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The Factor 10/MIPS-Concept: Bridging Ecological, Economic, and Social Dimensions with Sustainability Indicators

by
Friedrich Schmidt-Bleek

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The Factor 10/MIPS-Concept: Bridging Ecological, Economic, and Social Dimensions with Sustainability Indicators'

F. Schmidt-Bleek

Factor 10 Institute

Abstract

The present throughput economy will yield to a customised economy, in which custom-tailored services are more important than mass products, and access to services more important than ownership of goods. In the customised economy, the natural resources land, energy, and materials will be largely replaced by knowledge, know-how, and know-who in the process of providing wealth to people.

In this paper, ecological indicators are presented which can be used to quantify the resource productivity of products, services, systems, and performances. Together with Factor 10 they form a framework which allows the operationalisation of the sustainability concept. The indicators presented fit well into the economic realities of the customised service economy.

Key Words:

Sustainability, Indicators, Resource Productivity, MIPS, Factor 10.

The Throughput Economies Of The Past

On the average, up to 90 % of the biomass harvested as well as more than 90 % of the natural abiotic (non-renewable) materials disturbed by machines in their natural settings are wasted on the way to making products available to the end-user. From this perspective, humankind has hardly any supply problems. Surprisingly, we seem to be serious when calling this dismal situation "high tech", "high chem", and "eco- something or other". The products of the future will disturb and consume less natural resources, they will require a higher input of know-how, and will outsell present goods on all markets.

Classical environmental protection remains a superficial and insufficient answer to the ecological crisis. It typically works at the end-of-the-pipe and implies additional costs in money and resources. This still allows businesses and politicians to argue conveniently that economies need to prosper in the first place in order to afford environmental protection at all.

As long as "to prosper" means to maintain per capita consumption rates of resources similar to the ones prevailing in our throughput economies of the west to date, the pollution control strategy remains profoundly unecological as well as uneconomic.

It is not accidental therefore, that classical pollution control measures failed to be internationally harmonised at a meaningful level - as demonstrated recently again by the almost complete lack of success during the United Nations meetings in Kyoto, 1997, and Buenos Aires, 1998 devoted to curbing the emission of CO2 and some other gases relevant to climatic changes. Even the United States have pronounced that they cannot afford their share to help saving the earth in this fashion.

Small wonder, therefore, that twenty five years of costly pollution control efforts have not prevented environmental deterioration from increasing on a global scale. Only that now toxic industrial emissions and effluents are found more in the poorer countries, while they used to be characteristic of the "the North" twenty-five years ago.

The wealth of the industrialised countries is based to a considerable degree upon man-induced material flows that occur in the Third World, as for instance natural timber, overburdens from mining mineral resources, and the use of water resources for the production of agricultural products and aluminium. To satisfy Germany"s thirst for orange juice, four times as much land would have to be devoted to orange production as is now being occupied by fruit trees in Germany.

As things stand, the orange trees for stilling Germany"s thirst grow mostly in Brazil, some 10000 kilometres away. Ca. 25 % of the people harvesting the oranges are less than 14 years old at an average monthly salary of 70 Euro. 1 kg oranges sells for ca. 0.03 Euro in Brazil, the litre of orange juice in Germany for 0.6 and up to 2 Euro. Thousands of children die each year in Brazil from chemicals" poisoning while harvesting agro-products .

The Root Cause Of The Ecological Instability

Irreversible disturbances of ecological equilibria are caused directly by technical interference with environmental resources in situ, irrespective of how much material wealth is produced with the masses translocated from their natural settings, and irrespective of how much and what kind of emissions and effluents are generated (Schmidt-Bleek, 1993).

80 tons of non-renewable natural resources are devoted every year to maintain the material wealth of Americans and Europeans. The non-OECD countries have far less per capita consumptions at this time.

Of course, the more resources are put into an economy the more has to come out of it in form of emissions, effluents, and wastes. Traditional environmental policies were - and still are - largely geared to take care of these waste streams in one way or another, normally with public funds. For reasons of costs, not all outputs could be considered for this artificial tail end economy, so the term pollution was invented to sort out a minute part of the waste streams and the so-called environmental technology was developed to do the job. Huge additional natural resources were invested for that purpose. The catalytic converter is a typical example. Close to 3 tons of non-renewable resources are invested for its construction.

The impact of all this ecological disruption is increasing, and is beginning to be reflected in economic terms. For example, there is an increase in the number and severity of natural catastrophes such as storms, floods and droughts, to which the insurance market is responding by sharply raising premiums. Central America will take many years to recover from the devastating hurricane Mitch in early November, 1998. The United States has lost some 50 % of its topsoil by erosion, virtually all of it during this century. In the Ruhr valley, some 70 000 hectares of land have subsided due to former deepmining of coal, with the consequence that waters have to be pumped around the clock forever (?) to keep this area from flooding. Millions of people could otherwise lose their homes.

But the real reason for our ecological dilemma rests with our price signals to the market: Through our fiscal policies we reward those who waste natural resources and punish those who create employment, resources are too cheap and labour is too expensive. Only through a courageous policy shift will it be possible to lay the foundation for approaching sustainability in a serious manner.

Toward a Customised Economy

A radical reduction of the material throughput in "advanced countries" is imperative during the coming decades, while end use satisfaction as it exists today in these countries must be maintained - or even improved. In this sense, the industrialised nations are the real "development countries". Their goal is a consumer customised service economy, in which all products and services consume the least possible natural resources - from cradle to grave. Together with Lehner I have coined this future economy a "customised economy". In a forthcoming book we describe the government, business and the environmental side of the story (Lehner, Schmidt-Bleek, 1999),.

In order to reliably achieve the necessary dematerialization, decision makers in politics and business, but also the consumers, need a different price structure and valid, understandable, and internationally compatible indicators about the relative resource intensity of goods and services, because one can hardly manage that which cannot be measured and compared (Schmidt-Bleek, 1999/2).

National accounts must also change. They must reveal the consumption of natural materials - including their ecological rucksacks - that are invested on a yearly basis in order to create wealth and provide security for people (FSO 1995).

But this is not enough. While the improvement of the technical eco-efficiency is imperative for approaching a sustainable economy, even the most extreme dematerialization of material artefacts alone will not suffice á la longue. Rebound (boomerang-) effects must be avoided: As history shows, technical advances in investing less resources per unit wealth have traditionally been "eaten up" by increasing consumption. A change in the traditional development of consumption patterns is urgently called for: a revision of use - offering new forms of satisfaction, well being, and prosperity.

All Stakeholders Have Roles To Play

Dematerialization can be looked upon as a strategy in a process of consumers, producers, retailers, scientists, NGO's, and government, each with their own concerns and responsibilities, each with specific roles to play in initiating and managing the process of change (Leo Jansen, TNO Delft).

The required radical improvement of resource productivity must span the whole spectrum of objects serving peoples" needs ("service delivery machines"), starting from simple items all the way to complex technological systems: from the propeller of a ship to propulsion, from the propulsion to the ship as a whole, from a single ship to the complex transportation system. Ultimately, it is the dematerialization of whole economies, measured in terms of the total material flow (TMF), that signals failure or success on the way to sustainability.

The achievement of a target to dematerialise society by a factor 10 or more requires intensive changes in economic and environmental policies, in culture, (institutional) structure as well as technology:

- ♦ economic policy of today prevents reaching sustainable conditions, because it is not possible to profitably dematerialise goods and services sufficiently, environmental policies cause additional use of natural resources for "cleaning up" the output side of the economy (e.g. "green point" in Germany);
- ♦ culture, legitimating nature and volume of societal needs to be fulfilled, expressed in consumption patterns dependant on ease and status (sufficiency),
- ♦ structure, the economic and institutional organisation to fulfil legitimated needs (effectiveness),
- ♦ technology, providing the technical means by which needs are (to be) fulfilled (efficiency, productivity).

These four elements characterise development of society in a strong mutual interaction and interdependence. The "acceptability" and viability of environmentally efficient technical means is directly connected to the economic and institutional conditions (structure) and to the demands of society (culture). In this context, it should be well understood that these conditions and demands are not static at all: At best, they can be adjusted by wise changes of economic and environmental policies, accounting procedures, and business approaches. However, they may also change radically as a result of environmental or political shock episodes.

Factor 10

In 1992, I proposed to halve the global natural material disturbed yearly by technology in order to move decisively toward sustainability. It should be noted that this is an absolute (albeit only estimated) target for lowering the yearly totality of natural resources disturbed in their original settings. Therefore, showing the material input per unit of GDP as a measure for dematerialization is bound to be misleading (Schmidt-Bleek, 1983/1).

Since western style wealth, generated at present for less than 20 % people of the world, consumes in excess of 80 % of the natural resources disturbed and harvested globally, the "rich of this world" will have to invent ways to generate their wealth with some 10 % (or a factor of 10 less) of their present consumption in order to let the "poorer" nations claim their fair share of resources - and still halve the world-wide total flow of natural resources.

In the future, western style processes, products, buildings, infrastructures, and services would therefore need to be dematerialised by an average factor of 10 (compared to present conditions) in order to move reliably toward sustainability. With increasing world population - or increasing numbers of people living by themselves in any society - the factor 10 would have to grow, too (Schmidt-Blek, 1993).

Austria wrote the Factor 10 goal into her Environment Plan already in 1995. In 1994, UNEP-IE and the Business Council of Sustainable Development suggested a factor 20 as a goal for sustainability. In 1997, the European environment ministers supported factors 10 as a strategic goal. Dozens of visits in medium and small sized industries in central Europe have produced convincing evidence that factors of 3 to 8 increase in resource productivity for products can be routinely achieved already today by making better choices of materials (that is by giving preference to materials with smaller ecological rucksacks than had been previously embodied in their products), and utilising a wide variety of options for reducing waste, packaging and transportation intensities 3. To increase the dematerialization further, the utility of the products can be raised in many cases, their longevity improved, as well as cascading uses and recycling options foreseen when designing new products.

Measuring Complex Realities

When attempting to develop measures for the environmental performance - or the ecological stress potential - of economic units such as firms, regions, and households, or of products, infrastructures or services, one important thing to keep in mind is that there are always very large numbers involved. Some 6 billion people participate in the world market, at least 20 million small and medium sized enterprises exist world-wide today, some 5 to 6 million different products are traded internationally (changing in nature and composition at a rapid rate), and there are some 180 countries with differing climates, resource bases, as well as political, historical, and cultural realities - all living within, and depending entirely upon a single system: the planet earth.

When attempting to develop indicators for the ecological stress potential of processes, goods or services, one should keep this diversity in mind, particularly in view of the fact that the economy runs on a single common indicator, the price of goods and services. And prices are not derived from scientific principles. Often they do not even make economic sense. Yet they serve obviously very well on a world-wide basis.

It is therefore clear that purely scientific approaches "to enrich" the present price structure for goods and services with environmental information, or to develop indicators for public and private policy setting will likely fail. The fewer indicators one needs to portray the essence of the (un)ecological nature of policies, processes, goods, services and the economy as a whole, and the better such indicators can be incorporated into existing economic models, the better the chances to shift the overall economic performance of individuals, firms, enterprises, regions, countries and the world economy as a whole in the direction of improving ecological sustainability.

In a recent paper, the European Environment Agency has proposed a set of 9 indicators: Inputs raw-material intensity, intensity of gross inland energy consumption, land-use intensity, and the intensity of water consumption; Outputs: (impact/pollutants): greenhouse potential, acidification potential, ozone depletion potential, (hazardous) waste, and chemicals (EEA, 1998). The EEA notes: "There is clearly an element of "double-counting" in accounting for both, input of materials and output of pollutants. However, it is not possible at this stage to focus just on either material inputs or pollutants in order to monitor progress towards sustainability: and "double-counting" is at least erring on the side of caution."

Conditions For Ecological Indicators

When attempting to develop indicators for describing the ecological stress potential of goods and services, of individuals, firms, enterprises, regions, countries and the world economy as a whole, such measures should meet the following conditions:

1. They must be simple, yet reflecting essential environmental stress factors. They must be scientifically defensible, albeit not scientifically complete;
2. They should be based on characteristics that are common to all processes, goods and services;
3. The selected characteristics should be straightforwardly measurable or calculable, irrespective of geographic locations;
4. Obtaining results with these measures should be cost-effective and timely;
5. The measures should permit the transparent and reproducible estimation of environmental stress potentials of all conceivable plans, processes, goods and services from cradle to grave;
6. Their use should always yield directionally safe answers;
7. They should form a bridge to economic models;
8. They should be acceptable and usable on all levels: locally, regionally and globally.

Source: Schmidt-Bleek, 1993

MIPS, Rucksacks, Service Delivers Machines, LCA, S/MI, COPS, TMF, FIPS and TOPS

As outlined in Agenda 21 of the UNCED in Rio de Janeiro in 1992, there is a need for indicators of sustainability. Some national and international bodies as well as scientific institutions have since begun work on this subject (Adriaanse, 1993). The European Environment Agency in Copenhagen has recently moved proactively in this area (EEA, 1998), based, in part, on the work of the Factor 10 Club.

In 1992, I proposed the Material (including energy) Intensity Per unit Service (utility or function) - the MIPS - as a robust initial measure for estimating the ecological stress potential of goods and services from cradle to grave. With this indicator, one can operationalise the concept of sustainability on the economic micro-level and meso level, provided one takes additionally into consideration the available information on the specific eco-toxicity of materials involved. Simultaneously, I proposed Factor 10 as an initial overall target for increasing the resource productivity of western economies. This includes factor 4 and others which were proposed subsequently.

MIPS is computed

in material input per total unit of services delivered by the product over its entire useful life span (Resource extraction, manufacturing, transport, packaging, operating, re-use, recycling, and re-manufacturing are accounted for, and so is the final waste disposal). The total MI which is carried by a finished product is called its ecological rucksack.

The MIPS includes material along with energy inputs by counting the material fluxes associated with energy inputs. For electricity or solar heat inputs, the system-wide material intensity per unit energy input is taken as MI value.

Computing only the energy use for products or services can lead to serious errors when estimating the environmental impact potential associated with them. For instance, when assessing the MIPS of identical quantities of electricity delivered to the grid on a system-wide basis, German brown coal turns out to be ca. 50 times as material (plus energy) intensive as windpowered or natural gas burning systems, and some 8 times as material (plus energy) intensive as those using hard coal or photo voltaic cells. Another example is the aluminium car of a major European producer. Whereas the energy-only calculation shows that this car becomes more "ecological" than its steel cousin after some 140 000 km, more then 600 000 km must be driven before the lighter car begins to show its better resource productivity on a per kilometre basis (Schmidt-Bleek, 1998).

The value for S in MIPS is the total number of units of service (utility) delivered by the product during its life time, or the expected total number of service units that the product might supply during its life time (in the MIPS-concept, products are "service delivers machines" "Dienstleistungserfüllungsmaschinen" in German). The S-number is usually larger than that which is implied by the warranty on products.

It is evident that MIPS could be used as the entry point (or "base set") for a step-system approach in the process of eco-balancing products and services, based on LCA“s.

MIPS - which could be called eco-intensity - is the inverse of S / MI, the measure of resource productivity. Both include the ecological rucksacks of all materials - from cradle to grave.

The resource productivity can be improved by either lowering MI for a given S , as well as by increasing S with a fixed quantity of resources. Both changes can be achieved through technological as well as managerial/societal changes/innovations. For example, by increasing the longevity of goods, or by leasing rather than selling a product, and by sharing buildings, infrastructures, vehicles or machines can the total number of service units be improved dramatically, without a corresponding increase in the total input of natural raw materials. By following the request of hotel owners to utilise towels more than once ("to be nice to the environment"), guest can increase the resource productivity of providing towels without loss of convenience or hygiene by factors 2 or 3, and saving money (for the hotel owner) in the process.

The principal natural resources which are utilised by humankind to generate wealth are: material, energy, and land. MIPS is insofar incomplete, as it represents only material and energy intensities. Dr. Christa Liedtke at the Wuppertal Institute continues to work out the details for FIPS, the quantity of land (surface) used pro unit service. Factor 10 applies here in the sense that industrialised countries have to reduce their covering of land for technical purposes by at least by a Factor 10 as quickly as possible.

MIPS is the natural resource equivalent of COPS, the costs per unit service, the actual price of a haircut for instance, the costs of a withdrawal from an automatic bank, or the price for a flight ticket.

On the national or regional (macro) level, the Total Material Flow (TMF) approach - derived from the MIPS-Concept in my Deparment at the Wuppertal Institut - serves a similar purpose (Bringezu, 1996). The Factor 10 goal applies to TMF in particular, as it represents the integral total of all individual material flows on the micro level.

Ultimately, the ecological quality of goods and services could probably best be represented by the sum of three terms that would all have to cover the total life span of products:

MIPS = the Material (incl. Energy) Input per unit service

FIPS = the surface (F for "Fläche", a German word for surface area) coverage per unit service,

and by

TOPS = the eco-toxic exposure equivalent per unit service

It will be interesting to observe whether eco-toxicologists can ever agree on a simple and robust term (or a very few such terms, for instance addressing biotic and abiotic systems separately), that could serve as initial and rough indicator(s) for the eco-toxic intensity (TOPS) of different materials and goods.

Once more. Ecological Rucksacks

The ecological rucksack is defined as:

the total quantity (in kg) of natural material (M) that is disturbed in its natural setting and thus considered the total input (I) in order to generate a product - counted from the cradle to the point when the product is ready for use - minus the weight (in kg) of the product itself (Schmidt-Bleek, 1993).

The sum total of natural materials utilised (in kg) to make one kg of technical base (raw or starting) materials available (e.g. wood, iron, aluminium, copper, cement) is expressed as MI, called the "rucksack factor" of base materials (Schmidt-Bleek, 1998).

At the Wuppertal Institute, five different rucksacks were defined to describe the overall natural resource intensity of products. They correspond to the 5 environmental spheres that have been traditionally distinguished in environmental sciences and policies: water, air, soil, renewable biomass, and non-renewable (abiotic) materials. Factor 10 is applicable to all

On the average, industrial products carry non-renewable rucksacks that are about 30 times their own weight. This means that only about 5 % of the non-renewable natural material disturbed in the ecosphere typically end up in a technically useful form. In the case of a PC, the ecological (abiotic) rucksack weighs at least 200 kg per kg of product. This number calls seriously into question the expectation that modern communication can eo ipso contribute to a noticeable dematerialization of life styles.

For base materials (such as iron, plastic or copper), the MI values (rucksack factors) represent a new kind of material property. These factors allow the comparison of technical starting materials as regards their resource intensities and thus allow the computation of the rucksack of products, so long as the material compositions of these products are known (Schmidt-Bleek, 1998).

At the Wupperal Institute, MI values (rucksack factors) were assessed for a large variety of materials that make up industrial products. For the time being, they should be considered as preliminary average figures. Within the time and resources available it was not possible to compute specific source and process numbers for all base materials. Nevertheless, they allow the design of dematerialised products in many instances and permit important conclusions to be drawn very fast when comparing the resource intensity of products (Schmidt-Bleek, 1998). They are available on the internet: http//www.wupperinst.org/Projekte/mipsonline.

Typical approximate MI values (rucksack factors) for non-renewable resources) of base materials are as follows:

round wood = 1.2

glass = 2

plastics = 2 - 7

steel = 7

paper = 15

aluminium = 85

copper = 500

Platinum = 500 000

The Factor 10 Institute and the Factor 10 Consulting Network are proposing to establish centres for producing and distributing regularly validated MI factors. For the moment, MI factors are available on Internet from the Wuppertal Institute (Dr. Christa Liedtke) (http://www.wupperinst.org/projekte/mipsonline) and in several books (Schmidt-Bleek 1998). These lists also contain the rucksack factors for recycled materials which normally are considerably smaller (lighter) than those for virgin materials. The German ministry of research has accepted responsibility for creating a centre for resource productivity and material flows.

Defining Eco-Efficient and Eco-Intelligent Things

In recent literature, the term eco-efficient appears more and more frequently. This word was coined by Frank Bosshart, assistant to Stephan Schmidheyni during the preparations of the Business Council For Sustainable Development before the 1992 UNCED (United Nations Conference on Environment and Development) meeting in Rio. It is a term referring to both, economy and ecology: "Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity" (Business Council for Sustainable Development, 1992).

Eco-efficiency is therefore a concept for improving the ecological character of production related activities while maintaining/improving their profitability.

More recently, a plethora of different definitions has been assigned to eco-efficiency, making orientation rather difficult. However, the term has found a wide acceptance, perhaps in part because it allows wide interpretations. One could say that it is an operational concept which implies the use of less nature for producing more output under profitable conditions and which serves people. It provides no measure for gaining sustainability. But the MIPS- and the Factor 10 concepts are entirely compatible with it. The MIPS-concept provides a framework for quantifying essential parts of eco-effciency, it addresses the consumption side of the economy, and the Factor 10 provides a goal against which one may determine how much effort is still needed in industrialised societies to approach sustainable conditions (Schmidt-Bleek 1998).

One is not really comparing efficiencies when considering the respective resource productivities - or toxicities and eco-toxicities - of goods. Efficiency increases normally refer to the output improvement of existing machines and processes at fixed inputs. Such improvements rarely surpass a few percentage points. Historically, less than 1 % per year has been achieved in the average. Improvements in the order of factor 2 would therefore tend to take some 50 years to accomplish.

The resource productivity can follow the path of progress that was achieved by the development of labour productivity: Labour productivity did not rise by any significant increase of labour efficiency improvements. The typical traditional shoe-maker or tailor could not possibly increase his or her speed of work more than 10 or 20 % with the old tools. It was the application of more and more intelligent machines replacing hand-craft that allowed "labour productivity" to rise sharply (in reality, of course, human labour was increasingly replaced by machines). In a similar way, energy and material productivity can be increased far beyond the technical potential of efficiency increases of current technological systems. As indicated before, the way toward decisive ecological improvements must start with the question "what is the desired utility?", followed by whatever new and old technical solutions can be employed with an overall minimum of natural resources.

As the originally defined term eco-efficiency also refers exclusively to the production sector of the economy, potentially important adjustments in consumption and society as a whole are not addressed. And thirdly, this term does not consider the importance of minimising the use of space, the "consumption" of surface area of the earth (the third important natural resource that we need for wealth production in - addition to energy and material).

For these reasons, one might wish to use the term eco-intelligent when referring to systems, goods, services, utilities, consumption, and processes that are more promising than others as regards reaching sustainability, while providing wealth to all people..

Eco-intelligent goods are:

Competitively priced services and products (objects, tools, machines, buildings and infrastructures) that yield maximum possible utility - in terms of individual customers preferences - for the longest possible time with a minimum of natural material, energy, surface coverage and dispersion of toxic materials - from cradle to grave.

Among resource productivity experts, eco-intelligent goods are usually referred to as "low-mips".

Five Rules For Eco-intelligent Products

1. The number of service units obtainable from products ("service delivery machines") must be as high as possible during their entire useful life. Built-in obsolescence must stop.
2. The life-long material input into processes, products, and services must be as low as possible.
3. The life-long energy inputs into processes, products, and services must be as low as possible.
4. The land use (surface coverage) per unit service must be as low as possible, from cradle to grave.
5. The dispersion of toxins must be minimal.

Source: Schmidt-Bleek

Eco-intelligent production systems are:

Competitively priced technical and organisational procedures for producing products and services, conducted with the help of eco-intelligent goods, while minimising the consumption of natural material, energy, surface coverage, the generation of wastes, and the dispersion of toxic or eco-toxic materials

Eco-intelligent economies are:

market systems within political boundaries, providing a maximum of wealth to all their people by providing them with eco-intelligent goods that were produced with eco-intelligent production systems.

Eco-intelligent consumption is:

the use of eco-intelligent goods within the confines of the overall sustainable availability of natural resources.

The Total Material Flow Concept for Eco-Benchmarking Countries

On the macro-economic level, resource productivity refers to the aggregate quantity of natural resources consumed to provide housing, rail transport, medical care, higher education, or for generating exports etc. for a given number of people (and/or within certain geographical or political boundaries), for a period of time (normally one year, as this corresponds to the traditional frameworks of national accounts). In short, on a macro-economic level resource productivity refers to the task of providing material welfare to people.

The Total Material Input (TMI), or Total Material Flow (TMF) may be regarded as a highly aggregated indicator that relates to the global environmental pressure associated with the physical basis of an economy (Bringezu, 1996).

The Factor 10 Concept applies in particular at this level: On the average, industrialised countries are expected to reduce the per capita consumption tenfold within one generation. The average Factor 10 for decreasing the resource consumption in industrialised countries could be differentiated on the basis of national performances, once sufficient information on the TMF of countries was available.

The sum total resource consumption for a country can be assessed by aggregating all resources that were imported, generated within the borders, minus those exported (including all ecological rucksacks) during the course of one year.

The Wuppertal Institute has developed - in co-operation with the German Federal Statistical Office - an overall material flow account that comprises physical mass balance. It consists of:

- the domestic extraction from the environment,
- the domestic deposition and release to the environment,
- the imports,
- the exports.

The major points of information for Germany in the year 1991 can be stated as follows:

1. The throughput of water dominates the account (some 600 tons per capita-year).
2. The domestic input of abiotic (= non-renewable) raw materials exceeds the input of biotic (= renewable) inputs by a factor of about 50 (based on dry weight of the plant biomass from cultivation) (some 80 tons abiotic material per capita-year).

3. A tremendous part of the abiotic raw material input remains unused.
4. The input of biotic raw materials from cultivation is associated with an amount of erosion that exceeds the dry weight of the raw materials. Renewable inputs cannot be regarded as "free" with respect to environmental pressure (impacts).
5. On the output side the CO_2 emissions into air amounts to about 1 billion tons. This is more than one third of all waste disposal (excluding incineration) and corresponds to about 13 tons per capita in Germany.

Stefan Bringezu and co-workers have also computed the resource intensity of the 58 sectors of the German economy and inter alias concluded, that the sector building and dwelling consumes between 25 and 30 % of the total non-renewable material flux. On the basis of such information, focused plans for national dematerialization policies could be developed (Schmidt-Bleek, 1998).

This approach can also be applied to integrate social and economic aspects into the analysis: e.g. one can study the relationship between employment vs. material intensity in regions, or in economic sectors; or one can shed light upon the interrelations between subsidies and economic sectors.

More recently, the World Resources Institute has published a joint study, based on the Wuppertal methodology, in which the national resource performances of Germany, the United States, Japan, and the Netherlands were reported and compared (World Resources Institute, 1997). It is interesting to note that the material welfare of Japanese citizens is being provided with about half the non-renewable resources consumption per capita compared to the United States. This, too, is a clear indication that consuming natural resources can be decoupled from generating welfare.

Once the TMFs of countries are known, one cannot only establish a ranking among them in terms of their per capita consumption of natural raw materials, but one can also compute the "true" factor of required dematerialization for each country, as measured against the need for a global reduction of natural raw material fluxes by a factor of 2 and the need for international equity. The Factor 10 which we recommend for industrialised countries as an average yardstick could thus be differentiated and adjusted on a yearly basis.

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Zero Emissions Forum
Environment & Sustainable Development
53-70 Jinguame 5-chome
Shibuya-ku, Tokyo 150-8925
Japan

Tel.: +81-3-3499-2811
Fax: +81-3-3499-2828
Email: unu-zef@hq.unu.edu
http://www.unu.edu/zef

Zero Emissions Forum
Focal Point for Europe
c/o Rüdiger Kühr
Seehofstr.106,14167Berlin
Germany

Tel.: +49-30-42808559
Fax: +49-721-151234313
Email: mbox@zef-germany.de