even if specific materials were given (reasonable) environmental “loadings”, or were evaluated on a “material input” basis.

The implications of considering all kinds of resource consumption at once, are thus clearest in the case of private cars: compared to public transport, they are inefficient on *all* counts. The extreme energy cost of air transport remains a strong argument for limiting its use. But if the current very strong volume growth in air transport were simply to be transferred to land modes of transport, this would rapidly lead to unacceptable costs in terms of materials and land. In goods transport, there is a strong case for transferring freight from lorries to railways or inland waterways so long as the latter have underutilised capacity, whereas this would be less clear if new infrastructure needed to be built.

2.2.6 Resource efficiency within modes

Like modal choices, policies to improve resource efficiency within each mode of transport should take account of all aspects of environmental space. The limited interest that has so far been shown in the matter, has once more been strongly biased towards energy.

Paradoxically, however, the greatest improvements in energy efficiency over the past quarter-century have been achieved within two of the transport modes that have been *least* exposed to policy measures that might promote it, namely air and ocean ship transport. In both cases, overall energy intensity has been almost halved. And in both cases, this has been partly a result of better body and / or engine design, and partly of scaling up (a large ship can carry a given amount of freight, and a large aircraft a given number of passengers, with less energy than two or more smaller units). Smaller energy economies of scale have also been scored in long-distance road goods transport.

In passenger cars, achievements have been much more modest. Between 1975 and 1985, specific fuel consumption of new cars on the European market dropped by some 20 percent, but since 1985, there has been no further improvement. The latter is partly due to the fact that manufacturers have used up many of the easy options for improving efficiency - and partly that, since the 1986 oil price drop, consumers have tended to prefer heavier vehicles (fig. 1).

Of course, increasing weight also has a negative impact on the materials inten-sity of car transport. In addition, this will depend on the lifetime of vehicles (which appears largely stable) and the extent to which new cars are produced from recycled materials.

There has recently been some improve-ment in recycling rates, due partly to improved shredder technologies and to policies, including deposit schemes in some countries, to increase the turn-in rate of disused cars. State-of-the-art technology makes it possible to recover almost 100% of the iron and steel and 90% of the non-ferrous metals from scrapped cars.

However, this does *not* mean that cars have already “done their bit” towards securing compliance with environmental space for materials. For one thing, not all wrecks are yet recycled, certainly not with best available technology. Nor are many of the non-metallic materials usually recovered. More importantly, materials from old cars will not be able to cover 90-100% of requirements for new car production, until the number of cars stops growing from year to year.

Unfortunately, no data are available to permit an assessment of overall changes in the materials intensity of road transport *infrastructure*.

There is still considerable *potential* for increasing the *energy* efficiency of most modes of transport. For instance, a recent estimate by the World Energy Council suggests that the specific fuel intensity of commercial aircraft could be virtually halved again by 2020, if the maximum is made out of technological opportunities. (Statoil / WEC 1995). In cars, fuel consumption can be reduced by to about one-third by substituting fuel cells and electric motors for internal-combustion engines; with additional measures, such as a reversal of the current trend to increasing weight, and further reductions in aerodynamic and rolling resistance, it could be reduced to about one-fourth. Anything much beyond this - in normal-sized cars - would be stretching the laws of thermodynamics. If we continue to rely on internal-combustion engines, then the potential for energy savings is unlikely to be much more than 50%, compared to light vehicles of today. In diesel-driven lorries, the potential is very much smaller.

In trains already running on electricity, the potential for energy efficiency improvements is also more limited (perhaps 25-30%, including braking-energy recuperation) *unless* it occurs at the stage of electricity generation.

In the longer term, the question of fuel efficiency potentials becomes more complicated, in that it must be considered in conjunction with that of fuel switching to renewable sources. This could mean either batteries supplied with solar or wind-generated electricity, or hydrogen from the same sources.

In both the long and the short term, moreover, energy efficiency potentials must be considered together with materials efficiency. This is liable to pose major problems, whether we are onsidering (hybrid-)electric vehicles using conventional fuels, straight battery-driven vehicles or vehicles running on solar hydrogen.

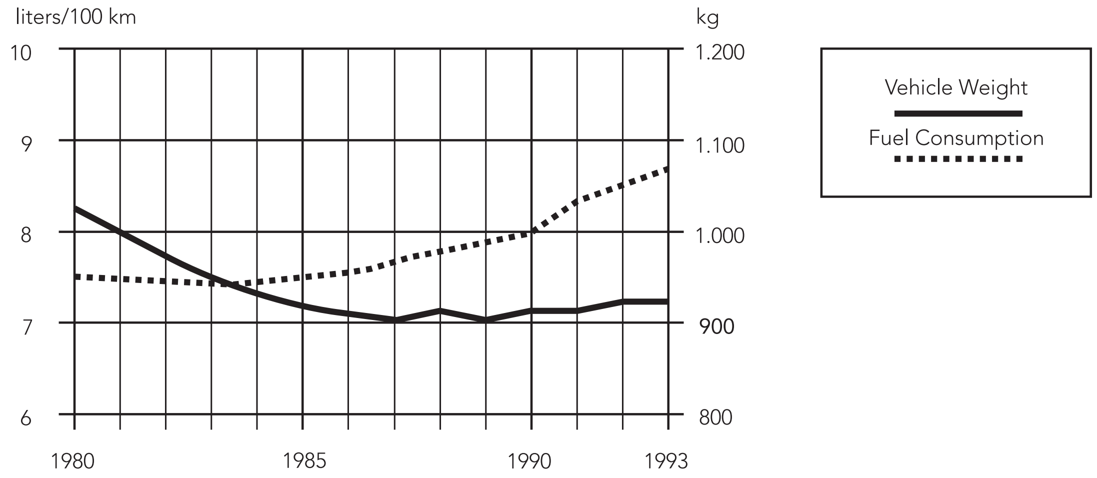


Fig. 1.
Development of new-car weight and fuel consumption in Europe

- Electric technologies tend to be copper-intensive. From the point of view of "material input" (cf box, p. xx), doubling the copper content of a car from, say, 10 to 20 kg is about as bad as doubling the steel content from 700 to 1400 kg.

- Batteries are even more intensive in materials for which the environmental space is constained. After 130 years of electric-car development, the standard power source remains the lead-acid battery, half a ton of which will give a car a range of 100-150 km. Should European rates of car ownership be extended to the entire world population of 2050, and the cars run on lead-acid batteries, this would demand some 2 billion tons of lead - simply to make the first generation of batteries. This is 800 years of current world mine production and more than is ever likely to be found in exploitable ore-mineral form. Proposed alternatives would require comparable amounts of other scarce metals (zinc, nickel) or present environmental or safety hazards (such as sodium-sulphur batteries).

- Hydrogen storage in whatever mode (compressed, frozen or bonded in a metal hydride) will demand far more materials per unit of stored energy than a conventional fuel tank. The safest solution, the metal hydride, is likely to demand quite large quantities of scarce metals. (A hydride of relatively abundant metals (iron / titanium) is possible, but would require some 20 kg of metal to store the equivalent of one litre of petrol).

If we aim to live within our environ-mental space for materials as well as energy, then technology alone does not appear to offer any "miracle" solutions. And when it comes to saving land resources, it has even less to offer.

2.2.7 Capacity utilisation

Improving capacity utilisation saves all kinds of resources, since it means carrying out a given amount of transport work with less movement of vehicles, and / or more transport on existing infrastructure.

At least, with respect to infrastructure, this applies up to an optimum point, beyond which "improving" capacity utilisation means increasing congestion. This point has already been passed on many stretches of road and many airports in the EU, resulting not in less, but in more energy consumption (cars running extra inefficiently, planes waiting to take off or land.) Much of the European rail network, on the other hand, is under-utilised, even along trunk lines which offer direct alternatives to congested roads. This merely strengthens the case for moving car traffic onto the rails.

Capacity utilisation of *vehicles* should also be an important target for policies. Improving it not only saves energy and materials directly, but *also* relieves the pressure to spend more energy, land and materials on infrastructure.

Today, the average capacity utilisation of private cars in EU countries averages just over 25% in rush-hour traffic and about 50% otherwise. *Outside* rush hours, capacity factors of trains and buses are also typically within this range. Also, local road goods transport often operates at very low capacity factors. In long-haul road and rail transport, capacity factors are fairly high - often close to 100% in one direction. The figures drop - to around 60% on average - when one counts return journeys, part of the problem being that there may not be an equal quantity of goods to carry on the return leg, especially not for special-purpose lorries or wagons.

The biggest opportunities for improving capacity factors, then, concern private cars in rush-hour traffic, trains and buses outside rush hours, and short-haul / unspecialised goods traffic. In the case of goods traffic, this may depend on better planning, more co-operation between enterprises doing own-account transport, and a relaxation of "just-in-time" requirements. In the case of public transport, the precondition for improved capacity factors in many areas will simply be an increase in traffic volumes, which would result from a modal shift away from private cars. Ride-sharing in cars should also be encouraged, though as a second-best option compared to public transport.

Although very useful, the realistic opportunities for improving capacity factors will not *dramatically* increase the amount of mobility to be had within our environmental space. It is worth remembering that travel to and from the job, where the chances of improving capacity factors of private cars are best, only accounts for about one-quarter of private car use in most EU countries.

At the same time, capacity utilisation may not only be thought of as the percentage of seats occupied when a vehicle is in use, but also as the percentage of the time for which it is in use. In the case of private cars, this is approximately 4%. This figure could be considerably increased through *car-sharing* schemes, in which a large number of households share a smaller number of cars, rather than maintaining one or two each. The advantage of such schemes is not merely that they reduce consumption of cars as such (cars that are used more intensively, will tend to attain a shorter lifetime in years, but nevertheless a longer lifetime in kilometres). The extra dividend in such schemes, whereby participating households share in the *full* costs of car transport (depreciation, maintenance, insurance etc. as well as fuel) on an "as-you-drive" basis, is that they encourage *rational* use of cars. Whereas car-owners tend to drive irrespective of the availability of alternative modes of transport, car-sharers will do so only when public transport is unavailable or the car offers specific advantages - say for transporting heavy articles or for weekend outings into the countryside.

2.2.8 Speed

One of the most fundamental laws of physics might well be framed above the heads of all transport planners.

It states that:

$$e_k = 1/2\ mv^2$$

i.e., kinetic energy varies with mass and the *square* of velocity. Simply put: The faster you want to get from A to B, the more energy it costs.

In practical life, this rule has its exceptions, because, for instance, internal-combustion engines operate at lower efficiencies below a certain "cruising" speed. Above this speed, however, the rule applies with full force, as it does to high-speed trains or ships.

With respect to land transport, something similar also applies to *materials* consumption for infrastructure. High-speed road transport demands motorways. High-speed rail transport demands tracks with few and very gentle curves and low grades. Unfortunately, landscapes were not originally designed for the sake of motorways or high-speed trains, so this means that much more earth and rock need to be moved, and much more steel and concrete expended than in building ordinary roads or railways. Thus, a Swiss estimate - drawing on data from Germany as well as that country and explicitly designed to reflect West European conditions rather than those of Switzerland alone - suggests that motorways demand about 15 times more concrete and steel and involve the removal of some 130 times more matter in tunnelling, than the construction of an equal length of second-class roads (Frischknecht 1994).

Something similar is likely to apply to high-speed rail links (>250 km / h). Since they also demand extra land *and* demand about twice as much energy per pkm as conventional (100-150 km / h) trains, high-speed rail is not, on balance, an attractive alternative to air transport. Rather, the preferred alternative to holiday air travel should be holidays at an appropriately leisurely speed. And the preferred alternative to business air travel should be technology that offers contact at speeds no aircraft can approach - i.e. telecommunications.

In the case of road traffic, some energy savings can be gained by reducing speed limits and better enforcing existing ones, though the figures are not dramatic. A British study (Fergusson 1994) found that the introduction and enforcement of a 60 miles per hour (97 km / h) speed limit on all roads, including motorways, would reduce overall road vehicle fuel consumption by 5%, while a general 80 km / h limit would save 7%.

2.2.9 Conclusions

If a policy is to be followed to bring transport within its environmental space, then all categories of resources must be taken into account. Such a policy would begin with the setting of *targets* for the reduction of energy, materials and land consumption by the sector. If one uses the overall reduction goals of "Towards Sustainable Europe" as a guideline, this means reducing transport energy consumption by half within the next half-century, reducing virgin materials consumption for vehicles and infra-structure by the order of 90%, and *immediately* calling a halt to the net appropriation of land by transport net-works.

To achieve anything like this, *all* means of reducing resource consumption must be mobilised. Improving efficiency within transport modes and increasing capacity utilisation may appear most painless. In combination, and if all other factors remained constant, it is technically possible that these strategies alone could reduce overall transport *energy* consumption by between 60 and 70%. It is presently far from certain that they could yield a 90% reduction in materials consumption; and even if either of these goals could be achieved on its own, it is still less certain if both could be achieved at once. Materials considerations are quite likely to constrain the options for energy savings so much that no more than a 50% reduction in this field is realistic.

What is certain, is that improvements in intra-modal efficiency and capacity utilisation will not suffice if the present negative trends in transport volumes, modal mixes and travel speeds persist.

If we are to live within our environmental space, we therefore need a coherent set of policies to counter the demand for *more* transport, *faster* transport and *more individualised* transport. Certainly, this will include the administration of a range of medicines already prescribed for instance in the Green Paper on Transport, though in far stronger doses. For instance, this means strong increases in fuel prices, and the redirection of funds from investments in roads, airports *and* high-speed rail links, to support for public transport.

But if such policies are to succeed and be accepted, they must go hand in hand with others that address the *underlying causes* of high transport demand. In part, this means policies promoting resource efficiency in all *other* sectors, which will reduce goods transport volumes. In part, it means a combination of physical planning and economic restructuring to bring producers closer to their markets and people closer to their places of work and other daily activities. (The role of the agricultural sector in this connection will be discussed in the next section). Last but not least, it means fostering changes of attitude, among businesses as well as private households. In the case of business, this means, among other things, challenging the just-in-time philosophy, promoting co-operation on rational transport solutions and more willingness to exploit the potential of telecommunications. In the case of households, it also means a greater willingness to cooperate (car-sharing, ride-sharing), as well as changed attitudes to holiday and leisure travel: letting the cult of farther and faster give way to that of closer and calmer.

2.3 Agriculture

As in the case of transport, agricultural policies designed to secure compliance with environmental space must aim at reducing consumption of energy, materials *and* land - the latter in several senses -at once. In addition, the sustainable use of *water* will have a major bearing on agricultural policies in some regions. In general, the goals of reducing materials and energy consumption in the field of food production are convergent. On the other hand, that of reducing land consumption will *ceteris paribus* put increased pressure on other resources - a conflict which can only be resolved if Europeans are willing to accept substantial changes in their diet. Policies for sustainability must therefore address food consumption as well as methods of production.

2.3.1 Materials consumption

Agriculture influences materials consumption in three main ways:

- through its own consumption of *inputs* (especially fertilisers and lime)
- through its consumption of *investment goods* (on-farm construction, machinery)
- through its influence on materials consumption in *downstream activities* (food processing, distribution and marketing).

In particular, the materials consumption involved in packaging, storage and distribution systems depends on the extent to which agriculture is regionally and locally specialised. A higher degree of local self- sufficiency would obviously reduce needs for transport and intermediate storage of food. It could also be coupled with more consumption of fresh and unpackaged (as opposed to processed and retail-packaged) produce, as well as facilitating the re-use of such packaging as would still be necessary. *Locally diversified* agriculture is a necessary, though not a sufficient, condition for a high degree of local self-sufficiency in food.

Some progress has already been achieved in reducing EU consumption of chemical fertilisers, partly by restructuring the Common Agricultural Policy (CAP) away from production-dependent subsidies towards other forms of support for farmers. In the Scandinavian countries, fertiliser taxes have also been introduced. To achieve compliance with environmental space, these lines of policy need to be radically strengthened and broadened. Consideration should also be given to taxes on heavy agricultural machinery, which not only costs resources but also causes soil compaction and erosion.

As mentioned in the previous section, a higher degree of local self-sufficiency can most obviously be promoted by increasing transport costs. At the same time, the idea of local self-sufficiency ties in well with that of promoting more mixed farming at the level of the individual enterprise. Like reducing external inputs and partly for the same reason, this is very much in line with organic farming practice. Increased support for conversion to organic farming is therefore also a relevant policy measure.

2.3.2 Energy consumption

Energy consumption *in* agriculture only accounts for some 3% of final energy consumption in the EU. However, studies from several industrial countries suggest that the total energy consumption involved in making food available to consumers is some 15-20% of final energy consumption. Besides on-farm consumption, the most important contributions to this figure come from the production of fertilisers and the processing, distribution and marketing of produce. The movement of inputs - including feeds as well as fertilisers - and the production of capital goods also cost energy, though less than the elements previously mentioned.

Reducing consumption of fertilisers - nitrogen fertilisers in particular - will thus be an important contribution to reducing energy consumption in food production. Integrating feed production and stock raising will also have a positive effect (less transport).

So will an increased degree of local self-sufficiency, by reducing energy consumption for transport as well as processing and packaging. (It is important to note that *local* self-sufficiency is of greater importance in this regard than *continental* self-sufficiency - although the former would obviously contribute to the latter. Transporting food across Europe by lorry can easily cost more energy than transporting the same food by ship from, say, South America.)

The policy measures that are desirable if we aim to reduce materials consumption, therefore agree with the objective of saving energy. In addition to those mentioned, it is worth noting that an *overall reduction in the relative importance of animal-food production* will reduce materials and energy consumption, not only per unit of food energy produced, but also per unit of agricultural area. This is because the operations involved in “refining” crops into meat and milk (housing and maintenance of animals) demand resources of their own. Also, the processing, distribution and storage of meat and dairy products tends to be more resource-intensive than that of most vegetable products, relative to their nutritional value. This means that changes in patterns of nutrition, which will be necessary if we are to reduce consumption of land as well as fertiliser and other inputs (cf. next sections) are likely to pay an extra dividend in terms of energy and materials.

2.3.3 Land consumption (1): Reducing agricultural area

If one accepts the view of “Towards Sustainable Europe”, i.e. that a fraction such as 10% of all original biotopes needs to be set aside for conservation, then obviously some agricultural land in Europe must be allowed to revert to nature. The important point is that this does not mean just any old agricultural land - for instance the “marginal” land already being taken out of production in many countries. It must include land representing a cross-section of all original types of habitat, i.e. including prime agricultural land - and rather large contiguous tracts at that, if the objective of re-establishing diverse and resilient ecosystems is to be achieved. This again will require not merely legislation, but compensation schemes for the potentially millions of people affected, if it is to be socially accepted.

Phasing land out of production also means that, to achieve a given level of production, yields on the remaining land must be higher. This suggests a conflict with the goal of reducing energy and material inputs - a conflict which can only be resolved by *accepting* a consider-able reduction in production and therefore in consumption of agricultural products. We shall return to this below.

2.3.4 Land consumption (2): Sustainable management

In section 1.2.3, we discussed different views of the environmental space for exploitation of agricultural land. If one takes the view of “Towards Sustainable Europe”, i.e. that environmental space is respected if and only if agriculture is conducted on organic principles, then the high road to this goal is obvious: strongly increased support for conversion to organic farming, possibly backed by a ban on other farming practices, to become effective e.g. from 2010.

If one takes a more differentiated view, for instance that sustainable land management should be understood as eliminating net soil loss and re-establishing a degree of diversity within the agricultural landscape, while reducing but not necessarily eliminating chemical inputs, then the appropriate policy measures may be correspondingly more differentiated.

Important measures aimed at reducing erosion and increasing diversity will tie in strongly, not only with each other, but also with measures aimed at reducing materials and energy consumption. For instance, elements of diversity such as hedgerows, shelterbelts, and natural vegetation along watercourses all counteract erosion. Mixed farming, desirable for several reasons already mentioned, is suited to smaller fields, potentially with semi-natural boundaries between them. An important part of the rationale for very large (and erosion-prone) single-crop fields is to permit the "rational" use of heavy machinery, which itself further promotes erosion as well as costing energy and materials resources. Policies that promote mixed, integrated or organic farming will tend to have a positive effect on landscape diversity and soil conservation as well. They will, however, need to be supplemented with targeted measures to these particular ends.

2.3.5 Land consumption (3): Reducing net "imports" of foreign land

Taken together, measures directed at bringing European agriculture within its environmental space will lead to a reduction in food output. If one assumes a 10% reduction in yields per unit of gross agricultural area, as does "Towards Sustainable Europe" - then this, combined with a similar reduction in area, will mean a loss of close to 20% in output.

If consumption patterns were unchanged, this would lead to a large *increase* in net "imports" of land. Even if agricultural exports were eliminated altogether (calculations in TSE suggest that about 11% of agricultural land in the EU is currently used for export production) there would still be additional *gross* demand for imports, if consumption in Europe remained the same.

To bring net imports of land down to zero, Europe would by contrast need either to increase exports (out of her reduced output) or to reduce agricultural imports (by about half, if the reductions were spread equally across all kinds of imported produce). In this way, the total availability of agricultural produce - weighted on the basis of land required to produce the various products - would be reduced by some 30%.

Physiologically, this would present no problem. As the "Sustainable Europe" study shows, Europeans could obtain a nutritionally excellent, though less meat-rich, diet from only 0.17 ha of arable land apiece, plus 0.11 ha of pasture - even after allowing for a 10% reduction in yields. This compares with the 0.3 ha of arable land - in Europe and other continents - plus 0.16 ha of pasture, that each EU citizen currently lays claim to.

However, we have noted that by 2050, global availability of arable land may be down to 0.13 ha per person, so that an equal share-out might mean an even more vegetarian diet - and very little room for consumption of non-food products such as coffee and cotton.

Politically, even the short term and the "Sustainable Europe" interpretation of environmental space - based on continental self-sufficiency - present more of a challenge. In fact, the short term arguably presents the greatest political problems.

In a world in which per capita purchasing power were more or less equally distributed across countries, an equitable global share-out of resources is exactly what would result under free trade. Food would flow from regions with a relative land surplus (e.g. Europe) to those with a relative deficit (e.g. East Asia). If preferences for animal vs. vegetable foods were also equally distributed, then the animal-food "quota" would also be rather similar everywhere. (And despite cultural differences, meat consumption does tend to increase markedly with income in most parts of the world).

Under present conditions, with gross income disparities between continents, the problems are quite different. So long as incomes, prices, preferences and trade regimes are unchanged, a reduction in European agricultural output will lead to increased imports. Europeans will demand coffee and cotton at prices that make Third World governments, companies and farmers prefer to grow them, rather than producing more food for home consumption. And European cows and pigs will continue to outbid Africans in the world grain market.

There are three possible short-term solutions: changes in preferences, in prices or in trade regimes. If Europeans voluntarily reduce their consumption of meat, then fodder output in Europe can be reduced without creating added demand for imports. If they voluntarily reduce their consumption of coffee, cotton etc., then demand for these products may be reduced to a level where it is balanced (in terms of land use) by the present level of European agricultural exports. In other words, no new export subsidies will be required to achieve such a balance.

If such reductions in consumption do *not* come about through changes in preferences, then they could be brought about through taxes. Consumer-level taxes on animal products (mainly produced in Europe) might be admissible under existing international trade agreements, whereas selective taxes on goods that are almost exclusively imported today, would be more likely to be ruled out as hidden trade barriers.

The last possible solution - that of out-right barriers (increased duties or bans) against imports, perhaps supplemented with increased subsidies on exports - would obviously mean the abrogation of existing trade agreements, in particular the results of the Uruguay Round. Apart from such “formalities”, increased trade barriers against imports from Third World countries would, at least in the short term, leave many people still poorer and estrange their governments politically.

A fully satisfactory solution to the problem of the “land drain” towards Europe can only be brought about by eliminating its root cause, i.e. the extreme income disparity between Europeans and the majority of the world’s population. This, of course, will take time. Europe can contribute to shortening that time, for instance by relieving poor countries of their debt burden, by increasing the level of development assistance and redirecting its content towards the elimination of poverty.

In the meantime, Europeans should begin - the sooner the better - to *prepare for* a future in which their cattle and pigs will no longer be able to outbid other people for land. They can be encouraged to do so by educational measures as well as by the removal of subsidies, if necessary to be followed by the imposition of taxes, on animal foods.

Ways could also be sought of *coupling* disincentives to overconsumption of land, with measures aimed at reducing global income disparities. One way of doing this - which might be acceptable to Third World countries - would be to tax consumption of non-food agricultural products, such as coffee and cotton, but at the same time earmark the revenue for additional development assistance - perhaps specifically for projects designed to reduce primary-export dependency. A near model for such schemes exists in the Danish coffee tax, whose proceeds were originally earmarked for industrial co-operation projects with developing countries.

2.3.6 Conclusion

If a policy is to be pursued to bring European agriculture within *its* “environmental space”, it will involve a radical restructuring of the CAP and national agricultural policies, in a direction along which only the first cautious steps have yet been taken. Subsidies which reward high yields and therefore input levels must be replaced by direct support for sustainable *farming practices*, including organic and integrated agriculture. In addition, targeted programmes must be introduced inter alia to secure land to be set aside for conservation; to promote landscape diversity and soil conservation; and to promote energy conservation in agriculture.

At the same time, an environmental space perspective means that neither agriculture nor Europe can be viewed in isolation. Agricultural patterns exert a significant influence on resource consumption in downstream activities. Particular emphasis should be given to measures which have a potential to reduce the latter, including a reversal of the trend to regional specialisation in agriculture.

Above all, policies to promote sustainable agriculture must go hand in hand with policies to promote sustainable nutrition, as well as sustainable consumption of non-food products from agriculture. Less consumption of animal foods will in itself contribute to reducing energy, land and materials consumption in agriculture as well as in up- and downstream activities. It is also essential, if we are to avoid a situation in which “sustainable agriculture” in Europe turns into increased demand for land in other continents.

The fundamental reason for Europeans’ relative over-consumption of agricultural resources - as of other resources - is the extreme income disparity between them and the majority of the world's people. The long-term solution consequently lies in eliminating this disparity. Meanwhile, domestic policies should be guided by the principle that we must begin the adjustment to future realities - the sooner the better.

3. Environmental Space and Indicator Systems

Good policy-making depends on good information - about where the problems are, about their magnitude, their causes and the success or otherwise of present policies in dealing with them. Policy-making aimed at compliance with environmental space will be no exception.

Indicator systems are one method of making relevant information available and digestible to policy-makers. In this chapter, we shall ask what kinds of indicators the environmental space concept calls for - be they "new" indicators or established ones, where there may still be a need to improve the quality of data or extend coverage to more countries.

3.1 Background

3.1.1 Environmental indicator systems

Over the past two decades, and not least in the past few years, many international agencies and national governments have developed sets of environmental indicators. These naturally tend to reflect what have been priority areas for environmental policy-making. Partly, this is a matter of choice. Partly, it is a simple consequence of the fact that most data have been generated in the areas on which most public and political interest has been focused.

Thus, existing indicator systems generally give a considerable amount of information on the *outputs* of the human economy into the environment: emissions to air and water, noise, generation of solid waste and hazardous substances - along with some on environmental aspects of agriculture and forestry, on protected areas and species status.

As for the input side - resource consumption - most environmental indicator sets include information on energy consumption and on land used for agriculture. Some also include water use and / or built-up land, but the usefulness of such information in reporting at the international level is limited by major gaps in the availability and the very variable quality of data. And consumption of materials is generally very scantily covered, if at all.

The most influential exercise in environmental indicating at the international level so far has been the "Core Set" of indicators developed by the OECD (OECD 1994). The "Core Set" includes 72 indicators in all, although only 30 are yet operational . They are classified in two ways: according to the issues to which they relate, and as indicators of either "pressures", "states" or "responses". We shall return to the latter concepts in the next section.

The list of issues used by the OECD is strongly output-oriented. It does include three kinds of "resources" in its own terminology (water, forests and fish); but the indicators proposed for these relate to *extraction*, not to OECD countries' *consumption* of resources. Among the 72 indicators, there are also three on aspects of energy consumption, of which two are motivated by the issue of climate change. But there are none at all on materials consumption, excepting fertilisers. Although the issues of biodiversity and soil degradation give rise to indicators on aspects of land use, there are none on the expansion of built-up land, nor on the appropriation of foreign land by OECD countries.

In connection with the review of the 5th EU Environmental Action Programme (5EAP), the EEA has developed its own set of indicators (Environment in the European Union; EEA 1995). Like the Core Set, the 84-indicator system of the EEA has the emphasis very much on outputs. It does, however, include one very simple indicator of minerals consumption, in adddition to some on energy, land use and water. (Perhaps significantly, there is also one indicator showing the EU *share* in world population, energy and minerals con-sumption. Still, this a long way from presenting consumption *targets* based on global equity.)

Also at the EU level, EUROSTAT is currently coordinating work on the construction of an "Environmental Pressure Index" (Jesinghaus 1995). This will be aggregated from indicators within 10 identified "problem areas", of which "resource depletion" has been recognised as one. However, the specific indicators in this area have yet to be identified. Whether or not they should provide good links to the environmental space concept, it is clear that the EPI as such, involving as it will a complex mix of inputs and (mainly) outputs, will not be an adequate measure of compliance with environmental space.

3.1.2 Indicators of sustainable development
Since UNCED-92, several proposals have been advanced at the international level for more comprehensive sets of "sustainability" or "sustainable development" indicators, as opposed to environmental indicators in the narrower sense. Two of the more important ones are the set adopted by the Policy Department of the UN Commission on Sustainable Development (DPCSD) and the "Indicators for Action" proposed by the World Wide Fund for Nature in co-operation with the New Economics Foundation (WWF / NEF 1994). The main difference between such systems and the straight environmental indicator sets is of course the inclusion of a large number of indicators of human development and welfare.

One might, however, expect "sustainable development" indicators to highlight the equity aspect of resource consumption. Both the DPCSD and the WWF / NEF indicators include energy and water consumption, while the latter also include timber consumption and the former an economic indicator of "intensity of materials use". Apart from this, both include some indicators on the *depletion or extraction* of resources (fish, minerals, timber also in the DPCSD set). Still, there is much to be desired in the coverage of resource *consumption*, which is the interesting quantity in the environmen -tal space context. Clearly, the selection of indicators in cases such as these is strongly influenced by concerns of data availability. These are more pressing at the global than at the EU level.

3.1.3 More resource indicators needed - not to the exclusion of others
The search for improved indicators of human, social and economic development remains extremely important. So is the maintenance and improvement of systems for reporting on emissions, waste, disturbance and other negative outputs to the environment, including those of mainly local or regional significance.

Our object here, however, is specifically to consider what indicators are needed to monitor and to further progress towards compliance with environmental space. In this area, it is clear that there are significant gaps in all of the indicator sets mentioned above, as there are in systems used for reporting at the national level.

Not only are important resource inputs omitted altogether from existing (operational or proposed) indicator sets. Where they are operational, the quality and / or coverage of data on such inputs is often poor. Where reliable data do exist, they are as yet in no case related to concepts of environmental space as such, i.e. to *targets* for resource consumption. Nor do existing indicator systems give sufficient information on the *causes* of trends in resource consumption.

3.2 What to measure? - Resource consumption, driving and braking forces

In the field of environmental reporting, a three-way classification of indicators has gained wide acceptance. This is the PSR (pressure-state-response) system used by the OECD, in which "pressures" may for instance be polluting emissions, "state" may be air or water quality, and "response" may be expenditure on cleaning measures. Ideally, the PSR system may be regarded as a chain of causal links: increased pressures put the environment in a poorer state, which (hopefully) provokes responses, that in turn lessen the pressures and turn the vicious circle into a good one.

However, the real world - as illustrated by the OECD's own Core Set of indicators, actually involves considerably more complex chains (or webs) of causation.

"Pressure" indicators in the OECD system can cover several links in such chains: e.g., not only urban air emissions, but also road traffic volumes; not only nitrogen emissions to water but also fertiliser applications and even agricultural production.

The concept of "response" indicators is also a complex one. In the OECD terminology, it not only covers direct indicators of government action (e.g. public expenditure on the environment or energy taxes) but also actions and even attitudes of business and house-holds. Then there are *indirect* "response" indicators (showing *results* of actions which may involve all three actors - e.g. recycling rates).

Recently, the term "driving forces" has been increasingly applied in indicator systems, in at least two quite different senses. In the DPCSD system, the expression "driving forces" *subsumes* "pressures", but also covers a range of basic socio-economic indicators. So

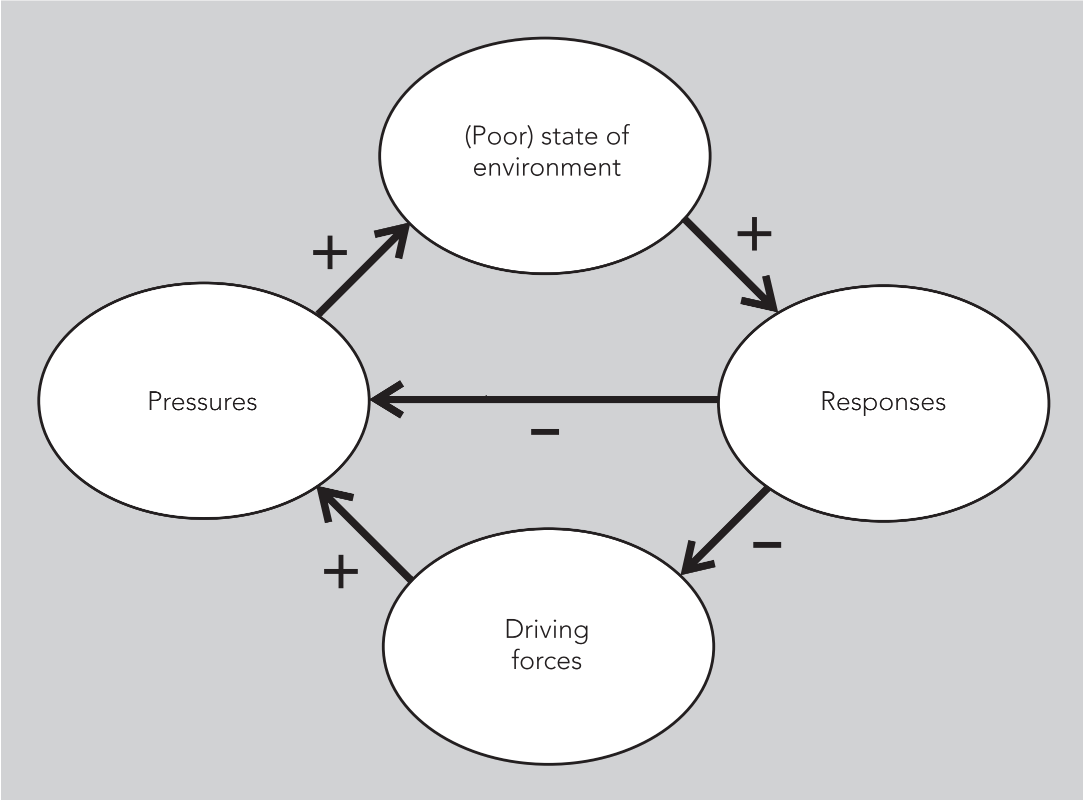


Figure 2

instead of a PSR there is a D(riving force)SR system, but without any notion of a causal link between "driving forces" and "states".

In the EEA indicator system, on the other hand, driving forces are recognised as distinct from "pressures". Here, "driving forces" refer to economic and other societal developments - *including* some aspects of resource consumption as such - which may contribute to "pressures" in the sense of emissions, disturbance and so on.

The figure above is a simplified illustration of the relationships between driving forces (in sense no. 2), pressures, state and responses. Ideally, responses should lead to reduced pressures, *either* directly (if the responses are of the "end-of-pipe" kind) or indirectly, by dampening the driving forces.

We noted that present indicator systems tend to subsume resource consumption either among the "pressures" or among the societal "driving forces". In the light of environmental space, however, there are good grounds for regarding it as a separate link in the chain(s) of causation.

It is an essential part of the environmental space concept that excessive resource consumption is a problem in itself. This is *partly* because of the present environmental pressures to which it inevitably leads, but *also* because of its negative implications for global equity and for future generations. Therefore, a reporting system based on this concept will logically need to focus on resource consumption. Similarly, if existing reporting systems are to be adapted to take account of environmental space, they will need to place greater emphasis on resource consumption and the forces driving it.

We have also noted that "response" indicators may be direct or indirect, purely political or not. *Indirect* indicators of response may also be seen as belonging to the same level of causation as what we have called "driving forces".

For instance, increasing recycling rates may be interpreted as a "response" leading to less (primary) materials consumption, whereas decreasing or static recycling rates may be regarded as a "driving force" behind such consumption. Similarly, increasing volumes of road traffic may be regarded as a driving force behind all kinds of resource consumption, whereas declining or stabilising traffic volumes may be interpreted as an indirect indicator of responses to the problem. Rather than "indirect response indicators", it therefore seems reasonable to talk of "braking" forces along with the driving ones.

Also, in policy-oriented reporting, it seems reasonable to distinguish between explicit *policy* responses on the one hand, and broader societal developments that affect driving or braking forces on the other.

Figure 3 illustrates the relationships outlined above.

Broadly, we may say that existing environmental reporting systems tend to e biased towards the upper right-hand portion of the diagram (with some exceptions as exemplified in the previous section). There is a corresponding need to improve reporting on the links in the lower left-hand part. We shall consider these in turn (as well as some possible indicators of policy response) in sections 3.5-3.9. Before doing so, we shall briefly consider some requirements for a good indicator system.

3.3 Performance indicators, background indicators and targets

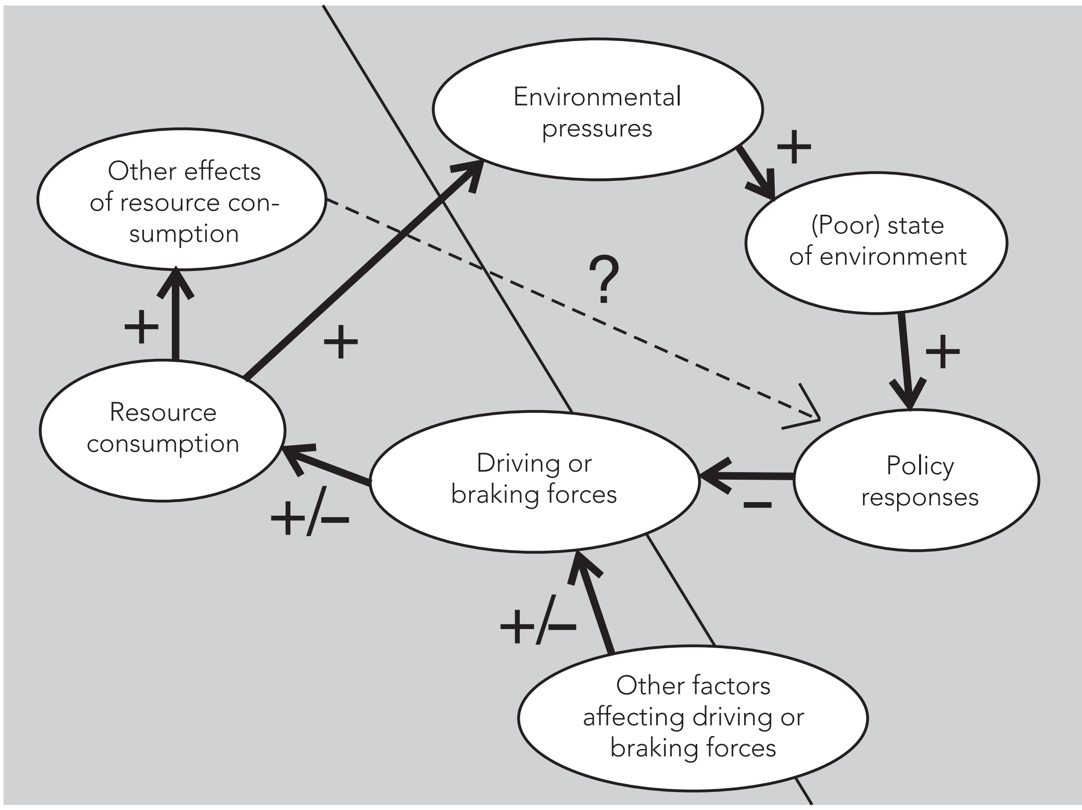
Indicators may be used to measure whether things (in our case meaning resource consumption) are moving in the right or wrong direction, and at what speed. In this case, we may call them *performance* indicators.

They may also be used to indicate the causes of these movements, which are of particular interest if things are moving in the wrong direction, or too slowly in the right direction. If so, action is called for, and we need to know what actions are likely to be effective. We may also want indicators to compare the strength of actions that are already being taken, especially across countries. We shall call the latter kinds of indicators "*background*" indicators.

If indicators are to serve as an effective guide on the way to compliance with environmental space, it is essential that some of them, namely the performance indicators, should be linked to *quantified targets*. Without such targets, it *may* be possible to say whether things are moving in the right or wrong direction. But it will never be possible to say whether things are moving *fast enough* in the right direction.

In most present international environmental reporting systems, targets are conspicuously absent. This is not surprising, since there are

Figure 3



few universally accepted environmental goals. At the EU level, the 5EAP does include reduction goals for emissions of some major pollutants, and the EEA's recent "Environment in Europe" report does present emissions indicators together with target values. Some national-level State of the Environment reports also present developments in emissions together with verbal and or / graphical references to national reduction goals. Targets for resource consumption, however, are extremely rare.

The very concept of environmental space implies quantitative targets for resource consumption. As we saw in Chapter 1, the TSE study has proposed such a set of targets at the EU level. National Friends of the Earth groups and research institutes have since carried out studies to clarify the implications of these targets for individual countries in Europe.

Policy-makers will no doubt wish to have further assessments carried out before either accepting the targets set in TSE or setting others. Lengthy discussions on precise targets for all resources should not, however, be allowed to delay the upgrading of reporting on resource consumption, nor action to reduce it. If necessary, indicators can, to begin with, be linked to targets which are explicitly defined as preliminary and indicative.

It is worth noting that TSE, for instance, suggests that one-quarter of the necessary reductions in resource consumption should be achieved by 2010. If environmental space for a given resource were taken to be 10% of present consumption (meaning that a 90% reduction is ultimately necessary) then the necessary reduction by 2010 would be 22.5%. If environmental space instead were 20% of present consumption, then the recommended reduction by 2010 would be 20%. This is hardly a dramatic difference. In other words, setting preliminary goals for the intermediate term should provide time enough for further study and political discussion of the long-term goals - without any danger of radically over - or undershooting the mark in the meantime.

3.4 How many indicators - for whom?

The purpose of indicators, as described in the **Dobris Assessment** (Stanners and Bourdeau 1995) is to "convert data into information" - i.e. into information digestible by policy-makers (and, at best, by the ultimate policy-makers in a true democracy - the general public). However, the distinction between "information" and "data" can hardly be made precise. One man's set of informative indicators, giving a concise and understandable overview of developments, may contain a great deal of what another would regard as data incomprehensible without further interpretation.

In the present paper, we are concerned with indicators at two levels. The first is that of indicators suitable for reporting directed at *all* policy-makers, including the general public. Taken together, these indicators should be capable of giving an "at-a-glance" impression of the progress being made towards sustainable resource consumption. The number of such "key" indicators should be no more than 10 or so, and they should belong to the performance indicators.

The second level is that represented by indicator sets such as those discussed in section 3.1, or used in national State of the Environment reports. Here, the *main* target groups will be policy-makers with a special responsibility for sustainability policies, and more interested sections of the lay public (including communicators capable of turning the contents into information for a broader public).

Such reporting could take the shape of separate reports on resource trends, appearing at annual or few-year intervals. It could also (and should preferably) be integrated with existing environmental reporting systems, as well as information on social development and equity, to form the basis for a complete system of reporting on sustainable development. Reporting at this level should include more detailed indicators of resource consumption trends as well as background indicators (of causes etc.). Nevertheless, the number of such indicators should be in the tens and not in the hundreds.

Even the latter requirement means that the mass of potentially relevant data must be radically condensed. There are two ways of doing this: by selection or by aggregation. Either method means that information gets lost. Selection means that many elements are left out entirely; aggregation gives an overall picture which may be more or less meaningful, but means that no information is conveyed on any individual element. We shall in fact suggest a combination of the two.

3.5 Performance indicators - Resource consumption

In sections 3.1 and 3.2, we discussed the need to improve reporting on resource consumption. In reporting specifically on progress towards compliance with environmental space, indicators of overall resource consumption as such will be those of the first order - the "performance" indicators, which should be linked to targets, as discussed in section 3.3. This section discusses the choice of such indicators, and of key indicators in particular.

If these indicators are to be incorporated into broader environmental indicator systems, there will also be indicators on the output side, which it is not, however, our task to consider here.

In accordance with the discussion in Chapter 1, indicators of resource consumption should cover land, materials, energy, water and marine resources. We shall consider these in turn.

3.5.1 Land

"Consumption" of land in our context covers several things:

1) The expansion of built-up area, which can be directly measured.

2) The absolute extent of land that is subject to exploitation by agriculture, forestry or other economic activities. This is close to 100% in most EU countries today and can best be measured "negatively", as the percentage of land strictly protected from such exploitation (i.e. in IUCN categories I-II).

3) The over-intensive exploitation of land that *is* used for agriculture and forestry. The pertinent indicators in this case will depend on one's view of the limits to sustainable exploitation. If one follows the reasoning in "Towards Sustainable Europe", for instance, then the percentage of land that is *organically farmed* will be a natural indicator of progress towards sustainability in agriculture, while an indicator of sustainable forestry might be the percentage of forest area that is naturally regenerated. Other possible indicators - in the case of agriculture - could for instance be the percentage of gross area not devoted to crops, or rates of soil erosion. The latter would, however, be more difficult to operationalise.

   If one believes that *integrated* farming is an acceptable approach to sustainable land management, along with organic farming, then the percentage of land managed on either set of principles might be a relevant indicator. The practical problem is that there are as yet no certification procedures or recognised codes of conduct for integrated farming.

4) The amount of land "consumed" through our own consumption of agricultural products. The pertinent indicator of this will again depend on one's view of what is acceptable. If the goal is continental self-sufficiency, then the most relevant indicator *for Europe as a whole* will be the *net appropriation of land in other continents to produce for European consumption* (1). This can be estimated by dividing European imports of agricultural products from other continents by estimated average yield figures per hectare, and subtracting European exports to other continents, divided by European yield figures. (In the case of imports/exports of animal foods, processed foods and finished goods made from agricultural products, such as cotton garments, conversion figures to raw crop equivalent will be needed).

If, on the other hand, the goal is that per capita land "consumption" in Europe should not exceed the average availability at the global level, then the *ratio between the former and the latter* (2) may be a more relevant indicator.

Naturally, either of these indicators would be subject to the criticism that not all agricultural land is of equal quality. This is *especially* true if one includes pasture in the concept: enormous tracts of "permanent pasture" in other continents have a productivity very close to nil. But even if one based the indicator on arable land only, average productivity in Europe (at least excluding Russia) would be somewhat better than the world average, while the hectares used for export production in Europe might be of either better or worse quality than the hectares Europe indirectly "imports".

Despite this, either of the indicators suggested would give important *directional* information for the foreseeable future. This is because Europeans presently consume more *and* better land than the world-average citizen, and would still be doing so if "net appropriation" fell to zero. *At least* until this should occur, the desirable trend for either indicator will be downwards. And if one's goal is an equitable global share-out of resources, the desirable trend for indicator (2) will be downwards *at least* until it attains the value 1. This might therefore be regarded as a preliminary target.

An alternative way of comparing "consumption" of land - this time in terms of (area x productivity) is to compare consumption of *agricultural produce* directly. The difficulty in this case is the large number of different products. Nevertheless, aggregate consumption of *animal foods*, which is what most tends to push land consumption upwards, will be an important "background" indicator (cf. section 3.6).

Timber consumption, although grouped with material resources below, might also be regarded as a proxy for "consumption" of forest land (in terms of area x productivity x intensity of exploitation).

3.5.2 Materials

Consumption of materials may seem a more straightforward concept than consumption of land, but in fact raises significant problems of definition and measurement.

Renewable and non-renewable materials
Materials include both of these categories, but they clearly raise rather different sets of problems in the environmental space context. Aside from agricultural raw materials, which compete directly with food production for arable land and the space for which is therefore most dependent on that resource (3.5.1), the most important renewable material by far is timber. Because of its central economic and, especially, environmental importance, timber consumption should be tracked by a separate key indicator, while other indicators are needed for non-renewable materials.

Apparent and real consumption
The second problem that individual countries (or the whole EU) have considerable "invisible" imports and exports of resources, in the shape of finished goods. A country's claim on environmental space should be regarded as the resource consumption occasioned by final consumption of goods and services in that country.

However, the data that are readily available from trade statistics only encompass imports and exports of materials in raw or semi-finished forms. Materials embodied in imports and exports of finished products are not accounted for. Conventionally, apparent consumption of materials is calculated by adding domestic extraction to visible imports and subtracting visible exports. This *excludes* materials embodied in imports of finished products, and at the same time *includes* materials embodied in exports.

It is of great importance to have indicators of the *real* consumption of materials at the national and EU levels, since this is what needs to be brought into line with environmental space. Naturally, it is not possible to calculate the *exact* amounts of materials embodied in imported or exported goods. Nevertheless, it is possible to make estimates which provide results that are considerably closer to the truth than are apparent consumption figures. Such estimates have, for instance, been made for Norwegian consumption of timber and iron (Statistics Norway 1984, Hille 1995) and for German consumption of a range of materials resources (Behrens-meier and Bringezu 1995a). Estimates of "invisible" imports and exports may either be based on value figures in the trade statistics, combined with input-output analysis to estimate materials "content" per ECU for each category of goods; or on tonnage figures, combined with estimates of materials and energy expenditure per ton of product. In either case, the estimation of specific (per ton or per ECU) resource costs of product categories is demanding, but once carried out, the results may be regarded as valid for a few years at a time. Between revisions, invisible import/export estimates can be updated using annual trade statistics only as input.

While real consumption figures are of primary importance, it is still also important to monitor apparent consumption. This is because the resource inputs to a country's industry - even though some of them may leave again in the shape of exports (and some stay behind in the shape of waste!) are *also* a necessary target for policies.

Aggregation
The third problem that arises in reporting on materials consumption in particular, is that of aggregation. Clearly, if we are to arrive at a list of no more than ten "key" indicators of resource consumption, then we cannot start counting non-renewable materials one by one.

As we have seen, the TSE study proposes a sweeping solution to the problem, viz. to aggregate all kinds of “material input”, or humanly induced movement of (in this context: solid) materials, in tons. Clearly, if one chooses to define environmental space for materials consumption in these terms, then the relevant key indicator is total material input.

In practice, this measure not only raises problems of principle (discussed in section 1.2.3) but also fresh problems of measurement, since many kinds of MI (overburden, tailings, earth movement in construction activity etc.) generally go unreported. They might nevertheless be estimated (in the case of overburden and tailings, standard conversion factors - tons of MI per ton of useful material extracted - could be used, cf. the case of aluminium discussed on p. 11).

The problems of estimation could be less, if one chose to define environmental space not in terms of MI (materials *moved*) but in terms of materials actually *used* to make products. However, aggregating these quantities (stone + sand + steel + lead + salt.....) in tons would be *less* meaningful than measuring MI. An aggregate of “materials used” would be entirely dominated by a few high-volume materials, in particular aggregates (stone, sand and gravel) or, if one chose to leave these out, by materials such as cement and steel. Metals and minerals that are used in low volumes, but whose environmental loads nevertheless make them of major concern, would hardly affect the sum. The MI measure compensates for this to some extent, because low-volume minerals tend to have relatively larger rucksacks than the high-volume ones - and this is itself *one of* the factors that can make their environmental loads of concern.

If, on the other hand, one believes that environmental space and therefore reduction goals need to be defined separately for individual materials or classes of materials, then a different approach to aggregation becomes relevant. This is to construct a *composite index* of materials consumption. This could most simply be done by annually calculating the unweighted average of percentage changes in consumption of the (say) ten to fifteen materials judged most important.

A more refined and preferable method would be to weight the materials according to (1) economic importance and (2) ecological criticality, as measured by the percentage reductions in consumption required for compliance with environmental space. The basis for weighting materials would naturally have to be periodically revised, as is the case with price indices. The drawbacks of an index based on a double weighting procedure would be (1) a possible loss in ease of comprehension and (2) that, being an index, the indicator could only be used to track developments over time, not for synchronous comparisons across countries.

Proposed indicators
As key indicators of non-renewable materials consumption, both aggregated (per capita) material input and a composite index based on specific materials of major importance may be found useful. These indicators should be based on real consumption (after accounting for invisible exports and imports).

For in-depth reporting, they would of course need to be supplemented by consumption data on *individual materials*, including the most important metals, industrial minerals and building materials. Here, apparent as well as real consumption figures would be relevant.

Timber consumption per capita should be a separate key indicator.

3.5.3 Energy
Aggregating and measuring energy consumption is rather more straightforward than is the case with materials or land.

One may define separate “environmental spaces” for exploitation of different energy sources at the global level. But since energy from widely different sources can be converted into the same end-useable forms (albeit not always at 100% efficiency), and can also be traded between countries, it is most meaningful to define the environmental space for *consumption* of (primary) energy as a single aggregate, in joule. Similarly, the first key indicator of progress towards compliance with environmental space in this field will be total primary energy consumption per capita.

As in the case of materials, this aggregate should be estimated in real terms (including the energy embodied in imported goods and services, but excluding the energy content of exports). And as in the case of materials, invisible exports and imports of energy may either be estimated by economic input-output analysis or by estimating the energy-content-per-physical-unit of categories of imports and exports. (Such estimates have for instance been made for Norway (Statistics Norway 1984; Hille 1995); and estimates of "embodied" CO_2 emissions resulting from fossil energy use have been made for several major OECD countries (Wyckoff and Roop 1994).

While real energy consumption should be measured in aggregate, it is *also* important to monitor progress in replacing less with more sustainable energy sources. These are relative concepts, since *all* energy sources entail some environmental costs. Nevertheless, a "key" indicator should draw the line between renewables and non-renewables. Since countries have no influence over the sources of energy that are used to produce the goods and services they import, the policy-relevant measure in this case is the share of renewables in total *apparent* energy consumption.

For in-depth reporting, these two key indicators should be supplemented with information on trends in use of individual sources of energy (oil, coal, gas, hydro, wind, solar etc.)

3.5.4 Water

Consumption of water also presents problems of definition, as indicated by the widely differing ways in which it is currently reported (where it is reported at all) by national statistical agencies. Reporting should cover consumption by all economic sectors (agriculture and / or energy conversion are often omitted today). A greater problem of principle is the fact that much of the ground or surface water "consumed" for purposes *other* than irrigation, is in fact returned to local watercourses, in a more or less polluted state. Nevertheless, gross abstractions are probably the best feasible, first-order indicator of pressure on water resources. They must be related to regional targets, which will depend on rates of runoff and aquifer recharge. Because of this, aggregate water consumption cannot be considered as a "key" indicator at the EU level or in most countries.

3.5.5 Marine resources

As the first priority, reporting on these should cover fish and other animal seafood. Ideally, "consumption" in this case should refer to the total *kill* behind a country's seafood consumption. However, since dumping of (especially) undersized fish is generally unreported, the *catch* (in round weight equivalent) required to make the country's consumption of seafoods (and marine feeds) possible, is probably the best feasible indicator. This of course necessitates conversion factors for imports and exports of processed fish products.

3.6 Background indicators (1): Driving and braking forces

3.6.1 Introduction

The forces driving or braking resource consumption (cf. fig. 2) can be decomposed along several dimensions. At least two of these are of central importance, if one wants to inform policy-making aimed at compliance with environmental space.

The first is to ask how particular *socio-economic sectors* are contributing to growth or the opposite in resource consumption. This is important first of all because policy-making tends to be sectorally organised. It is important for policy-makers at the sectoral level to know whether they are "doing their bit" towards securing compliance with environmental space, just as it is important for those with cross-sectoral responsibilities to be able to identify the sectors that present the greatest problems and / or potentials.

Quite apart from the present organisation of policy-making, a sectoral break-down can be useful because different sectors use resources in different ways, which are then susceptible to different kinds of policy measures.

The other dimension of central importance is what we may call the volume / intensity dimension. The resource load of a society depends on its total income, on how that income is disposed (across more and less resource-intensive goods and services) and on how the goods and services are produced (with more or less resource-intensive technologies). Each of these factors may be a target of policies, but partly different sets of policies will be required to improve the efficiency of technologies and to influence consumption patterns. It is therefore important to track developments in each of these fields.

3.6.2 Resource consumption by sectors

Many existing environmental reporting systems already split consumption of certain resources (most commonly energy, and sometimes water) by sectors. Built-up land is split by sectors in the national statistics of some countries, though such sectoral break-downs are less often included in environmental reporting. No regular environmental reporting systems that we know of split materials consumption by sector.

There is still a need to *harmonise* reporting on sectoral energy consumption, and to upgrade and expand reporting on sectoral consumption of water and built-up land. This means agreeing on which sectoral breakdowns make sense from the point of view of policy-making aimed at reducing consumption, and seeing to it that corresponding statistics are gathered.

In the case of materials, it is at once more difficult and less obviously relevant to policy-making, to split consumption between the same kinds of sectors that may be used in the other three cases.

Energy
For overview purposes, final energy consumption is often divided between the following sectors:

- Primary industries
- Secondary industries
- Services
- Transport
- Households (or a "residential" sector)

In addition there is the consumption of the "energy sectors" (i.e. energy conversion and distribution), which, together with losses, equals the difference between primary and final energy consumption.

There are in fact good practical reasons for using the six-way split shown above (including the energy sector), in reporting on energy consumption. This in preference to the simpler three-way split (manufacturing / transport / other) used for instance in the Dobris Assessment and several OECD publications, and also to breakdowns by national-accounts sectors. The six sectors represent naturally distinct foci of attention in shaping policies to reduce consumption, because the main uses to which energy is put are quite different as between them. There is one major exception: both households and services use energy mainly for heating, cooling, lighting and ventilation. But, at the same time, households and businesses are quite different in their behaviour and with respect to the policies that are likely to be effective.

Land
A similar categorisation makes sense with respect to (built-up) *land*. Within the primary sector, however, mining and quarrying operations become significant as consumers of land in some countries (more so than of energy) and should be separated from agricultural construction. Also, recreational facilities (outside urban areas) are increasingly important and should be considered separately from land used for urban services. Finally, parks and other public open spaces within urban areas should be separately identified.

Water
Where figures on water consumption are split by sector, this may be done (as it is in the Dobris Assessment) in a way quite similar to that suggested for energy, except that transport is omitted and the primary sector split between agriculture and mining / quarrying. As in the case of energy, this makes good policy sense because of the different ways in which the sectors (agriculture, energy conversion, manufacturing, agriculture and services / households) use the resource.

Materials
Solid materials present a different set of problems altogether. Materials are first extracted within the primary sector, then passed on, often through many stages, within the secondary sector, until whatever has not become waste on the way enters into a finished product - i.e. a product which is not to undergo further processing.

The finished product may, indeed, end up in any one of the "sectors" suggested in the case of energy. It may be a turbine or a pylon (energy sector), plough or pesticide (primary sector), factory or machine tool (secondary sector), cash register or school blackboard (service sector), car or bridge (transport sector), house or household good (residential sector). Actually estimating the amounts of materials that end up in each of these sectors - and the amounts of waste that arise on the way - is, however, a demanding exercise, of the kind that may be carried out on a project basis but hardly in connection with regular reporting.

More importantly, there is no obvious reason why there should be different sets of policies directed at *construction* of houses, of offices and of factories, or why the *production* of tractors and ploughs should be the target of one set of policies, distinct from those directed at production of paper machines and lathes. Nor is there any way of differentiating between production of PCs destined for factories, schools and homes.

Rather, there are - at the first level - two obvious target groups for policies aimed at reducing materials consumption. The first is the secondary industries in their role of producers. The second is the purchasers of finished products. It is impossible to apportion materials con-sumption *between* these. Nor is it likely to be cost-efficient, for purposes of regular reporting, to monitor the split of materials consumption between categories of purchasers of finished goods.

Another matter is the possibility of splitting materials consumption between *sub-sectors of secondary industry***.** Since the same materials may be handled in turn by several branches, there are only two ways of doing this "cleanly": (1) to ascribe consumption of materials to the *first* branch that handles them, or (2) to ascribe it to the *last* branch that handles them. The former approach leads to such unsurprising results as that the iron and steel industry is responsible for practically 100% of iron ore consumption, the mineral products industry for most clay and limestone consumption, and so on. The latter approach can yield much more interesting results. How much of steel consumption ends up in deliveries from the construction industry? The vehicle industry? The electrical goods industry? - What is the eventual split of timber consumption between the printing, paper goods, furniture, construction and other industries? This kind of information at once tells us which kinds of *products* it is most important to target (in policies towards purchasers and which *production chains* it is most important to target (in policies towards industry).

Information of the latter kind can - with some qualifications - be obtained from economic input-output analyses (see for instance Behrensmeier and Bringezu 1995a, who have used this method to estimate total "material input" behind final deliveries from 23 sub-sectors of industry in Germany).

The input-output method does have its limitations. It may nevertheless be possible to refine and adapt I-O analysis so that acceptable estimates can be made at regular intervals of how consumption of major materials is split between secondary sub-sectors delivering finished products. For reporting at the level we are presently discussing, it will naturally only be possible to cover a selection of the most important materials, and a limited number of sub-sectors in each case. For most materials, the sub-sectoral split of most fundamental interest will be that between construction and manufac-turing. Within manufacturing, it should be of interest to split consumption between deliveries of investment goods, consumer durables and consumer non-durables, since these may be the targets of different policy measures.

3.6.3 Consumption patterns and technologies

The forces driving (or braking) resource consumption may at the most aggregated level - that of a total economy - be regarded as:

1) the **level** of final consumption of goods and services (in this context including investment goods)

2) the **mix**, or "pattern" of consumption (as between more and less resource-intensive goods and services)

3) **technology**, or more precisely the (in)efficiency with which resources are used to produce each type of good or service.

The first of these is conventionally measured in money values, and equates in a closed economy to the GDP. The use of the GDP as an indicator of production or (roughly) of consumption levels has been widely criticised, most particularly on the grounds that it excludes "informal" production. How-ever, most such informal production consists of services which (in Western Europe) add little to the resource load of a society. For an analysis of our kind, therefore, the GDP would seem an acceptable measure of the first driving force.[6]

The *mix* of consumption (and, at a less detailed level, of investments) is also regularly measured in national accounts, but the various product categories are not conventionally ranked in terms of resource intensity. So there is *no conventional measure of the sustainability of consumption patterns.*

The *combined effect* of factors 2) and 3) is sometimes expressed by the "intensity" of the economy with respect to particular resources, most commonly energy (e.g. MJ per unit of GDP). However, such indicators are inadequate, as they mask the relative contributions of technological improvements, of changes in consumption patterns and in industrial structure to increasing or decreasing resource intensity. (Changes in industrial structure can be an important independent variable in an open economy, where the

[6] There are obviously more reasons why the GDP is inadequate as a measure of welfare or want satisfaction (as opposed to consumption). For instance, it includes social reapair costs, and takes no account of the fact that goods may be used in ways that provide more or less satisfaction, more or fewer "service units" (cf. section 1.3). But although it may be desirable for some purposes to discuss resource intensity in terms of resource consumption per welfare or service unit, the latter concepts are difficult to quantify. Also, goods that are inefficiently used from the point of view of welfare provision demand no less resources than if they are efficiently used. As a measure of the first force driving resource consumption, GDP is therefore at least as valid as these alternative concepts.

structure of production is not determined only by domestic consumption, but also by what a country happens to import and export).

Therefore, we need to look for more specific indicators, which can tell us on the one hand something about the sustainability of consumption and investment patterns, and, on the other, the resource intensity of production - and do so in ways that are comparable over time and across countries.

Economic indicators of consumption patterns
The possibility of constructing a single indicator of the sustainability of consumption patterns (as defined by economists) hinges on that of *ranking categories of consumption in terms of resource cost in relation to price*. If people spend a given income on products that cost a lot of resources per ECU, then the pattern of consumption is less sustainable than if they spend it on products that cost a lot of ECU per resources.

As already mentioned, the number of ECU spent on various categories of goods and services in EU countries is already available from national accounts. The first problem is therefore one of estimating the claims made on environmental space by corresponding categories of consumption.

First-order estimates of the amounts of *materials* expended to facilitate broad categories of private and government consumption have been made in Germany, using economic input-output matrices (Behrensmeier and Bringezu 1995b, see Table 3). Estimates of the amounts of *energy* expended for the sake of similar consumption categories have for instance been made in Norway, using existing estimates for some product categories and production steps, and ad-hoc estimation procedures to fill in the gaps (Hille 1995, see Table 4).

However, the problems involved in distributing consumption of environmental space among consumption categories (and investment categories, if these are treated separately) should not be underestimated. Studies such as those mentioned show a great need for more basic data as well as improved methodologies. If these problems are overcome, the question will remain of how consumption of energy, of materials (however aggregated) and of land (in one or more senses) should be weighted. This problem is essentially no different from that which arises in making comparative life-cycle analyses of individual products. Another problem is that the relative prices of product categories vary over time and across countries, so that a "sustainability ranking" of product categories would not necessarily be valid everywhere or forever.

One way of simplifying things could be to limit the number of consumption categories to three: those with *unambiguously* high resource / ECU ratios, those with unambiguously low resource / ECU ratios, and the remainder. This would necessitate splitting some of the broad categories shown in Tables 3 and 4, before regrouping them. There is something to suggest that, for instance, animal foods, private-car transport

Table 3.
"Material input" occasioned by consumption categories in W. Germany, 1990.

(Min. = Minerals, FF = Fossil fuels, Bio. = Biotic raw materials, Tail. = Tailings and overburden (from mining), Exc. = Excavation for construction, Ero. = Erosion.)

	Material input (tons per capita per year)							
Consumption category	**Min.**	**FF**	**Bio.**	**Tail.**	**Exc.**	**Ero.**	**Total**	**%**
Food, beverages, tobacco	1.25	0.40	2.29	2.48	0.16	1.47	**8.05**	**15**
Clothing and footwear	0.36	0.11	0.09	0.70	0.06	1.11	**2.43**	**5**
Dwellings and residential energy	3.70	1.29	0.25	7.66	1.00	0.11	**14.01**	**26**
Furniture and household operation	0.95	0.17	0.21	1.48	0.07	0.24	**3.12**	**6**
Health and personal care	0.51	0.10	0.07	0.78	0.06	0.04	**1.56**	**3**
Transport and communications	1.98	0.93	0.10	2.88	0.15	0.07	**6.12**	**12**
Recreation etc.	1.26	0.16	0.31	2.22	0.10	0.15	**4.20**	**8**
Other goods and services	1.26	0.14	0.12	1.76	0.10	0.06	**3.44**	**6**
Govenment consumption	3.52	0.54	0.33	4.88	0.62	0.20	**10.09**	**19**
Total	14.79	3.84	3.76	24.85	2.31	3.47	**53.02**	**100**

Source: Behrensmeier and Bringezu 1995, figure 4 (basic figures provided by H. Schhtz, Wuppertal Institute).

Table 4.
Energy consumption occasioned by consumption categories in Norway, 1992.

Consumption category	Percentage of real energy demand (est. 1992)	Percentage of money value of consumption (Nat. accounts 1991)
Food, beverages, tobacco	16.5	17.9
Clothing and footwear	2.5	4.8
Dwellings and residential energy	30.5	13.5
Furniture and household operation	3.0	4.7
Health care etc.	1.0	3.6
Transport and communications	24.0	9.2
Recreation etc.	4.0	6.4
Other goods and services	2.5	8.1
Government consumption	11.0	29.7
Unallocated, including energy for energy infrastructure	5.0	-

Source: Hille 1995.

and residential energy would be found to belong to the "high" category in most if not all EU countries, whereas much of government consumption and private consumption of non-transport services would belong to the "low" category.

If further study should confirm the possibility of identifying such "high" and "low" categories, then a "sustainability of consumption index" might be constructed, for instance by subtracting volume changes in consumption of very high resource / ECU products from those in consumption of very low resource / ECU products. The validity of such an index would of course need to be kept under review. Should eco-taxes reach levels at which one ECU spent on car transport no longer led to unambiguously greater resource consumption than one ECU spent on a haircut, the index would have served its purpose and could be discontinued.

Physical indicators of consumption patterns
Whether or not is found possible to develop a single measure of the sustainability of consumption patterns, it will certainly be useful to report regularly on *absolute consumption of the goods and services that place the highest absolute claims on environmental space.*

These are quite easy to identify. They are (1) food, in particular animal foods; (2) transport and (3) buildings, including the energy used to heat, cool, light and ventilate them.

Together, these things are responsible for most of our claims on environmental space for agricultural land, built-up land, materials *and* energy.

When "consumption" of these products is considered in physical units, there is no compelling reason to distinguish between consumption in the strict economic sense and investments, or even inputs to production (such as goods transport, business trips or food bought by restaurants). (The relevant physical units are: animal foods in MJ, buildings in square metres, transport in passenger- and ton-kilometres).

There is one qualification to the previous point, if we are concerned with real consumption. In an open economy, some investments and inputs - some buildings, some goods transport and some business trips - will be serving export production rather than local consumption. In the case of buildings, this will apply especially to manufacturing premises, much less to buildings for the service sector, and not at all to dwellings. One might choose to include only the latter two categories in an indicator; in any case, their share of the total should be specified. It is hardly practically possible - for purposes of regular reporting - to differentiate between transport serving export production and the remainder, although the relative order of magnitude of such transport will need to be (implicitly) estimated at intervals, as part of the basis for estimating real domestic consumption of energy and materials (cf. section 3.5). For annual reporting purposes, the raw figures must do.

While food, transport and buildings are of the greatest importance, it may also, in in-depth reporting, be found useful to include physical-unit data on developments in some other consumption categories. One instance is clothing and other textile goods (of interest due to the very high land and water intensity of cotton production, high land intensity of wool production and high toxic-emissions intensity of synthetic as well as natural fibres).

Technology
Above, we described technological efficiency as one of three logically distinct factors influencing resource consumption, the others being the level and the mix of final consumption.

For reasons that we have already touched on, however, it would not only be difficult but also of doubtful relevance to link reporting on technological efficiency directly to final consumption categories in the stringent economic sense. Estimates of resource inputs by consumption category are likely to remain so approximate that monitoring changes, at least at intervals of up to a few years, will be difficult. More importantly, many of the goods consumed in a given country (or the EU) are imported, so that policy-makers cannot influence the efficiency with which they are produced, whereas they *can* influence that of their own export industries.

Energy efficiency
Hitherto, reporting on technological efficiency has concentrated mainly on *energy*. To the extent that such reporting has been disaggregated, it has generally been by "sectors" similar to those listed in section 3.6. There are quite good technical reasons for this, since the possible technical meanings of energy efficiency - or the inverse, energy intensity - vary as between the sectors. Also, some of these sectors can simultaneously be linked to the physical consumption indicators suggested above (food, transport, dwellings and buildings for the service sector).

In the **residential** and **service** sectors, it is most relevant to express intensity as energy consumption per square metre (and heating or cooling degree-day, in making comparisons over time or across countries).

In the **transport** sector, energy intensity should be expressed as energy consumption per passenger- and ton-kilometre.

In the **secondary industry** sector, it is hardly possible to arrive at simple, physical indicators of energy intensity. Most energy consumption in the sector is for actual production processes, delivering an enormous range of incommensurable products. The only simple, practicable measure of intensity is that of the economist: energy consumption per ECU of output.

In **agriculture and fisheries,** intensity can also be expressed as energy consumption per ECU. Alternatively, it can be expressed as energy consumption per unit of food energy output. A shift towards more vegetable relative to animal food production would be likely of itself to lead to a drop in the latter measure. To avoid "double-counting" such an effect, the energy-per-ECU measure might be preferred.

In the **energy** sector, the measure of intensity is rather obvious, namely primary energy input per unit of final energy delivered to users.

Along with sectoral indicators, an *aggregate* measure of energy intensity is still to be desired. This could be constructed as an index, by weighting percentage changes in intensity in each of the sectors above, according to their share in total primary energy consumption.

Materials
Indicators of *materials* efficiency present greater challenges than those of energy efficiency, and not only because of the variety of materials to be considered.

If we conceive materials intensity as consumption of primary (extracted-from-Nature) materials per unit of service or satisfaction provided by goods - a way of thinking that we have touched on previously - then there are at least six ways of reducing intensity:

1) lessen wastage of materials during production
2) "shrink" products (use less materials relative to the goods' utility value)
3) substitute recycled for primary materials
4) increase product lifetime
5) substitute goods or services with inherently low materials intensities for goods with high intensities (e.g. televised texts for newspapers)
6) increase the intensity with which each product is used during its lifetime.

(In the great majority of cases, each of these measures *also* leads to less energy consumption).

The last method is unambiguously a way of increasing the efficiency of consumption, rather than of production. The fifth would conventionally be regarded as a change in the *mix* of consumption. We shall not consider these two further in this context.

Whether increasing product lifetimes increases the efficiency of production (in economic terms) depends on how increasing durability affects product prices. Irrespective of this technical point, however, it would certainly be useful to track developments in absolute product lifetimes. Retrospective information on lifetimes - i.e. the average age at which products are abandoned - is directly available only for a few products, such as motor vehicles, which must be registered and deregistered. For other products, sampling or statistical estimation procedures are required. The usefulness of reporting based on such techniques nevertheless deserves further consideration. So do the possibilities of prospectively monitoring product durability and reparability, through testing and assessment procedures of new products.

The remaining methods of increasing materials efficiency: reducing wastage, product shrinking and increasing recycling, are listed in increasing order of importance as well as ease of measurement. *Absolute wastage* is a quantitatively minor problem for most materials. For instance, it is true that only 55-60% of the timber entering a sawmill comes out as sawn timber, but most of the remainder is generally either used as raw material in the pulp, paper or board industries, or converted to energy. Similarly, the metals "wasted" in stamping, cutting etc. in the engineering industry are increasingly recycled. Also, monitoring wastage for a range of important materials through all stages of the many production chains they enter into, is likely to prove costly.

Product shrinking may have considerable untapped potential for some product categories, while in others it is constrained for instance by the dimensions and / or capacities of the human body (consider clothing, furniture, passenger vehicle bodies or reading matter).

It will be somewhat easier to monitor the (sales-averaged) weight of specific consumer goods on the market than to monitor wastage in production. A number of problems would, however, remain on the way to constructing meaningful indicators. For some kinds of goods, utility value per unit may change markedly over time. Also, weight reductions may be due to material substitutions, which can be good or bad depending on the availability and life-cycle characteristics of the materials in question. And indicators would have to be in the shape of composite indices for product categories, since the alternative - selecting a small number of specific "indicator" products - could yield very misleading results.

It may be possible to monitor consump-tion of specific materials, and / or of materials in aggregate, per square metre of new building construction, which is important on account of its large share in total materials consumption. In the case of other construction (infrastructure), finding common denominators will be more difficult.

Recycling has enormous unrealised potential in the case of metals and very large potential in the case of timber (both paper and construction timber), though somewhat less in the case of most industrial minerals.

Recycling rates (or rather rates of recovery-for-recycling compared to total materials consumption) are also much easier to calculate for a whole economy, than are rates of wastage or product shrinking. Recycling rates for aluminium, paper and glass are already included in some environmental indicator sets. The list should be expanded. For instance, iron / steel and copper are both, on account of volume or specific environmental load combined with scarcity, of greater concern than aluminium. Construction timber is in most countries at least as important in volume as paper. Other demolition "waste", which can replace fresh aggregates in new construction, is also important. It may also be useful to monitor recycling of plastics, although technical problems remain to be solved before this can be considered of unambiguous environmental benefit.

While it may be difficult to find good indicators for some of the specific measures that can be taken to improve materials efficiency in production, it may be possible to develop indicators which *subsume* all such measures. The very simplest method of doing this would be to divide input of (a selection of) raw materials to the secondary sector, by total output of that sector (in ECU). Materials "put in" in the shape of imported semis or parts, already processed to beyond the chosen standard level of measurement, would then have to be "converted" (this would for instance mean converting imported pulp or sawn timber to roundwood equivalent). So far as possible, conversion factors should then reflect current efficiencies and recycling rates in the domestic economy.

The most important problem in measuring intensity in this way (e.g. timber, pig iron or cement consumption per ECU of secondary output) is once again variations in industrial structure, over time and between countries. For any one raw material, structural changes in the secondary sector of an economy are liable to have even greater consequences than they will have for energy consumption. (All secondary branches consume energy; only one or a few handle large amounts of timber, chlorine, copper or cement). Applying structural correction factors is again one possible solution.

Alternative approaches would be

- to select only one or two indicator branches for each indicator material - measuring, for instance, pig iron / steel consumption per unit of output in the engineering industry, cement consumption per unit of output in the construction industry, chlorine consumption per unit of output in the chemical industry, and timber consumption per unit of output in the pulp and paper and construction industries. By weighting percentage changes, such measures could also be aggregated into a materials efficiency index. This would mean a gain in comparability over time, but greater expense and probably a certain loss of relevance. This is because improvements in efficiency would be measured only over parts of production chains.

- to base an indicator on aggregate consumption of all kinds of materials in tons, whether measured at the raw material / semi level or in terms of “material input”. The advantages and disad vantages of these solutions follow from the discussion in section 3.5.

3.7 Background indicators (2) : Factors affecting driving or braking forces

In the two preceding sections, we have discussed three forces that may drive or brake resource consumption: the levels of consumption and investments, the mix of these, and the resource intensity of technologies. Each of these is in turn determined by a range of factors, on some of which it may be useful and feasible to develop indicators.

GDP growth
The factors affecting the *level* of final consumption (plus investment) are extremely complex, and cannot be entirely separated from those affecting the mix of consumption.

Most conventional explanations of growth in the GDP focus on the supply (production) side of the economy. In other words, the *desirability* of the highest possible level of consumption is taken for granted (with the one modification that people also want some leisure time, which is a constraint on production and therefore on consumption). So all that needs to be explained is how human, organisational, technological and other factors make it possible to fulfil the goal of economic growth.

By contrast, environmental and other NGOs have often focused on the *artificial creation of demand.* The means at which they have pointed range from advertising and planned obsolescence to urban planning that inflates transport needs and wage differences that make role models of people with extremely high levels of consumption. Indicators of these (advertising expenditure; urban density; wage differentials) and other factors might indeed be constructed, and in some cases already exist.

Mix of consumption
Factors affecting the mix of consumption include many of the objective realities that can also be said to inflate its aggregate level, besides a host of cultural, social and psychological factors that are hard to quantify. However, one very important factor is eminently quantifiable, namely the *price relationships between different goods and services.*

These are of most immediate interest where we can identify directly competing products with clearly different resource loads. How is the price of meat evolving relative to those of vegetable foods? The price of owning and operating cars relative to those of public transport?

The case for claiming that these products have different resource loads can be stated independently of their prices. (Most) vegetable foods claim less resources *per unit of nutritional energy* than (most) animal foods. Similarly, public transport as a rule claims less resources *per passenger-kilometre* than private-car transport.

However, all kinds of products ultimately compete with one another. If the price of petrol is doubled and those of cinema tickets halved, people are likely to drive less and go more often to the cinema. The resource loads of car driving and cinema attendance cannot be compared against any physical yardstick, only in per-ECU terms. If we can identify broader categories of goods and services which currently have distinctly different resource loads per ECU (cf. the discussion in section 3.6.3), then it should be of interest to monitor their relative price trends for as long as these differences exist (in fact, this would be a precondition for keeping a check on the validity of any "sustainability of consumption index").

Technology
The efficiency with which natural resources are utilised in production is likewise influenced by their prices, both absolute and relative to other inputs, especially labour.

Other factors affecting technological efficiency include the funding and effectiveness of R&D in relevant fields, the efficiency with which relevant information is disseminated and the attitudes of management and workers and the organisation of labour. Attempts have been made to quantify some of these also. In Norway, it has even been proposed to construct a single indicator of the country's contribution to technical innovation leading to resource savings. The feasibility of the latter, however, remains dubious. Government financial support for resource-saving measures may be easier to measure, cf. next section.

3.8 Background indicators (3): Policy responses

Policies to promote compliance with environmental space will necessarily be many-faceted, including both legal and financial instruments, shifts in government investment policies, education, information and so on. Many of them will be difficult to quantify. It is in accordance with the principle of subsidiarity that countries should find their own ways of reaching the target, and that the methods chosen may be incommensurable.

Despite these caveats, it may be of interest to develop indicators for some of the responses which are easiest to quantify, that is: taxes and direct government outlays on measures designed to reduce resource consumption. We shall suggest three fields for such indicators.

The first is *consumer-level taxes* (less subsidies) on more vs. less sustainable categories of goods and services. In this context, "more sustainable" means "costing less resources per ECU, if neither taxed nor subsidised". Ideally, one might desire an indicator of *average* tax rates on broad categories of goods and services ranked according to sustainability, as discussed in connection with the mix of consumption. However, calculating average net tax rates for the whole range of goods and services might prove a difficult operation, and still produce results "blurred" for instance by taxes introduced for health or social reasons.

A simpler approach would therefore be to compare net tax or subsidy rates on a small number of goods and services, or kinds of goods or services, of particular interest. They could for instance be: domestic air travel, new cars, petrol, domestic electricity, public transport and a selection of low-resource, non-transport services.

It would also be useful to monitor the relationship between *taxes on labour and on natural-resource inputs to production*. At the moment, there are few taxes on material inputs to production (fertilisers are an exception in some EU countries). To begin with, therefore, the matter would boil down to comparing energy and labour taxes.

It is important to note that direct and visible tax and subsidy rates cannot be relied on to tell the *whole* story of how governments influence costs or prices. For instance, the case has been made in many countries that car transport and / or electricity generation are at the receiving end of substantial "hidden" and / or indirect subsidies. It is hardly realistic, however, to expect agreement on the extent of such subsidies or how indicators should be constructed to expose them. We have also suggested an indicator of government outlays to promote resource conservation. This obviously raises problems of delimitation; in particular, it can be difficult to determine whether R&D expenditures have resource savings as their main objective or not. It may be easier to delimit direct financial support for the *implementation* of conservation measures, plus information and counselling activities.

3.9 Background indicators (4): Effects of resource (over)- consumption

As Fig. 2 suggests, *some of* the effects of resource consumption - especially polluting emissions - are better covered by present environmental indicator systems than is resource consumption itself. There is, however, an important hitch even to these “some”. This is that the environmental pressures created by exploiting resources which Europe imports, in more or less processed forms, from other continents, do not show up in European statistics. Nor is it probably feasible to estimate more than at best a very few of these effects. This in itself is one very good reason for reporting on what can at least be estimated, viz. the consumption of (European and imported) resources as such.

The other major effects of European overconsumption of resources, i.e. that non-renewables are being depleted and that Europeans are also occupying more than their share of the space for renewables, are not generally reflected in environmental reporting. Some national reporting systems do give information on the ratio of national reserves to production (R/P ratio) of selected mineral resources. However, this is not the central question according to the environmental space concept. Rather, it is the ratio of national *consumption* to *global resources* (as distinct from reserves).

There may be good reason, in national and EU-level reporting, to present indicators *comparing present per capita resource consumption to the global average*, as an indicator of present disparities and progress (if any) in reducing them.

Apart from this, we have already emphasised that reporting on resource consumption must be linked to *targets*. The adoption of targets presupposes an assessment of the full range of effects of resource consumption, on the environment as well as on inter- and intergenerational equity. More important than further groups of indicators, therefore, will be the inclusion in in-depth reporting of an introduction explaining how targets have been established.

3.10 Conclusion

In order to guide policy-making directed at compliance with environmental space, there is a compelling need for the EU and Member States to improve reporting on resource consumption. This applies with particular force to materials consumption, but also to energy, water and land use.

Improved reporting on resource consumption as such must be backed by and directly linked to improved reporting on the forces driving it, as well as those which offer possibilities of braking it, and which policies should be designed to strengthen.

In this chapter, we have discussed a set of indicators which might be included in a system of reporting on progress towards compliance with environmental space. Some of these, especially including a majority of the suggested “performance” indicators, will be *necessary* elements of any such reporting system. Others have been presented as options or alternatives to one another.

Further study will be required to determine the relative cost-efficiency of these indicators.

Many of the proposed indicators will depend on new or improved estimation procedures. Many are also dependent on basic data that are not currently collected in all EU countries - in a few cases, not even in any. This is to be expected when indicators are required to guide policy-making in new fields. The costs and benefits of expanded data collection should be evaluated in this light, but also take account of the fact that many of the data in question can be relevant as well to established planning objectives.

The EEA has a vital role to play in fostering and co-ordinating efforts towards improved reporting on consumption of environmental space. This does imply a revision of the Agency’s present Work Programme, in which the focus, of monitoring efforts in particular, is strongly on emissions and other environmental outputs. But it falls clearly within the stated Mission of the EEA to focus also on resource use and on the driving forces - the “human activities and economic sectors” - at the root of environmental problems.

A working goal for the EEA could be to present a first overview report on the subject of environmental space in connection with the next major assessment of Europe’s environment, within the year 2000. By the same date, the EU as well as individual member states should have adopted targets for reductions in resource consumption.

Appendix to Chapter 3:

Overview of suggested indicators and data availability

Below is an overview of the performance and background indicators on resource consumption suggested in sections 3.4 and 3.5, together with comments on data requirements and current availability.

An asterisk * indicates that the indicator is already the subject of regular statistical reporting at the EU level or in at least several EU countries (even if coverage may be more limited or definitions differ slightly from those we have suggested).

A double asterisk ** shows that the indicator (subject to the same qualifications) is included in the Dobris Assessment, or can be easily arithmetically derived from indicators included there. (E.g., the indicator suggested may be a per capita figure, whereas the Dobris Assessment presents national aggregates only).

In reporting, all performance indicators (including key indicators) should be presented together with both **trends** and **targets**. This could be realised graphically, e.g. by diagrams comparing actual trends with trajectories leading to compliance with environmental space. In addition, world-average figures for per capita resource consumption could be included for comparison. Most of the relevant data are available from UN sources.

For key indicators, the targets suggested in "Towards Sustainable Europe" are mentioned where applicable.

Key indicators:	Comments:
Land	
**Built-up land per capita (m^2) *TSE Target: No increase from 1990 value (EU: 0,051 ha)*	Some EU countries have good data today, but usually updated only at 5- to 10-year intervals. In others, data are lacking or of poor quality.
Percentage of agricultural area organically farmed *TSE target: 100% (2010)* and/or	Data are currently collated for EU countries by IFOAM (the International Federation of Organic Agriculture Movements), but the quality of data at the national level is very variable. There are few official statistics, but government support certification schemes are likely to improve the position.
Percentage of agricultural area subject to organic or integrated farming practices (alternative to previous indicator)	Not available today. Presupposes agreed definition of integrated farming practices.
Percentage of forest area naturally regenerated and exploited by selective felling, or subject to otherwise agreed sustainable management practices *TSE target for natural regeneration + selective felling: 100%*	Not available today
**Protected area (IUCN Cat. I-II) as % of total land area *TSE Target: 10% (2010)*	Data available today.
Net appropriation of arable/agricultural land in other continents, per capita (ha) *TSE Target: 0*	Can be calculated from trade statistics and FAO yield figures. Conversion factors are needed for animal foods and processed agricultural products.
Ratio of arable land consumption per capita to global average availability (alternative to previous indicator)	As above

Key indicators:	Comments:
Materials	
Material input per capita (tons) *TSE Target: for EU, c. 10% of 1990 value (2050).*	Requires statistics on domestic extraction of raw materials (includings aggregates) and estimation of "rucksacks". Imports and exports of finished products, semis and raw materials must be converted to raw equivalent (taking account of estimated percentages of recycled materials) and rucksacks estimated. Import/export and production figures for major materials (except aggregates) are available in most EU countries; in some, A problem especially in smaller countries is that staistics on certain materials may be suppressed where there are only 1-2 producers, importers or exporters.
Composite index of non-renewable materials consumption (tons) per capita	As above, except for calculation of rucksacks and conversion to raw equivalent. A selection of representative/critical materials on which to base the index must be identified.
Timber consumption, m^3 per capita *TSE target: 0.56*	Statistics on extraction and visible trade available in most countries, though complete figures on extraction are still lacking in some. To arrive at real consumption figures, imports and exports of pulp, paper, board and other products must be converted to roundwood equ
Energy	
Real primary energy consumption per capita (GJ) *TSE target: for EU, 60 GJ* (2050)	Apparent consumption available from EUROSTAT. Requires in addition estimates of energy "content" of imported and exported goods and services.
*(*) Percentage of apparent energy consumption derived from renewable sources (Dobris data on electricity only) *TSE target: 60%* (2050)	EUROSTAT and IEA statistics available and reliable for all countries for hydro and geother-mal electricity. Coverage and reliability of statistics on other renewable energy sources very variable but improving.
Other performance indicators:	
Land	
**Land use by category (overview)	Data generally available today, with some exceptions for built-up land
**Apparent consumption of fertilizers (kg/ha agricultural land) and pesticides (kg/ha arable land)	Data generally available today
Materials	
* Apparent consumption of specific major materials - total and estimated amount derived from virgin raw materials (tons or m^3, kg per capita)	Generally available from production and trade statistics, with some exceptions for aggregates, timber and materials on which statistics are suppressed
Real consumption of specific major materials - total and estimated amount derived from virgin raw materials (tons or m^3, kg per capita)	See above. In addition, this indicator requires estimates of materials consumption behind imports and exports of finished prodducts and of percentages derived from recycling. For imports , world-average ddata could be used for the latter (available e.g. for some metals from Metallgesellschaft AG)
Energy	
Apparent energy consumption by source (PJ, %)	Available in principle from EUROSTAT. Coverage and quality of statistics on renewable sources other than hydro very variable but improving.

Key indicators:	Comments:
Water	
Total abstractions, m^3 per capita and as percentage of availability	Data availability and coverage currently very variable, quality often poor. Need for regional (sub-national) data.
Seafood	
Consumption of animal seafoods and feed, round weight equivalent (tons, kg per capita)	Statistics on catch, imports and exports generally available. Conversion factors needed for imports and exports of processed products.
Background indicators:	
Sectoral resource consumption	
**Energy	Available from EUROSTAT and IEA
*Built-up land	Sectoral statistics available in some EU countries, but groupings and definitions vary widely
**Water	Sectoral statistics available in some EU countries, but groupings and definitions vary; some sectors may be omitted altogether
Materials	Not available today. Split of materials consumption by secondary sub-sectors requires I-O analysis, probably supported by more data on physical flows.
Level and mix of consumption and investments	
Aggregate consumption and investments (ECU)	Available today
Mix of consumption (percentage shares, ECU)	Available today
Sustainability of consumption index	In addition to data on mix of consumption, requires further analysis of resource loads of consumption categories
Physical-unit data on consumption and investments	
Building space, m^2 and m^2 per capita (dwellings and service sector specified)	Data on dwellings becoming available for most EU countries from EUROSTAT. Coverage of other buildings variable. New construction often better covered than building stock.
**Motorized passenger transport work, pkm and pkm/capita	Data available for most (not all) EU countries, but not corrected to take account of foreign travel by residents or travel within country by non-residents. The former leads to a significant net underestimation of air travel in almost all countries. Some countries still do not estimate pkm of private car travel.
**Goods transport work, pkm and pkm/capita	Data available from EUROSTAT (excluding international shipping)
Consumption of other goods, physical units per capita.	Data on selected goods (esp. appliances etc.) published by a few national statistical agencies only. Estimates can often be made from production, import and export statistics or provided by national associations of wholesalers or retailers.
Technological efficiency	
Energy intensity in	
- Residential sector, MJ/m^2	Energy consumption figures available; calculation depends upon availability of building space (see above).
-Service sector, MJ/m^2	As above.
-Secondary sector, MJ/ECU	Basic data available

Key indicators:	Comments:
-Primary sector, MJ/ECU	Basic data available, quality variable
-Transport sector	Energy consumption figures available, but split between goods and passenger transport must be estimated. Transport work, see above.
-Energy sector, MJ/MJ	Basic data available from EUROSTAT and IEA
Materials intensity:	
- Consumption of specific materials per unit of secondary sector output (t/ECU)	Output data available. Input requires conversion factors for imported semis and parts. Suppression of trade and/or production statistics for some materials in some countries may be a problem.
- Materials intensity index (composite of several branches and corresponding materials)	Output data available. Calculating materials consumption by specific branches requires new data collection from enterprises or I-O analysis, the latter also dependent on solution of problems as for the previous indicator.
- "Material input" per unit of secondary sector output	Output data available. Re input, see "material input" under key indicators.
- Trends in product lifetime	Not available today, except retrospectively for vehicles. Lifteime for some product categories can be roughly estimated retrospectively from available data. Prospective estimates of durability require new testing and assessment procedures, which will not be applicable to all product categories.
- Trends in product weight	Not available today. Basic data to construct the indicator generally available only in the case of vehicles. For other products, new procedures (sampling or reporting by producers/importers) will be required, in addition to information on market shares.
- *(*)Recycling rates	Data published in many EU countries today for some materials, most commonly paper, glass and/or aluminium. Published data relate recovered quantities either to apparent consumption or to domestic production. In order to relate them to real consumption, the latter must be estimated, cf. performance indicators. Data on steel scrap recovery are also available from EUROSTAT. For other materials, new data collection or estimation procedures will be required in most countries.
Factors affecting driving forces	
Factors affecting aggregate demand	Data on some are available in most countries.
Price trends for products with different resource loads	Data available today (CPIs). This is sufficient to construct indicators in the case of directly comparable products whose resource load can be compared against a common physical denominator. For other product categories, further study of resource load per ECU may be required (cf. sustainability of consumption index).
Policy responses	
Consumer-level taxes on selected products/product categories with high and low resource loads	Basic data available. In the case of energy goods, collated by EUROSTAT. Determination of resource loads per ECU of pre-tax prices may require further study for some products, cf. above.
(*)Taxes on labour and natural resources	Basic data available. Energy taxes collated by EUROSTAT. Average taxes on labour (for appropriate economic sectors) may need to be calculated for the purpose by national agencies.
Government support for resource-conserving measures	Basic data available from budget documents, except where combined with other outlays under common headings. Major problem is securing common definitions across countries.

4. Environmental Space and Environmental Policy Assessments[7]

4.1 Introduction

This chapter examines the potential application of the "environmental space" concept to environmental impact assessment (EIA) and policy analysis. The point of departure is that the environmental space concept has two central implications for such analysis:

Firstly, the traditional emphasis in EIAs has been on outcomes of industrial and development processes, such as "end-of-pipe" pollution. The environmental space approach argues that to achieve sustainable development within a sound economy in Europe, it is necessary to complement this approach by considering changes in production and consumption patterns which would reduce material flows and pollution at source. This provides a practical linkage between environment and the economic and social dimensions of industrial society. Overall, the ES concept is intended to achieve a more proactive management of the economy and the environment on sustainability principles, at the level of the nation, and for Europe.

Secondly, although environmental space cannot be exactly quantified on the basis of empirical science alone - meaning that goals and targets must rest partly on political judgement, and may need to be adjusted along the way - it can provide a correct directional policy guidance.

Generally, the promotion of environmental space has potential to influence production processes in sectors such as industry and agriculture, and to help build a broader, public constituency around sustainable development issues and to foster beneficial changes in consumption patterns. Environmental policy analysis incorporating environmental space could make a positive contribution.

More specifically, environmental space can provide a unifying element to assist the "vertical integration" of environmental policy in Europe from project level analysis (EIA) to the bio-regional, programme or national policy level (strategic environmental assessment, SEA, and indicator systems as discussed in the previous chapter) to that of the European Commission. Over time, this type of integration could help generate a more unified and coherent policy approach to sustainable development within the context of subsidiarity.

The chapter has three sections. The first examines environmental impact assessment at the project level and the second considers strategic environmental assessment. A final section considers environmental space within a decision framework which integrates project-level EIA with higher order analyses, spatially, and in policy terms. The purpose is to discuss whether the environmental space concept could lead to better informed decisions leading to sustainable development. These will need to based on systematic linkage of the environmental aspects of policy decisions with the economic and social dimensions, and to the use of "top-down" policy and regulation to foster bottom-up innovation. Such linkage is at the heart of the ES concept.

Neither EIA nor SEA is defined here, on the assumption the reader is familiar with both.

4.2 Application to environmental impact assessment

Project-level EIA is institutionalised in the EU by Directive 85/337/EEC for Annex I and II projects, and the methodology is reasonably well advanced for predictions of biophysical impacts. EIA is a useful and important aspect of project appraisal, and there is no reason to alter this statutory function. As with many types of systematic project analysis, the EIA is necessary, but not sufficient, for informed decision-making, and there are advantages to furthering the integration of environmental space analysis into EIA.

First, without adjusting the statutory functions of EIA, the analysis could be expanded to encompass the impacts of a project on consumption of key resources identified within the environmental space methodology. This would provide an additional point of reference to assess the contribution of any project toward, or away from, sustainable resource use. A sustainable project ought ideally, over its lifetime, to contribute to

[7] *Apart from minor revisions this Chapter has been written by Prof. Michael Carley, Hirriot-Watt University, Edinburgh.*

reduced consumption of land (in one or more senses) and key materials as well as energy. If a project should entail increased consumption of some resources and less consumption of others, its viability might nevertheless depend on whether environmental space were most constrained for the former or the latter kinds.

More effective use of scarce materials and resources could generate not only environmental but financial benefits to the project or industrial plant, and to the national economy, as a result of encouraging innovation and efficiency in production and consumption processes. For example, a focus on reduction of material flows and energy for material processing can lead to reductions in the cost of production, leading to reduced product prices or enhanced profitability for the firm.

Second, providing a consistent environmental space methodology within EIA could generate more effective integration of EIA results at broader levels of analysis, for example, SEA of a bio-region or of national policy directed toward industrial sectors, such as chemical engineering.

Integration of environmental space into EIA presupposes, however, a certain level of political commitment to the environmental space concept at the EU and national levels, as is already the case in Denmark, and some relatively uncomplicated methodology for assessing environmental space. Such a proposal is unlikely to be acceptable if it is seen to be contributing to bureaucratic procedures, without understanding of the potential benefits. It might be useful, for a trial period, to encourage voluntary environmental space calculations, rather than include these within the statutory requirements.

4.3 Application to strategic environmental assessment

Site-specific EIA is seldom sufficient to allow full integration of environmental factors into decision-making. There are many reasons: a project may be in reasonable fulfilment of an environmentally-misguided policy, such as an environmentally-sound bridge which is part of a road building programme which will raise CO2 emissions; there may be cumulative impacts of more than one project in space and time, which are not significant at project level, such as a number of mining or forestry projects in a watershed; there may be drastic cumulative impacts of relatively insignificant actions (like driving a car on one journey, or one boat fishing at sea), which are not addressed in project-based EIA.

This situation is recognised by the Commission. For this reason, on the occasion of the adoption of Directive 85/337/EEC, and through the Environmental Action Programmes, the Commission has indicated its intention to develop Strategic Environmental Assessment for policies, plans and programmes. Spatially, SEA could also be applied at the level of the bio-region. The increasing acceptance of sustainable development as a legitimate goal of policy underlines the need for SEA. However, a formal SEA proposal has not yet been submitted to the Council of Ministers.

More so than at the EIA level, the environmental space concept offers significant potential to contribute to effective SEA, in generating positive environmental benefits by providing more detailed guidance on acceptable boundaries of resource consumption and pollution load, but also by forcing consideration of alternative technological and managerial approaches which can generate similar stream of benefits at reduced environmental costs. For example, the determination of agreed long-term environmental space targets could stimulate innovation in production processes, or in linkages between production and consumption (e.g., re-use or product recycling) by industry. This could be supported as required by policy innovation or financial incentives within a framework of eco-taxation.

Application of environmental space analysis at a sectoral level, such as to chemical industries, could generate innovation throughout the sector. Policies aimed at reductions in pollution or resource use may also be much more acceptable when applied to all firms in a sector, or indeed to all firms in the EU, rather than for any one firm.

It is important to stress that SEA is an informed assessment of the outcomes of programmes or policies, not necessarily a strictly quantitative measurement of that outcome. Like environmental space itself, SEA is to some extent directional. However, this is not a particular constraint, because the SEA will only be one of a number of relevant analyses to strategic decision making, which will also include the use of national and EU-level indicator systems. The SEA task is to inform the decision process so it is more likely that robust decisions will be taken, and to alert us to potential environmental dangers in the policy direction we are heading, so that precautions can be taken.

Here the directional guidance provided by the environmental space concept within an SEA framework could be a valuable addition to the range of analytic approaches for decision-making. Application at the strategic level implied by SEA will cause all "downstream actions" in the policy flow to become more infused with some genuinely sustainable outcomes, rather than just paying "lip-service" to the idea of sustainable development. This enabling of innovation by policy is complemented and supported in the other direction by a flow of information on good practice from the field to the policy process. This does presuppose, however, that an effective regulatory framework for SEA is developed by the EU and Member States, along with the necessary quality control, guidance, training and research and institutional strengthening.

4.4 Potential for better integration of project-level and strategic environmental assessment within the EU and Europe

One of the of the biggest challenges of sustainable development is to integrate levels of analysis and policy (project, fluvial, national, EU, Europe and so on) so that mutually reinforcing actions occur up and down the policy system and the ecosystem. This is a type of subsidiarity, which generates a coherent, sustainable development strategy at the European level, but without undermining either national sovereignty or local, "bottom up" initiative, for example at the level of the community or the company.

The environmental space concept could provide a "common thread" throughout the decision framework and assist in making this higher level of integration more feasible. In a way, an hypothesis that this is possible is currently being tested within the Sustainable Europe Campaign, through which the "Towards Sustainable Europe" study is being followed up by FoE groups and research teams in some 30 European countries. Whether this is a reasonably successful approach will be determined during 1996 on return of all the national studies to the European co-ordinating centre, and their assessment. The returns will also help to validate and improve the methodology for assessment of ES at the European level.

Following this, further consideration can be given to the extent to which the application of the environmental space analysis at different levels within an EIA / SEA framework could contribute to the integration of policy and action for sustainable development in Europe.

One area of development is to use knowledge of environmental space to improve and expand policy targets for lower-order analysis such as EIA or cost-benefit analysis, to give these forms of project analysis "value-added" in terms of their contribution to understanding, not only the implications of individual projects in themselves, but their contribution to the broader thrust of sustainable resource use, either negative or positive. Negative impacts of large projects could indicate need for better science or better policy, which positive impacts of projects on resource use could provide models of industrial innovation worthy of replication.

Another area which should be of growing importance in policy analysis is in SEA focused on land use planning, and the integration of urban and rural development plans, and transport plans. Many Europeans are beginning to recognise that land is a vital but scarce resource, easily degraded or alienated, perhaps for a century or more, from sustainable use by such processes as poorly-planned urbanisation, industrialised agriculture or the extension of road transport networks without consideration of the environmental and social implications.

It is difficult to conceive of a sustainable Europe which did not have in place sophisticated land use analysis procedures and land use planning processes, particularly at the level of the watershed. Environmental space calculations on the land resource could make a useful contribution. However, such calculations are hampered by unstandardised categories for land use; poor knowledge of the difference between the urban, suburban, rural and natural land use functions; and poor or non-existent data collection on the land resource. Considerably more research and analysis on European land use is required if sustainability is to be achieved. The environmental space concept can provide a framework for this analysis.

4.5 Conclusion

Although environmental space is about reduced and thus more efficient resource consumption, its basic thrust is not negative but positive. The concept challenges Europeans to use the best knowledge, best policy and new technology to achieve a high-quality standard of living within the boundaries of environmental space. Countries which are at the forefront of sustainable development will also be most competitive and at the leading edge of industrial development, and will have highest quality of life in the 21st century. The implication for application to EIA / SEA is that environmental space must be presented, not as a negative factor, but as a positive inducement to industrial innovation, and as a sophisticated addition to our "toolkit" of project and policy assessment tools.