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Ecological Footprinting

A Technical Report to the STOA Panel

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1.0 INTRODUCTION

This report presents **arguments and evidence** reviewing the Ecological Footprinting methodology, comparing it with official and non-official indicators that are currently under development. It accompanies an earlier **options** report, which included an executive summary and introduction to the different indicators. This and the earlier report were prepared by ECOTEC Research and Consulting and commissioned by the European Parliament's Committee on Environment, Public Health and Consumer Policy. The aims of the proposed study were to:

- review of the **ecological footprinting** methodology;
- summarise recent studies on ecological footprinting undertaken internationally;
- critically assess whether the methodology addresses the physiological, environmental and ecological concerns of the Union as expressed in its legislation and other official documents; and
- assess the strengths and weaknesses of the methodology in comparison to other methodologies, with comparable scope.

The study team have reviewed state of the art literature and have interviewed recognised experts in the indicator's field working in academia, non-governmental organisations and national and international public agencies. A list of the material that has been reviewed and the experts that have been contacted is included in section 7.0.

The past 10 years has seen a great deal of interest in the development of environmental and sustainable development indicators. This report reviews the major intellectual traditions and current best practice in the several important areas of indicator work. The study does present not an exhaustive discussion of all such work but does try to cover the most important ideas.

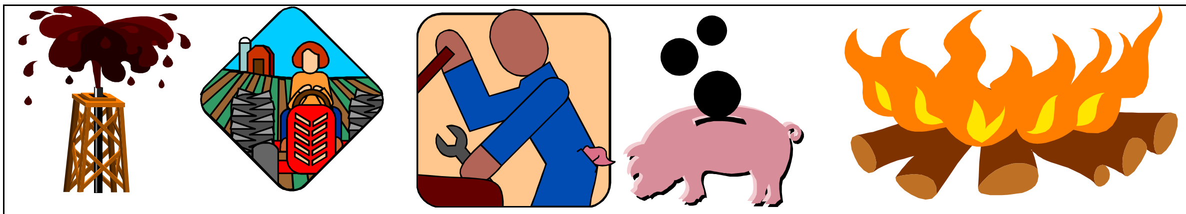
2.0 CONCEPTUAL OVERVIEW

2.1 If we can't measure it how can we manage it?

GDP and inflation have become the pre-eminent measures in discussions of economic performance at a national level. Though the construction of these indicators is not always widely understood they are universally recognised and at least grasped in spirit within policy circles. Similarly, consumers compare the *price of goods* when deciding upon which product to buy.

Many people feel that a unified environmental indicator is needed to offer politicians and consumers a better indicator on which to base their decisions. The success of GDP and inflation shows the role that widely accepted environmental indicators could play in assessing the success of policies and holding policy-makers to account. Some would go so far as to say that the absence of an equivalent environmental indicator tends to downplay the importance of the environment within policy making.

2.2 Economy and environment interactions



RESOURCES → ECONOMY → EMISSIONS

RESOURCES

Fixed
- Land

Renewable
- water, timber, food, sunlight

Conditionally renewable
- fish, soil

Non-renewable
- fossil fuels
- non-energy minerals

ECONOMY

Production
Agriculture
Industry
Services
Traded goods

Consumption
Households
Investment
Government

EMISSIONS

Physical
- CFCs, Greenhouse gases

Human health impacts
- carbon monoxide, heavy metals

Natural Ecosystems Toxicity
- pesticides, BOD

In order to propose a framework for recording the scale of human impacts upon the environment it is necessary to consider the way in which society interacts and relies upon the environment. For the sake of this discussion these are categorised into two sorts:

- **Resources**: these are either materials or characteristics of the environment that are utilised by economic activity, and;
- **Emissions**: these are either material releases or changes in the character of the environment brought about by economic activity.

This characterisation is intended to help organise environmental concerns.

2.2.1 Resources

Overuse of resources gives rise to problems of **scarcity** and **physical degradation**. The extent to which we should be concerned about resource use depends upon the class of resource. It is instructive to think in terms of **fixed resources** such as land - these are not consumed by economic activity but can be degraded. Renewable resources include timber and fresh water which have a cyclical flow. We need to ensure our exploitation remains within the natural rate of flow. **Conditionally renewable resources,** such as marine fish, are resources where current exploitation rates are close to the carrying capacity and present rates of exploitation threaten their long term viability. **Non-renewable resources** are used up as they are exploited and will therefore at some point in time run out.

As well as scarcity excessive resource exploitation causes physical disruption of the land surface. This can be visually intrusive (the site of a clear felled forest or an opencast mine).

Over use, or mismanagement of our resource endowment threatens the environment and our own future access to the environment. The current pressure upon fish stocks is a good example of this - technological improvement in our detection and capture of fish is causing many fisheries to collapse.

Land is many ways a special resource. It is not consumed by economic activity but its appropriation for one use precludes other rival uses. Some uses of land result in irreversible changes in its properties meaning it cannot be restored to its earlier use. For instance, when a plot of undeveloped land is built upon there are impacts upon biodiversity, water retention and soil stabilisation. In practice it is difficult to restore land to its former use at least in the short term.

2.2.2 Emissions

Emissions are of concern because they change the environment in a manner that damages some trait of the environment. Not all emissions are of environmental concern. For instance most buildings emit heat into the environment but this is rarely regarded as a problem since it dissipates harmlessly.

For the sake of this study we have considered emissions that affect the **physical characteristics** of the world such as global warming, ozone layer depletion and acidification. Emissions can also be harmful to **human health** such as heavy metals, particulates and benzene. Emissions can also disrupt **natural ecological processes** such as insecticides and biological oxygen demand. Many substances are simultaneously fall into more than one of these categories. Some emissions arise directly from resource exploitation. Mining mobilises substances that have been otherwise been held within the soil in a harmless fashion (for instance methane emitted from mining, or heavy metals mobilised from crushed rock during mining operations).

The environment has a natural capacity to recover from emissions of many substances. For instance organic substances with a high biological oxygen demand will automatically be respired by water organisms so there is no long term threat. Similarly airborne acidic gases will eventually be neutralised by alkaline substances in the soil so long as the rate of deposition does not exceed the soils' critical load. Higher concentrations of carbon dioxide will eventually give rise to faster rates of photosynthesis and capture by the oceans.

2.2.3 Carrying capacity

The term *carrying capacity* is derived from the ecological literature. It refers to the number of organisms that can survive within a habitat's resource base. There are useful parallels between this idea and the more general environmental constraints that environmentalists warn of. Specifically the issue is whether there is any finite limit to the resource extraction or rate of emission that will undermine the long term sustainability of the environment. These finite constraints will set the extent to which society can extract to emit resources if the economy reaches a steady state position.

In the case of the non-renewable resources the carrying capacity is zero. Since the resources are finite and not generated anew (at least not in a time frame a human generation would find meaningful) any extraction is unsustainable. However the resource might be so plentiful its finiteness might not be a practical concern – hence the joke the stone age did not come to an end because the world ran out of stones. For fixed resources such as land the finite amount is an absolute constraint. For renewable resources such as water and wind the rate of the substances cycling or throughput sets a natural carrying capacity. Conditionally renewable resources like fish stock are most threatened by human exploitation since mismanaged stocks can be driven to extinction.

The idea of carrying capacity also has an analogue when considering emissions. These are well articulated in the Natural Step's System Condition 2 and 3.

Figure 1: *Operationalising Carrying Capacity for Emissions*

System condition 2

Substances produced by society must not systematically increase in nature.

This means that, in a sustainable society, substances are not produced at a faster pace than they can be broken down and reintegrated by nature or redeposited into the Earth's crust.

System condition 3

The physical basis for the productivity and the diversity of nature must not be systematically diminished.

This means that, in a sustainable society, the productive surfaces of nature are not diminished in quality or quantity, and we must not harvest more from nature than can be recreated.

source: Dr Karl-Henrik Robèrt, Swedish oncologist and originator of The Natural Step

The above box gives a conceptual framework for establishing the carrying capacities for emissions of substances that accumulate or which are biologically active. It can be impractical to establish systems conditions as stringent as these. A great many artificial substances are environmentally benign even though they are not broken down effectively within the environment. For instance plastic residues in landfill are not thought to pose any special environmental risk. An alternative approach might be to concentrate accumulations of substances that threaten the environment.

The Sustainable Process Index approach developed at the scientists working at Graz University of Technology, Austria. (Krotscheck C and Narodoslawsky M, 1996) includes a procedure for comparing human emissions of pollutants with the carrying capacity. The procedure depends on the assumption that the medium into which pollution is emitted has a natural rate of renewal or refreshing (for instance the flow of fresh water from rainfall to sea). Pollutants are naturally present in the medium even before human activity. Any added pollution can be diluted back to the natural concentration by adding sufficient of the medium.

The table below expresses the natural dissipation rates for selected air pollutants (expressed per unit land) calculated on this basis. This procedure for handling emissions is far from satisfactory for a number of reasons: dilution of the pollutant is rarely a sustainable management procedure, secondly for media such as "air" the concept of renewal rate is hard to conceptualise and thirdly the procedure cannot be used for pollutants that do not naturally occur in the media but which are harmlessly broken down by the environment including many synthetic organic compounds.

Table 1: Allowable yearly dissipation into the compartment "air" (global values)

Substance	**mg m^{-2} yr^{-1}**	**Substance**	**mg m^{-2} yr^{-1}**
CO	9800	H_2S	390
VOC (total)	6500	CS_2	2.0
CH_4	4500	Phosphorus (total)	28
Sulphur (total)	1280	No_x	131
SO_2	255	NH_3	200

source: Krotscheck C and Narodoslawsky M, 1996

The figure below gives an overview of the principal approaches to establishing the world's carrying capacity. Ehrlich and Holdren's IPAT formulation of society's impact upon the environment emphasise the driver's that can influence total impact. Within liberal, democratic societies it is only T that can be influenced in a manner supportive of the environment.

Impact = Population x Affluence x Technology

Figure 2: *Measures of carrying capacity and human impact on the Earth*

Studies about nature's capacity to support human life go back many centuries. Some focus more on energy requirements, others on non-renewable resources, and others again on photosynthetic potentials. But all are based on the same principle: tracing resource and energy flows through the human economy. Much intellectual ground-work was laid in the 1960s and 1970s. Examples are Eugene and Howard Odum's eMergy analysis examining systems through energy flows, Jay Forrester's advancements on modelling world resource dynamics, John Holdren's and Paul Ehrlich's IPAT formula, or, in the spirit of the International Biological Programme, Robert Whittaker 's calculation of net primary productivity of the world's ecosystems. The last ten years have witnessed exciting new developments: life cycle analyses (e.g., Müller-Wenk), environmental space calculations (Johann Opshoor and the Friends of the Earth), human appropriation of net primary productivity (Peter Vitousek et al.), mass intensity measures such as MIPS (Friedrich Schmidt-Bleek and the Wuppertal Institute), the Sustainable Process Index SPI (Christian Krotscheck, Michael Narodoslawsky), the "Polstar" scenario model (Stockholm Environment Institute), or the ecological footprint concept (Mathis Wackernagel and William Rees, and similar studies by Carl Folke), to name just a few. Their applications may vary, but their message is the same: quantifying human use of nature in order to reduce it. As most of them are compatible, results from one approach strengthen the others.

Source: Mathis Wackernagel, et al (1997)

2.3 What are the fundamental scarcities? What measuring rods should we use?

Later in the discussion consideration will be given on how to aggregate the range of pressures described in section 2.2 into a single index. This will require that different pressures be expressed in the same unit. In this section we step one step back and consider *what are the underlying scarcities one would wish to track*. In other words what is really important to the economy and how is it best expressed. The focus of this discussion will be land area in order to develop the idea of ecological footprinting.

There are a number of measures that are possible candidates for expressing scarcity.

In economic dialogues we are used to thinking about **money** value of goods. This idea can and has been extended to environmental goods and services. When considering industrial production we are used to thinking about the **mass** or **number** of items (or even number of molecules or atoms). In thermodynamics we are used to thinking in terms of the high quality (flexible) **energy**. In considering biological productivity of the world the **area** of ecosystems limits production. In environmental discussions we find that the rate at which materials can be treated or detoxified is often related to the **volume** of the environmental sink.

In trying to choose a single unit of measure to express a raft of environmental concerns we would ideally like the unit to be:

- well understood;
- related to some property of the environment that is scarce or constrained and;
- convertible in a meaningful way for a range of environmental concerns.

This is true for money and area. It is probably no coincidence that first set of national accounts calculated for the UK, the Domesday Book, completed in 1086 recorded land holdings of the Norman barons. Land was the source of the principal flows of food, building materials and energy for the pre-industrial society. The contemporary incarnation of the national accounts is of course measured in money. The development of the national accounts, principally since the Second World War, was necessitated by the increased sophistication of the economy, our reliance on built capital and the exploitation of sub-soil rather than renewable resources.

Operationalising sustainable development means substituting renewable resources for sub-soil resources and making greater use of recycling and materials minimisation techniques. It is worth remembering that the availability of most renewable energy sources is constrained by the amount of incident sunlight. *Wind* arises from differential heating of the sea and land, *hydro-power* arises from solar energy being used to vaporise water and carry it to a higher altitude. These are all some function of the area of sea and water exposed to sunlight! Only geothermal and (to an extent) tidal energy originate from sources other than the Sun.

By definition sub-soil reserves occur not on the land surface, but below it. They fit uneasily to any land based measure. One approach might be to consider the land that has to be disturbed in order to gain access to the deposit. This is a two dimensional attempt to cope with a three dimensional problem but it might be the only practical way of handling the issue.

Environmental services such as absorption of carbon dioxide and neutralisation of acid gases occur on the land surface and we can without stretching the imagination too far think in terms of the area needed to detoxify or sequester these substances.

Mass and **energy** can and are used as the measuring rod in environmental indicators. Both are intuitively easy to understand. The total mass of the environment is not a limiting factor on development indeed we know from thermodynamic laws that mass is neither created nor destroyed in (non-nuclear) economic processes. It is not the mass of resources that are in short supply but the toxicity, scarcity and unwanted physical properties of particular substances. To be a meaningful single indicator any mass based index needs to go beyond summing the total quantity of all materials.

The availability of energy is a binding constraint on activity. Energy can in principal be used to construct equipment to detoxify substances, recover useful materials from ores and industrial waste. It represents a credible and useful alternative numeraire that could be used for measuring impacts. Odum (1989) discussed the “shadow” area of US cities. He points out that though they occupy only 6% of the area their shadow area appropriate 35% of continental USA.

Monetary valuation of resources and emissions has been researched at great length. Valuations have been undertaken for many environmental phenomena. Techniques for valuation have, however, not been operationalised for all environmental concerns. Biodiversity remains a challenge. However valuation, in part because it has had much greater professional attention devoted to it, remains controversial. Some of these controversies are confined to highly technical differences of implementing particular valuation techniques. For instance should the value a consumer places on the environment be calculated on his willingness to accept a reduction in provision or his willingness to pay for additional environmental provision. Some controversies are much more fundamental - should valuation be based on the cost of remedying the environment, investing in technologies that avoid pollution altogether, calculate the value of damage done or ask consumers how much money they might spend on the reducing pollution. Different approaches give rise to different numbers and there is little agreement about which to favour. To provide a feel for the scale of the controversy different analysts valuing carbon dioxide emissions have placed the value as negative (assumes that there are win-win carbon savings) and large and positive (based on the damage caused by global warming). Valuation of resources tends to based either on the economic rent[1] earned from a non-renewable resource or the cost of obtaining the same service for an alternative renewable source.

2.4 The case for single indicators

This report is concerned about single indicators but a single indicator is not universally seen as a good thing.

Proponents of a single indicator feel that GDP, proxying for living standards, is used to place different countries into an economic hierarchy. GDP is used to judge the overall success of nations. Nations inevitably formulate policy to that makes them look good on this measure. This all occurs despite GDP's widely known limitations. GDP is a summation of spending by "final consumers" (households, Governments, investment and overseas) irrespective of the social value the purchase. Its compilation adds together the expenditure of a bellicose nation arming itself to the hilt to the wages of a nurse tending to the sick.

The arguments for single indicators generally hinge on the idea that consumers and decision makers are better served by a single easy to understand 'warning' indicator than not having one. The uses of such an indicator will be discussed in more detail later as different candidate indicators are introduced.

Arguments against single indicators are usually framed in two ways. The first is that single indicators are not necessary. Proponents of this view would argue users are sophisticated enough to manage with more than one data series. Claims that economic policy making is overwhelmingly dominated by a single indicator (GDP) fundamentally misunderstands economic policy making. Economic decision making uses many different indicators including retail price inflation, unemployment rate and strength of the currency amongst many others. Those complaining about the pre-eminence of GDP have created a straw horse. Arguably inflation rather than GDP is the most important single economic indicator; both the European Central Bank and the US Fed target inflation not GDP.

The second argument used against single indicators is that in order to be calculable they must aggregate "apples" and "oranges" putting fundamentally irreconcilable issues into a common unit of measure in order that they may be added up. For instance evaluating water abstraction by looking at the energy used to pumping and purifying completely misses the prime environmental issue which is scarcity and damage to water ecosystems. Any single index that purported to include "water" abstraction would then be misleading and giving a false sense of completeness.

A third complaint against single indicators is that different environmental concerns are all constraints in their own right. Putting them into a single measure implies a trade-off that does not exist. No amount of improvement in water quality compensates us for the loss of the ozone layer.

These are all serious charges and many professionals are not persuaded that a single environmental indicator is a desirable goal for statisticians.

[1] The economic rent of a resource is often valued as the cost of the final commodity minus the cost of extraction and refinement

3.0 ECOLOGICAL AND ENVIRONMENTAL INDICATORS IN THE LEGISLATION

The increasing importance of environmental issues has raised the profile of indicators provided by the EU, national governments and international organisations. The Amsterdam Treaty of the European Union sets out 'balanced and sustainable development' as one key priority.[2] This was a step forward from the Maastricht Treaty 1991 which had referred simply to 'sustainable growth respecting the environment'.

There is no official European Union definition of sustainable development. In the context of the development process of developing countries the following definition was used:

'Sustainable development means the improvement of the standard of living and welfare of the relevant populations within the limits of the capacity of the ecosystems by maintaining natural assets and their biological diversity for the benefit of present and future generations.' *Regulation on measures to promote the full integration of the environmental dimensions in the development process of developing countries.*

3.1 Commission work on Environmental Indicators (prior to 6th Environmental Action Programme)

Practical steps towards Environmental Indicators and Green National Accounting were set out in a 1994 Communication to the Council and the European Parliament (COM 94 670 final). This paper argued against a Green GDP and instead supported a mixed approach of satellite environmental accounts and physical indicators/indices related to the pressure of human and economic activities on the environment.

The Dutch NAMEA system has been put forward by the Commission as the preferred framework for the development for environmental accounting. Eurostat and members state statistical offices are taking forward work to develop these accounts. The NAMEA approach is closely integrated with the conventional national accounts borrowing from it concepts and classification schemes for the economy. The advantage of this close integration is that the NAMEA can be used as the basis for direct economic and environmental comparisons between sectors and for the construction of economic models incorporating environmental emissions and resource use. The NAMEA approach eschews the valuation of pollution. However some limited work has been undertaken on valuing sub-soil assets such as fossil fuels in terms of their 'economic rents' (which means the excess value of the resource over and above its cost of production). In other words the value the market places upon its scarcity.

The second strand of work brought into being by COM 94(670) is the development of the European System of Integrated Economic and Environmental Indices. This programme of work seeks to develop environmental indicators that are allows environmental performance of different sectors to be to presented in a comparable way. This project envisaged the establishment of a set of European Weighting Coefficients. As a result of this

[2] Article 2, Treaty on the European Union, Amsterdam 1997

Communication, Eurostat runs a multi-annual project to investigate pressure indicators in the EU, '*Towards European Pressure Indicators*' or TEPI.[3] This project aims:

- To calculate and present the 6 priority pressure indicators in each environmental policy field, for all 15 EU Member States.
- To present, where possible, the contributions of the economic sectors to the environmental pressure.

Through extensive consultation with experts in 10 policy areas and scientists this project has developed 6 environmental indicators for each policy area. In parallel, work was carried out to investigate which economic sectors cause these environmental pressures. Future work includes an assessment of the possibilities of aggregating these indicators into single indices and potentially a single European Sustainability index. Such a development requires serious methodological and weighting consideration.

3.2 The Sixth Environmental Action Programme

The recently published Sixth Environmental Action programme sets out three different sets of indicators to be monitored in the future.

The first is a set of 11 headline indicators (see Table 2) which clearly and simply illustrates the key environmental trends and provides an indication of the state of the environment. They aim to address the need for a few key indicators to describe how the environment is developing as a whole and will be monitored annually or bi-annually. Results will be disseminated through a dedicated website and leaflets. The indicators have been chosen methodologically rather than on the basis of data availability considerations and as a result there are some gaps in the data. The Commission is working with Member States and their statistical agencies to develop a consistent base of data. It was decided that a single aggregate indicator was too dependent on subjective weightings in aggregating different environmental pressures. In addition, it was unclear what role such a composite indicator could play for policy makers since it internalises such trade-offs.

[3] See http://www.e-m-a-i-l.nu/tepi/

Table 2: Headline Indicators in the 6th Environmental Action Programme

Issue	Indicator
CLIMATE CHANGE	
1. Climate Change	Emissions of Greenhouse Gases
NATURE & BIO-DIVERSITY	
2. Nature & Biodiversity	Designated "Special Protection Areas"
3. Air Quality	Air Pollution - acidifying substances
ENVIRONMENT & HUMAN HEALTH	
4. Air Quality	Smog creating substances - ozone precursors
5. Urban Areas	Air pollution in urban areas – particulates (dust), sulphur dioxide and nitrogen dioxide
6. Water Quality	Water pollution - concentrations of nitrate-nitrogen and phosphorus in large rivers
7. Chemicals	No Indicator due to lack of existing, comparable data
WASTE & RESOURCES	
8. Waste	Municipal and Hazardous waste
9. Resource-use	Energy Consumption
10. Water Quantity	European Water abstraction
11. Land-use	Land use - arable land, permanent grassland, permanent crops, forest land, built up areas, length of road network

The second is a more detailed set of (60-70) environmental quality indicators which can be used to inform policy evaluations and priority setting. These indicators are presented by the EEA in the annual *Environmental Signals* reports.

Thirdly, there is a core sets of integration indicators for 9 policy sectors such as transport, agriculture and energy. This development follows the Cardiff European Council Meeting in June 1998, which requested the identification of indicators in order to monitor progress towards environmental integration strategies implemented in different policy sectors. Indicators are already well advanced in the area of transport due to the initiative 'Transport and Environment Reporting Mechanism'. Work is also undergoing on developing a broader set of indicators, which could be used to provide a EU-specific set of sustainable development indicators applicable to sectoral integration strategies.

3.3 Other environmental indicator initiatives

Environmental issues are included in the development and evaluation of Structural Funds interventions. Environmental protection and sustainable development are a key priority in the interventions. The Energy intensity of the economy is one of 27 key structural indicators proposed to inform structural policy as a measure of sustainable development (Commission 2000).

The Commission's Eco-labelling legislation aims to provide a benchmark and seal of eco-efficiency around products in certain (so far 15, work has begun on a further 12) product groups.[4] In order to achieve the seal the product has to satisfy criteria set down in separate legislation for each product group. The label is only attained by products with the 'lowest environmental impact' amongst directly comparable products. As such there is no aggregate indicator or measure of eco-efficiency across different product ranges. The criteria follow a 'cradle to grave' assessment of the product in line with a Life Cycle Assessment (LCA) and are developed in consultation with representatives of industry, commerce, environmental and consumer organisations and trade unions.

The collection of data for and monitoring of indicators within the EU is carried out by the European Environment Agency (EEA). The Agency produces an annual indicator-based *Environmental Signals* report which provides an assessment of the state of the environment in Europe according to a *DPSIR framework* (Driving forces — Pressure — State — Impact — Response).[5] According to this framework certain social and economic developments exert pressure on the environment, and as a result the State of the Environment changes. This leads to impacts on human, health, ecosystems and materials that may lead to a societal response on the Driving Forces, states or impacts or directly. Although this simplifies the interactions between the environment and the different actors it provides a framework for presenting and analysing information. This approach is relatively descriptive and aims to provide information on the actual situation with regard to environmental issues.

The Agency works closely with a network of experts in order to develop and calculate indicator frameworks. They are currently considering EF alongside different sustainability methodologies; EF was included in the report 'Environment in the European Union at the turn of the century' as well as the 2000 *Environmental Signals* report. Recent work has also been carried out for the Agency investigating the Total Material Requirement (TMR) and 'Environmental Space' concepts.

3.4 United Nation initiatives

The UN is also following a twin track approach on the environment through its work on the environmental accounting and sustainable development indicators. The highlight of its work on environmental accounts was the 1993 Interim Manual on System of Environmental and Economic Accounts (SEEA rev. 1). Unlike the NAMEA the original SEEA saw an estimate of a single green GDP figure as a logical and attainable target for environmental accounting. The revised SEEA manual is currently being drafted by the UN, World Bank, IMF, OECD and Eurostat. It places more emphasis on physical accounts such as the NAMEA than the original SEEA.

The United Nations' (UN) focus on sustainable development indicators follows the Earth Summit in Rio de Janeiro in 1992 which recognised their importance. In 1996 a draft menu of 134 indicators for all countries to use in reporting on sustainable development was produced. These indicators have subsequently been tested in various countries.[6] On the basis of this work around 60-70 sustainable development indicators were defined within the framework of the Commission on Sustainable Development (CSD) and were made available to decision-

[4] See http://www.europa.eu.int/comm/environment/ecolabel/program.htm

[5] See http://reports.eea.eu.int/

[6] See http://www.un.org/esa/sustdev/index.html

makers in 2000. The UN also produces the Human Development Report, which includes the Human Development Index (HDI) for over 150 countries.

The third UN indicator of relevance to this study is the Human Development Index. This does not contain any insights into the environment (the issue is not covered by the HDI) but it is of interest because of the impact the HDI has had as a heavyweight social indicator that is widely respected and used by the media and politicians.

The HDI is complemented by the Capability Poverty Measure, which presents the proportion of the population with inadequate health, access to basic services and gender inequalities. This can therefore indicate strong inequalities between groups within a country which are averaged out in the HDI.

The World Bank carries out research into a number of different sustainable development methodologies. Significant effort has been put into Genuine Savings and other wealth based methodologies as a measure of sustainability.[7] The latter measures the stock of wealth in a country including produced assets, natural assets and human and social capital. Genuine savings rates are to be included in the Bank's major publication 'World Development Indicators' which provides an expanded view of all elements of development for almost 150 countries, including a section on environmental indicators. Within the context of environmental performance of projects the Bank has developed guidelines on indicator frameworks, selection criteria for environmental project indicators, and issues to consider for various environmental areas.

In addition the World Bank supports the introduction of Green accounting procedures and sees a great potential in addressing environmental issues within a context that national ministries of finance can understand. This work feeds directly into wealth measure and genuine savings rates calculations.

The OECD has developed its own set of core sustainable development indicators, first produced in 1991 and subsequently reviewed in 1994 and 1998.[8] These indicators are based on a 'Pressure-State-Response' (PSR) approach. In addition the OECD is working to develop sectoral integration indicators in sectors such as energy, transport and agriculture and indicators with the accounting framework to take account of environmental concerns in economic policies. The Directorate of Statistics is also monitoring the greening of national economic accounts and the development of environmental accounts.

Many Member States base their approach on a 'Driving forces, Pressure, State, Impact, response', or *DPSIR*, framework. An analysis of State of the Environment Reports across Member States in 1997 found that each of these reports contained some DPSIR elements (Smeets and Weterings (1999)).

[7] See http://wbln0018.worldbank.org/environment/EEI.nsf/all/Environmental+Indicators?OpenDocument

[8] See http://www.oecd.fr/env/indicators/index.htm

Box 1: *The Human Development Index*

The Human Development Index (HDI) measures three aspects of a country's progress with regards to development:

- longevity (life expectancy);
- knowledge (literacy and education level); and
- standard of living (GDP per capita).

It is arguably the most well known and widely reported alternative indicator to GDP and is widely quoted and reported in the media. The HDI aims to focus on people rather than economic growth as a measure of development however the environment is excluded from the framework. It is often used to show that countries with very different income levels (such as Saudi Arabia and Peru) can have similar levels of human development. The HDI is calculated on an annual basis within the United Nations Development Programme (UNDP) for the Human Development Report. A time series of the index is available for 174 countries from 1975-98.

Country	**HDI 1975**	**HDI 1998**	**GDP per capita (PPP US$)**	**Rank HDI 1998**	**Rank GDP 1998**
Canada	0.865	0.935	23 582	1	9
France	0.844	0.917	21 175	12	17
Hungary	0.772	0.817	10 232	43	42
United Arab Emirates	0.737	0.810	17 719	45	24
Saudi Arabia	0.588	0.747	10 158	75	43
Peru	0.635	0.737	4 282	80	87
Malawi	0.312	0.385	523	163	172

Source: Human Development Report 2000

The basic data for the index are internationally comparable and taken from UN organisations and the World Bank. The index is relatively easy to understand and methodologically transparent for the general public. It can inform policy-makers about health and education provision but otherwise is somewhat limited. It does not make any attempt to judge sustainability but offers the maximum score (one) as a target.

In addition most reports included some *efficiency* indicators, expressing the relationship between different parts of the causal chain, in particular between environmental pressures and human activities. The most common examples of these relate emissions or energy used to the population or GDP and therefore stimulate the use of new technologies that reduce resource use and/or pollution levels of human activity.

Some reports also included *performance* indicators, which relate the situation to how it would be, i.e. to performance against targets. As such they can be used to judge whether targets have been met and whether there is a need for additional or different policy interventions. These were included less frequently, however, than either of the other types of indicator.

Given the importance of performance and efficiency indicators, the EEA works to encourage Member State statistical offices to use them in their reports. (Smeets and Weterings (1999))

The UK has a list of 15 headline indicators for sustainable development of which 7 address environmental/resource issues. These indicators are intended to make up a 'quality of life' barometer which can be used to measure progress and fits with the strategic objectives in the area of the environment. Sweden has developed a list of core Green indicators in ten programme areas.

The Dutch National Environmental Policy Plan uses indices of indicators of the state of the environment based on six environmental themes to construct an aggregate index to measure the progress achieved towards environmental objectives (GUA 2000). Work by the Friends of the Earth Netherlands using Environmental Space and EF methodologies have played a role in developing government policy.

Austria was the first country to adopt the *Factor-10* target of increasing their resources productivity by a factor of 10 in order to achieve sustainability. Germany aims to 'increase resource productivity 2.5 fold by 2020 compared to 1990.' Germany's *Umweltbarometer*, produced by the Federal Environment Agency, presents indices in six environmental policy areas and then aggregates these scores into a single environmental indicator, the *DUX*[9]. This aims to provide a single indicator to present the development of the environmental situation clearly and transparently.

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[9] See http://www.umweltbundesamt.de/

Box 2: The DUX

The DUX is calculated by assessing the progress made towards achieving environmental goals in six environmental topic areas of the *Umweltbarometer* (Environment Barometer). Indicators are compared with the data from a base year and against a target set for the future. Each indicator scores up to1000 points to the DUX index. 1000 is scored when the target has been achieved. When no progress has been made (i.e. the indicator is at the same level as in the initial year) then the indicator scores 0. If the situation has worsened then the indicator can receive minus scores.

This framework was developed in co-operation with a national television channel and a regular dissemination of the development of the *DUX* is planned. It does not aim to describe the environmental situation in Germany but rather to present progress made towards environmental targets in important areas. As such it makes an assessment of environmental policy clearer and more transparent. It is limited in so far as it does not include any biodiversity issues. In addition the index gives equal weighting to different environmental areas whilst in fact some may have critical impacts. Scoring against targets also raises methodological questions in that their achievability is likely to vary.

The Umweltbarometer and DUX (October 2000)

Issue	**Indicator**	**Target**	**Score /1000**
Energy	Productivity of energy use (GDP/energy use)	Double the productivity of energy use from 1990-2020	164
Land/Soil	Daily increase in land area which has been built upon or used for transport (ha)	Reduce daily increase in land area to 30 hectares/day by 2020	-11
Climate	Annual CO_2 emissions (million tonnes)	Reduce CO_2 emissions by 25% by 2005 in comparison to 1990	607
Air	Decrease in standardized Sulphur dioxide (SO2), Nitrogen Oxides (NOx) and Ammonia (NH_3) and volatile organic compounds (VOC) emissions in comparison to 1990	Reduce Sulphur dioxide (SO2), Nitrogen Oxides (NOx) and Ammonia (NH_3) and volatile organic compounds (VOC) emissions by 70% between 1990-2010	692
Water	% of measurement points of running water achieving chemical standard II (based on concentration of nitrates and absorbent organo-halogen compounds (AOX))	100% (100% of measurement points) of running water achieving chemical standard II (based on concentration of nitrates and absorbent organo-halogen compounds (AOX))	0
Resource use	GDP/consumption of non-renewable resources	Increase efficiency of resource use 2.5 times by 2012 in comparison to 1993	53
DUX (Total /6000)			1505

Source: www.umweltbundesamt.de

4.0 ECOLOGICAL FOOTPRINTING METHODOLOGY AND CASE STUDIES

This section reviews the principles and application of ecological footprinting (EF). It draws on contemporary EF studies and discussions with the leading practitioners in the field.

The *Ecological Footprint* (EF) of a population is the area of land and water ecosystems needed to provide the resources and assimilate the waste of the *population* being studied. The *population* can be a person, product, firm, region or country. Since the area of land owned or controlled by the population is usually a finite and identifiable quantity, it can be compared to the EF. This juxtoposition of the *actual* land available and the EF and the difference between the two, termed the "ecological deficit", serves to show the dependence of the population of ecosystem services outside of the political area. The rationale for representing impacts upon the environment in units of area is that biologically productive land area produces or absorbs flows of many of the materials utilised by our society. Uses are often mutually exclusive are therefore in competition for the finite area of productive land in the world.

Ecological Footprinting was developed in the early 1990s by the academics Mathis Wackernagel and William Rees in Canada. A number of textbooks have been written on EF methodology (Wackernagel and Rees, 1996; Chambers, Simmons and Wackernagel, 2000) and there has been lively debate in the academic literature (for instance *Ecological Economics* March 2000 special issue on Ecological Footprinting). Ecological Footprints have been produced for different scales of organisation; from the world/nation (WWF, 2000), cities (Folke, C *et al*, 1997)), companies (Chambers, N and Lewis, K 2001), individuals (Best Foot Forward's eco-cal software) and products.

4.1 What is ecological footprinting

The EF statistic combines several environment impacts into a single area measure. Conceptually, EF can include biological and energy resources, pollution, land use, waste disposal and provision of natural habitats. EF *does not seek to include* social issues such as income distribution, education and crime nor economic issues such as inflation, GDP and unemployment. EF is therefore not a measure of sustainable development.

In practice, EF calculations have been less ambitious and have only included a limited range of environmental concerns. The box below shows the environmental pressures typically included.

National EF = Food + Timber + Carbon Storage + Buildings and road + Biodiversity

In other words the national EF comprises the land used to provide food, timber and sequestering the carbon dioxide from burning fossil fuels. A notional area of land is also set aside for maintaining biodiversity.

4.2 Compound approach and component approach to EF

Two approaches to calculating EF have developed over the past five years. The compound approach developed by the originators of the EF concept, Mathis Wackernagel and William Rees, makes use of whole economy data to calculate national EFs. The second approach, developed by the UK based consultancy Best Foot Forward, calculates EF for sub-national populations, products, firms and households. It makes use of a more eclectic selection of data. The methodologies and concepts of both approaches are described below.

4.2.1 Compound approach

The objective of the Compound Approach is to utilise internationally standardised data to arrive at a robust *under*estimate of the EF. Because comparisons are to be made across countries and across time it is important that the underlying data is easily available and conforms to agreed definitions.

The compound approach, typified by a study funded by WWF, uses UN data on agricultural production, forest production, area of built land and trade. Because the focus is on the *nation as a whole* there is no need to identify which sectors, firms or sub-national regions make use of particular resources or emit pollutants. In this respect it is a rather easy methodology to operationalise utilising whole economy data that is produced in a standardised format by the UN and other agencies such as the IPCC. Trade data are needed because the EF calculation seeks to identify the impact of nations' *consumption* rather than *production* and so imported goods have to be added and exported goods deducted.

The methodology calculates the supply and demand for different classes of land. These are:

- Crop land
- Grazing land
- Forest land
- Fishing ground land
- CO_2 absorption
- Built-up land

The *demand* for each type of land is calculated from the quantity of production *plus* imports *minus* exports. So for instance the demand for crop land would be calculated from the mass of crops produced plus imports minus exports. The total quantity of crop production is converted in an "area" by dividing by world average yields. This would be repeated for each of 18 different crops. Net imports of commodities are converted into their land equivalent using information on CO_2 absorption in their embodied energy and any direct land inputs. Domestic areas of cropland are not used to avoid variation in yields arising from excessive use of inputs (or better growing conditions).

The supply of land is drawn from FAO statistics. Three land types are recognised: crop land, grazing land (which includes lightly wooded areas) and forest land. The area of land therefore excludes areas that not biologically productive. Areas are further adjusted to take account of variations in quality of land both between types and between countries. Typically crop land is scaled up since it is biologically highly productive and grazing land often scaled down.

The surface area of land is therefore not used directly but adjusted according to its bioproductivity. The unit of measure is an "area unit" which is 1 hectare of biologically productive space with world average productivity. Across the world the average number of "area units" per hectare of land use is given below for five different land uses:

- Crop land - 3.33
- Grazing land - 0.37
- Forest land 1.66
- Fishing ground land 0.06
- Built-up land - 3.33

In other words built-up, crop and forest land is more bioproductive and grazing land and fishing ground less bioproductive than average. The area unit equivalence is calculated for each country. So one hectare of cropland in UK is 8.98 area units whilst in Finland it is only 4.16 area units (both higher than the world average of 3.33).

In the WWF study UN trade data is analysed under 72 categories (e.g. cereals, timber, fishmeal) and the net trade is translated into land equivalents by assessing the energy needed to manufacture the goods (literature review) and any land directly utilised. Information on the built-up land is the most poorly documented and comes from various studies interpreting satellite imagery.

The item "CO_2 absorption" land is a fictitious area type and is the demand for land that would be needed to sequester the carbon dioxide emitted as a result of the country's direct and embodied fuel consumption. Energy, or rather the carbon sequestration, makes up the largest proportion of the EF of European countries. National data on fossil fuel usage (and energy embodied in traded goods) is converted into carbon dioxide emissions. It is assumed that 35% of this CO_2 dissolves in the ocean. The EF is calculated for the remaining 65% assuming it would be sequestered by forest *to avoid increasing global CO_2 atmospheric concentrations*. The area of forest needed to sequester the carbon is a weighted average of the different forest biomes in the world. Output from nuclear-fired electricity is converted [by thermal equivalence] to CO_2 also.

The difference between the ecological footprint (the demand for land in area units) and the supply of land (the actual bioproductive area controlled by the population measured in area units) is termed the "*ecological deficit*" and is one of the key statistics reported by the analyst.

4.2.2 Component approach

This is used to assess the EF of a (sub-national) population or product. It is necessarily more data intensive than the compound approach since national statistics are rarely collected in a manner that will easily identify material and energy flows for a sub-national population. When EFs are being calculated for products and firms commercially sensitive data on purchases and outputs are used.

The compound approach relies heavily on trade data to convert a population's production into consumption. Data on production, consumption or trade is not readily available at the sub-national level; and so some sort of analysis of non-official data is inevitable. The principal novelty, and strength of the component approach, is the bottom-up methodology which first establishes the amount of **activity** undertaken by a population under a list of headings given below. Activities are converted into **energy and direct land use**. Finally this is converted into **global area units** to allow comparison with the global constraint. How this is applied to real situations is described below.

Table 3: Component impacts considered in a component analysis

❑ Electricity (domestic)	❑ Gas (domestic)	❑ Electricity (other)
❑ Gas (other)	❑ Travel by car	❑ Travel by bus
❑ Travel by train	❑ Travel by Air	❑ Road Haulage
❑ Rail freight	❑ Sea freight	❑ Air freight
❑ Food	❑ Wood products	❑ Recyled waste (glass)
❑ Recycled waste (paper and card)	❑ Recycled waste (metals)	❑ Recycled waste (compost)
❑ Recycled (other)	❑ Waste (household)	❑ Waste (commercial)
❑ Waste (inert)	❑ Water	❑

Source: Simmons et al (2000)

Regional analysis

When used for a geographical unit the practitioner lists and quantifies the impacts of the components consumed in Table 3. Often publicly collected data are not available and interviews with the relevant parties need to be carried out. These are converted into an equivalent area of land using algorithms developed by Best Foot Forward derived from the literature and especially analyses of the embodied energy used to produce and distribute the goods.

Data are collected at a great level of detail. The EF of the Isle of Wight (Best Foot Forward, 2000) included an inventory of (imported) electricity, gas, bulk stone and aggregates, liquid fuels, agricultural products, foods, numerous retail items (included nappies, batteries, paints, cars). Information on locally produced goods namely aggregates and foodstuffswas also collected.

The second stage calculates the embodied energy and direct land use applying UK specific conversion factors. These together are used to compute the demand for land from the Isle of Wight's consumption. As with the compound approach the goal is to obtain the land in terms of a reference unit based on the **global average productivity**.

Table 4 gives an example of the conversion factors used in order to calculate the EF of use of motor cars on the Isle of Wight. It takes account of fuel use, manufacture and maintenance of cars and also the road space occupied by roads (assumes by 86% of road space is used by cars). The final figure is calculated on the basis that car occupancy is 1.6 per motor vehicle on average.

Table 4: Product conversion factor for UK car travel per passenger km

Component	Inputs	CO_2 emissions	Built land	Total Footprint
Petrol	0.0904 li/km	0.22 kg/km		0.000050 ha/car-km
Maintenance and manufacture	0.0423 li/km	0.10 kg/km		0.000022 ha/car-km
Road space[2]	0.26 m ha		0.73 m ha eq.[1]	
Footprint			0.0000017 ha / car-km	0.000089 ha/car-km 0.000046 ha/km

1) figure for 'global average' land assumes UK road space has bioproductivity 2.8 fold greater

2) 10 times smaller than the published table to correct for an error in the original

Source: Best Foot Forward et al (2000)

Water is integrated into the measure by looking at the energy needed to deliver water. In the case of the Isle of Wight - a popular destination for tourists - a proportion of the energy supplied the island has to be netted off to correct for use by off-island inhabitants.

In the Isle of Wight study dealt with the footprint waste disposal activities. The footprint included the energy, land and transport needed to handle the waste materials. The volume of waste was also a useful sanity check of the inputs data since one would not expect the mass of matter entering the Isle of Wight economy to differ greatly from the weight of waste production.

The *supply* of land in the Isle of Wight makes use of the actual land areas of crop, pasture, built-up and forest and adjusts these bearing in mind the relative productivity of the Isle of Wight relative to the world average. 12% of the land area is subtracted from the actual area the proposition is that this should be set aside for biodiversity purposes.

By contrasting the *demand* and the *supply* for land by residents of Isle of Wight the authors assess the sustainability of consumption. Both are expressed in terms of the area of land of land per citizen.

Product analysis

The Component-based approach can also be used for product analysis. Again energy use makes up a large part of the eventual footprint. Pollution is not incorporated. This can give possibly misleading information when comparing different products. For instance when comparing aluminium to PVC packaging, aluminium would doubtless have a higher footprint. However the life-cycle toxic emissions of PVC are likely to be higher.

4.3 Applications of EF

EF has been applied at a variety of different scales - nation, region, sector, firm and product. The can, in principle, be done with some of the other methodologies but the "scale variants" are known by other names, have different practitioners and different assumptions. For instance monetary environmental estimates are undertaken at the national level (Green GDP), at the firm level (green accounting) and at the policy level (environmental cost benefit). The same is true of indicators.

This section reviews the manner at which EF has been used at different levels. The **product level** and **firm level** are especially important given that these are likely to be of interest to consumers and businesses - a widening of the constituency that might apply EF.

The claim made by EF practitioners is that the technique links products, services and activities carried out by businesses to global carrying capacity. This is in contrast to other firm or product level indicators such as LCA (product) and green accounting (firm). The latter are simply inventories of impacts by a business. The EF goes further - it aggregates these impacts into a single unit of measure.

The section discusses case studies showing the state of the art in this field.

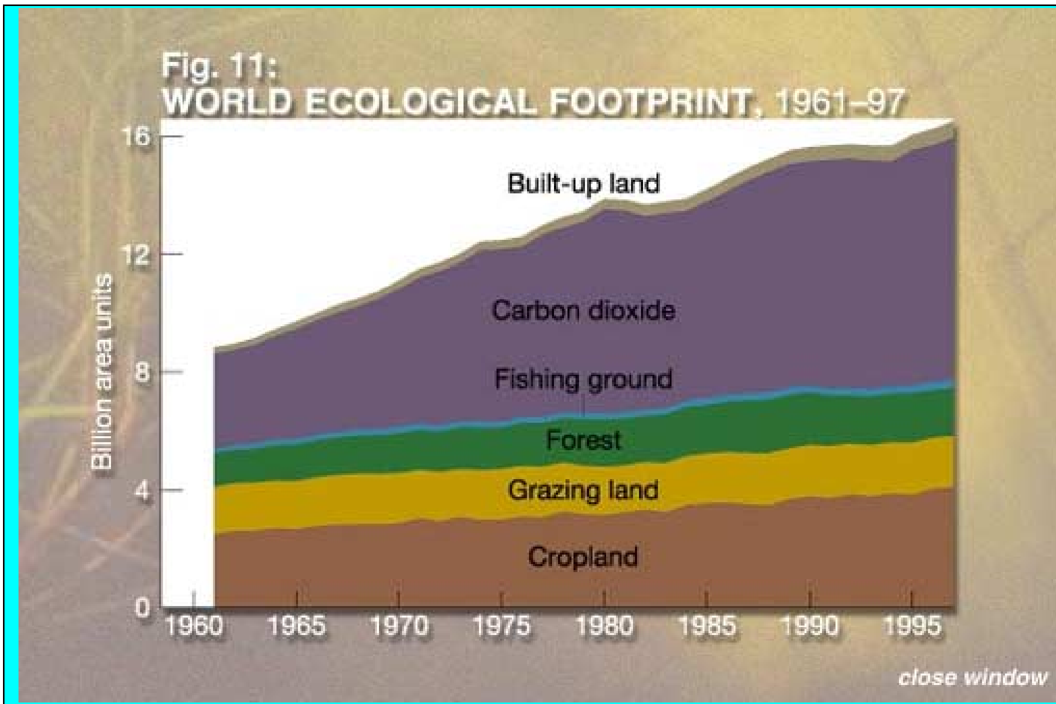
Box 1: Living Planet Report 2000 - WWF

The WorldWide Fund for nature's (WWF) 'Living Planet Report' presents the EF as one of two main indices to quantify changes in the state of the Earth's ecosystems.

The EF is calculated for 152 countries for 1996 and the global EF from 1961-97. The EF is aggregated from individual footprints presented dealing with: cropland, grazing land, forest, fishing ground, carbon dioxide and built-up land. The carbon dioxide footprint (from energy consumption) accounts for 60% of the total ecological footprint. The main conclusions of the report are:

- In 1997, the EF of the global population was at least 30% larger than the Earth's biological productive capacity
- Larger EFs in the industrialised world are responsible for the ongoing loss of natural wealth in the southern and temperate regions

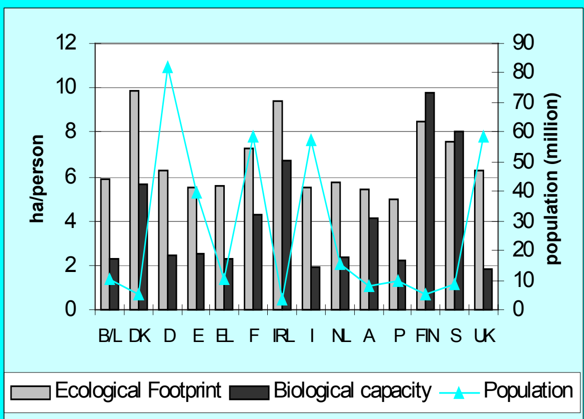
The report recognises that the categories of footprint are still relatively crude and the calculations only aim to give a first-order estimate of the ecological demand. Figure 11 (drawn directly from the WWF report) land use changes over the period 1961 to 1997.

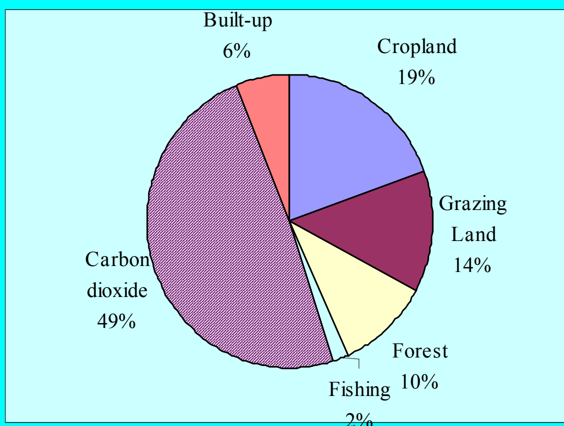


The most obvious point coming across is the importance of carbon dioxide sequestration which makes up almost exactly 50% of the EF on a world wide basis.

The figure below shows show the EF varies (on a per capita) basis for the EU 15 countries.

Ecological footprint EU-15 by country and by land type, 1996





The analysis found that the fair share of bioproductive land available to each of the world's citizens is 2.2 ha or just **2.0 ha** if 10% of land is set aside for biodiversity. Within Europe land use ranged from 5.0 ha / capita in Portugal to 9.4 ha/capita surprisingly in Ireland. This suggests that European countries are overshooting Europe's share of the global resource and sink base and a resulting "…depletion of the Earth's natural capital stock." It is interesting to note that the within the EU countries the share of carbon dioxide and food in the overall EF was much the same as the world average. This arises because the North American per capita energy consumption tilts the average so much.

The national EFs pioneered calculated by Mathis Wackernagel have enjoyed a great deal of publicity internationally and have been the focus of attention at the national administrations and local Governments. One of the original EF studies undertaken by William Rees was of Vancouver, Canada showing it had an EF 174 times greater than its political area.

Box 1 below reviews a study undertaken by Carl Folke and colleagues which examines the EF of 29 cities surrounding the Baltic Sea. This study highlights some of the challenges when trying to develop EF (or any other indicator) for sub-national areas.

Box 2: Renewable Resource Appropriation by Cities - Folke C. *et al*

This study examines the EF of 29 cities with a population greater than 250,000 that lie on river basins that discharge into the Baltic Sea. The cities are in Poland, Denmark, Sweden, the Baltic States, Finland and Russia. These cities have a combined population of 22 million compared to a population of 85 million in the whole basin. Data relate to years between 1989 and 1992.

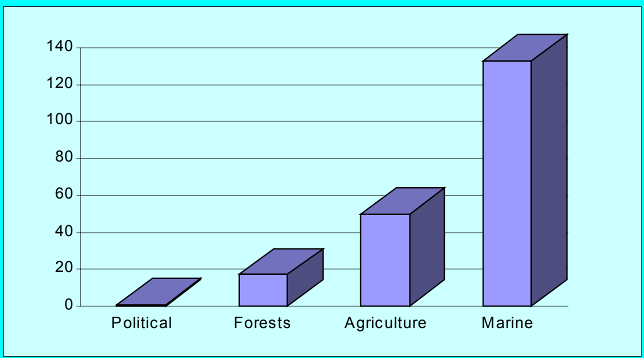
The following datasets were used:

- Data on national production, imports and exports covering from FAO on crop; grazing; forest; marine
- Population data for the cities from Sweitzer estimated using a GIS database of the Baltic
- Marine fish yields from Odum (1983)
- Forest production and yields were drawn from national yearbooks.

For each city consumption per capita was assumed to be the same as the national average *no data on food imports and exports through the cities political boundaries was used.*

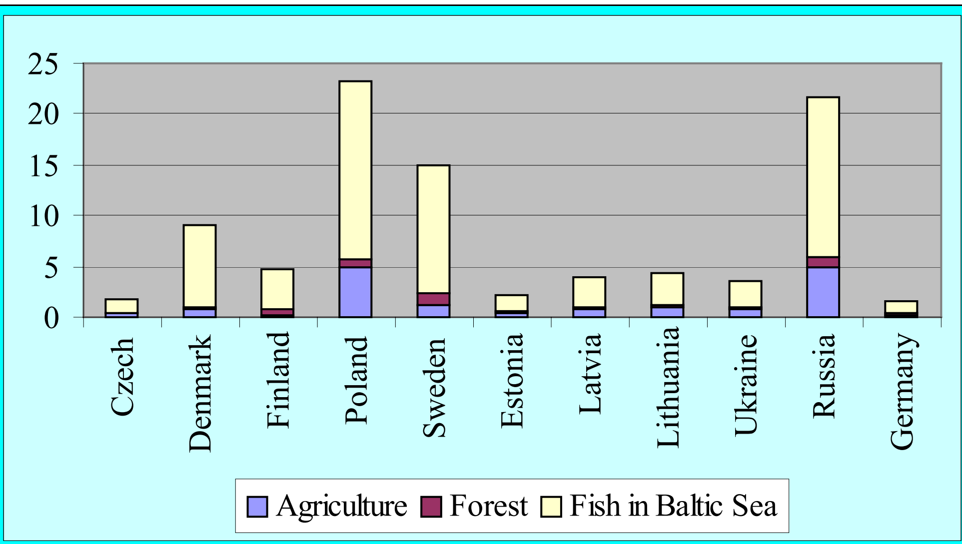
The area of land appropriated to provide the biological resources consumed by the cities was estimated as being 200 times greater than their political area of 2217 km^2. Materials are derived not just from European eco-systems but also tropical and Mediterranean areas. The graph below shows the area of different ecosystems appropriated per hectare of city.

Appropriated Ecological Area per hectare political area for 29 Baltic cities



"….Baltic cities depend on the productivity of large life support systems outside their borders"

Percentage of Baltic land and sea appropriated by different countries



The above diagrams both show the pressure that present fishing efforts in particular are placing upon the Baltic marine ecosystems. The population of the 29 cities together appropriate about 70% of the Baltic Sea area, their forest and food demands appropriate about 20% of the land area.

The cities study was undertaken in 1997 and the methodology differs from most other EF studies in that carbon sequestration is excluded. The work draws attention to the high level of appropriation of marine bioproductivity. The authors stress that the marine ecosystem is a natural system and pressure exerted by humans have profound impacts on the ecology. Unlike managed terrestrial ecosystems production cannot be increased by increasing the intensity of production - higher yields through more efficient fish capture methods undermine the resource base.

Box 3 shows how EF techniques can be used on individual products. One of the features of EF is that the land ecological space appropriated by a population can be compared to the area set by its political borders. Obviously this cannot be done when the population in question has no political borders as is the case for companies or products. This does not invalidate the approach since EFs still delivers a single 'bottom line' (covering carbon sequestration and space based resources inputs) to be compared per employee or per unit turnover for similar companies or between different brands of the same produce.

Box 3: Ecological Footprint Analysis of Different Packaging Systems - Lewis *et al*

This short project undertaken by Best Foot Forward sought to compare different packaging types using two different types of EF and LCA. The study was novel in that it covered emissions of SO_2, chemicals that gives rise to ground level ozone problems and phosphorus as well as CO_2 sequestration. The underlying data were collected by the Danish Environmental Protection Agency. Comparisons were made for refillable glass, disposable glass, steel cans, refillable PET, disposable PET and aluminium cans. The LCA data is shown in the table below.

Life cycle analysis data (LCA) that fed into the comparative EF study *(kg/stored 1000li)*

		Refillable green glass	Disposable green glass (33ml)	Aluminium (33 ml)	Steel can (33ml)	Refillable PET (50ml)	Disposable PET (50ml)
Emissions	**CO_2**	174	356	370	455	84.5	280
	SO_2	0.747	2.24	1.71	2.14	0.612	3.1
	VOC	0.0561	0.0931	0.0665	0.0821	0.0359	0.0356
	Methane	0.00313	0.00465	0.00658	0.015	0.0017	0.00347
	CO	0.00823	0.0128	0.0196	0.0266	0.00576	0.025
	NO_X	0.836	1.42	1.69	2.03	0.589	1.93
	Ammonia	0.00647	0.0247	0.000356	0.000398	0.000227	0.00028
	Phosphorus	0.00694	0.00694	0.00108	0.0458	0.00256	0.00256
Waste		60400	66800	90700	152000	16400	48000
Resources	**Aluminium**	0.0647	0.124	0.207	0.327		
	Brown coal	593	1100	1610	2580	256	442
	Coal	691	294	374	286	681	4560
	Oil	10300	17400	17600	22100	7290	16600
	Iron	0.0672	0.128		20700	3080	
	Natural Gas	13800	1390	11300			9820
	Tin	13.3	13.3				

Two different weighting schemes were used to aggregate the above LCA data into a single unified EF. The first the Best Foot Forward approach (BFF) was based on critical loads; the second the Sustainable Process Index (SPI) was based on the rate of natural renewal of the media into which the emissions are emitted (see Table 1 of this report).

The authors calculate a comparative ranking for the three different procedures.

Relative ranks (1 best, 4 worst)

33 ml containers

	BFF	SPI	LCA
Refillable glass	1	1	1
Disposable glass	2	2	2
Aluminium	3	3	3
Steel	4	4	4

50 ml containers

	BFF	SPI	LCA
Aluminium	3	2	2
Steel	4	3	4
Refillable PET	1	1	1
Disposable PET	2	4	2

The relative ranking of the LCA was undertaken by the authors of the original LCA study. The three approaches give fairly similar relative rankings when comparing glass, aluminium and steel. The SPI gives a poor ranking for disposable PET because of the high index for SO_X and NO_X. The BFF weighting procedure ignores NO_X altogether and critical loads takes a much more relaxed view of the impact of SO_X.

Box 3 shows how in principal EF might be used to compare across different products. We have reservations about the approach, which relies on some kind of treatment of emissions arising from the production of goods (echoed by the authors themselves who conclude "…the treatment of pollution within EFA is still in its early stages"). These arise for the following reasons.

- The EFA approaches each could only handle a subset of the 16 emissions and resources tabled in Box 3.

- The treatment of resources by the BFF was partial considering only the energy used in extracting and processing the resources
- SPI weights use a procedure that ECOTEC considers misleading to assign weights (see section 2.2.3 for critique).
- The BFF weighting procedure, whilst better founded conceptually, is very partial covering emissions of SO_X, substances producing ground level ozone and phosphorus - these are sub-set of air pollutants; water and land pollutants are not covered at all.
- Products (more so than countries) have different relative performance in terms of energy use and emissions of different pollutants. The methodology emphasises energy and excludes pollution. As presently constituted, EF will give misleading results when comparing products where the relative balance between the two differs.

We believe more conceptual works needs to be done on introducing more pollutants and till this is successfully completed it is hard to see how product level EF can be used for judging between different products.

4.4 Strengths and weaknesses of EF

Ecological footprinting has attracted criticism and praise in equal measures. Its virtue of simplicity in understanding is seen by some as an over-simplification of environmental problems.

Critics of EF (van den Bergh & Verbruggen, 1999; Ayres, 2000 and Opshoor, 2000) mainly in academic circles point out the following weaknesses. Criticisms suggested by these studies are listed below in stylised form:

1. Human welfare is a multi-dimensional issue and a single index over-simplifies.
2. The EF lacks transparency;
3. CO_2 is the only emission covered by EF - why not other greenhouse gases and other pollutants?
4. The aggregation procedure ignores social weights and local scarcity of different land types - the focus is on quantity rather than quality of resource;
5. Appropriation of ‘urban land’ ignores the gradation of environmental damage arising from different urban land uses (for instance road space is more harmful than a city park).
6. The unit of measure the ‘area unit’ is a hypothetical measure that could be confused for actual geographic land.
7. EF does not distinguish between sustainable and unsustainable land use.
8. The EF calculation does not allow land to simultaneously provide biodiversity, wood and carbon sequestration.
9. CO_2 absorption land is a hypothetical rather than actual land-use, which contrasts with other elements in the EF.
10. EF ignores the role of the oceans especially in CO_2 sequestration.

11. EF and the ecological deficit is calculated at different scales (world, nation, region, city) but since the political boundary is essentially arbitrary from the environmental perspective the ecological deficit is essentially an irrelevance; and

12. The attention drawn to the ecological deficit shows an anti-trade bias.

EF supporters and practitioners would argue that many of these issues are either unfair, misunderstand the aims of EF or have been addressed. Criticisms 1 and 2 are not something that objective reasoning can resolve. In many ways EF is more transparent than most other single index indicators and part of its success has been the ease with which it can be communicated, and carry resonance with non-technical audiences. Criticism 3 is of course valid, EF does not capture the full range of ecologically significant impacts. Practitioners are open about this and usually describe EF as a *lower bound* estimate of ecological impacts. Some progress has been made in introducing other pollutants into the analysis but these changes even if widely implemented will fall far short of being a complete estimate of ecological impact. There are no plans to include pollutants or processes that irreversibly damage bioproductive capacity such as species extinction, emissions of plutonium and aquifer destruction.

Criticisms 4, 5 and 6 are really asking what the unit of measure really means. The value of a biodiverse habitat is a function of its rarity, its pristineness, and its contiguousness with other similar habitats (to allow genetic mixing). Simply valuing land by its area (adjusted for bioproductivity relative to the world average) rather than the ecological, physical and landscape changes arising from appropriation is missing a huge amount from the analysis. These criticisms are, while factually valid, unreasonable. The unit of measure of EF is a hectare of biologically productive space with world average bioproductivity. Expecting this measure to be weighted for the *quality* of biodiversity and social values rather than just bioproduction is more than a single dimensional indicator could reasonably expected to do. No one expects national accountants to demonstrate that £1 of GDP brings the same amount of happiness to each citizen spending the money.

Criticism 7 identifies that the most important question we can ask of land utilisation is *Are management practices ecologically sustainable?* rather than the absolute quantity of land use. EF ignores this issue. Indeed the process of reweighting the *supply* of land for local yields glosses over sustainable differences arising from the intrinsic fertility of the land (genuine qualitative differences in land) and unsustainable practices such irrigation which boost yields by exploiting non-renewable groundwater deposits, or energy intensive fertilisers (Folke, *et al*, 1997). Practitioners (Wackernagel *per com*) are attempting to take account of unsustainable ground water use to adjust the amount of cropland. However there is a spurious credibility given by EF through adjusting supply of land for national yields without considering whether soil fertility and water resources are being compromised by national practices. Current practice overstates the supply of land so therefore understates *ecological overshoot.* This is consistent with EF's claim to be a conservative estimate of sustainability. Efforts are made for supply of fisheries and forest land to use an optimistic estimate of maximum sustainable yield rather than what might be an unsustainable actual yield per hectare.

Critics say that EF assumes biodiversity, carbon sequestration and timber production are mutually exclusive activities (Criticism 8) and so demand for land is overstated. The perspective of the practitioners (Wackernagel *per com*) is that biodiversity is a feature of *mature ecosystems* where there is no net carbon accumulation or timber growth. Similarly immature forests (that sequester carbon) cannot be harvested for timber since the process of harvesting releases much of the fixed carbon. Though we agree with critics that current EF practice exaggerates the separation between these functions so probably overstates demand slightly we doubt that an adjustment would make a big impact on the results because a large proportion of carbon fixed by forests is lost soon after felling.

Criticism 9 is made frequently. Ayres (2000) puts it thus: "the hidden implication which is not sufficiently clearly spelled out by the EF proponents, is that in a sustainable world energy would be obtained from fossil fuels but the latter be burned …in just such quantities as to permit the resulting carbon dioxide emissions to be absorbed by vegetation in the country". Van den Bergh and Verbruggen (1999) make several points: "The idea behind this [the EF approach] is that sustainability is realised if the carbon sink is not exceeded….CO_2 assimilation by forests is one of many options to compensate for CO2 emissions, and indeed a very land-intensive option….This approach faces three problems…the suggested sustainable energy scenario is not even technically (or environmentally) feasible. Second, the solution would depend on the availability and cost of land…Third, the EF approach is not consistent with the marginal cost thinking of economics, and therefore unnecessarily unrealistic from an economic perspective."

The issue is an important one because the CO_2 absorption footprint is 50% or more of the overall footprint in developed economies and accounts for much of the apparent overshoot of the present consumption patterns. The problems arises because of the asymmetrical way EF handles CO_2 absorption relative to its treatment of agriculture, forestry and urban land demands. The latter three uses are a statement of actual current practice. One might disagree with details but two facts are undeniable 1) substantial areas of land are used for these functions and 2) that our society appropriates the biological outputs. The CO_2 absorption calculation calculates the area of land *as though the population were maintaining constant atmospheric CO_2*. The recent breakdown of COP6 at The Hague serves to highlight how far from the current political reality EF's behavioural scenario is. As a society we are allowing CO_2 concentrations to rise and are likely to continue doing so. Over the next 50 years there is prospect of a reduction in fossil fuel and an increase in renewable energy use by the developed economies. More than one renewable technology is likely to appear in some eventual sustainable energy mix including land extensive techniques such as biomass (which might have a higher EF per unit of delivered energy than the CO_2 absorption figure), but also land efficient techniques such as wind, hydro and still experimental techniques such as wave and tidal power. Proponents of EF (Wackernagel and Silverstein, 2000) argue that strong sustainability considerations (ethical position that suggests the environment should be handed on with all important types of natural capital intact) require that the present generation need to fully address the accumulation of CO_2 in its indicator construction. They make a second argument that if the current generation planted biomass to replace the run-down of fossil fuel an even greater area of land would be required. We find neither of these arguments relevant to current policy analysis and would instead go along with van den Bergh and Verbruggen's suggestion that the EFs representing politically plausible CO_2 reduction scenarios be investigated further.

The recent WWF study addresses the issue of carbon sequestration by oceans (criticism 10). We find Criticisms 11 and 12 both perplexing. The different scales at which EF are calculated are not arbitrary but reflect the political entities that exist in our society. It is quite legitimate to draw attention to the fact that cities rely on their hinterland, and that affluent densely populated countries import land from more sparsely populated country. Pointing this out is no more anti-trade than an analysis of a country's current account position.

It must be said that highly developed densely populated countries such as the Netherlands and Hong Kong will usually have an ecological deficit. That does not necessarily mean that they are unsustainable. Given the level of trade, ecological deficits have to presented with care as they can be misapplied by politicians, NGOs and the general public. This is not a criticism of the methodology of EF but the way it is sometimes portrayed.

There has been much less discussion in the academic press about component form of EF partly because it is newer and the studies often carried out for private clients have been less openly publicised. The main reservation we have is for product level analysis. Here the methodology emphasises energy and misses out important components of pollution. This will give misleading results when comparing products where the relative balance between the two differs.

There are several strengths of EF which shall be mentioned in summary form.

1. The unit of a measure *biologically productive land and sea standardised to the world average level* is easy to comprehend.
2. EF has a credible and concrete upper bound constraint.
3. Proponents of EF have gone to some effort to explain the limitations of EF especially in terms of coverage. As a result its assumptions and weaknesses are transparent.
4. As a result EF is a powerful communications device with resonance over a wide variety of different audiences.
5. EF is a flow concept that can be contrasted with other flows such as GDP and HDI.
6. The data requirements for national EF calculations are reasonably easy to locate, make use of widely known official data and do not hinge on untenable assumptions (except for proviso in point 7).
7. The ‘strong sustainability’ ethical position of EF, though controversially applied with CO_2 absorption, does give a consistency of approach to handling different issues.
8. Except for proviso in 7, we would support EF comparisons over time and per capita EFs across countries as being a credible estimate of major human impacts.

Our proviso is to do with the handling of carbon absorption. As argued already this could be addressed by handling energy in a more pluralistic way (for instance examining the EFs implied by one or more politically credible renewable energy scenario).

5.0 ALTERNATIVE SINGLE AND MULTIPLE INDICATOR METHODOLOGIES

This section discusses some of the other 'officially endorsed' and 'experimental' approaches to producing aggregate environmental indicators. It reviews each of them at the strategic level and considers the different aggregate indicators in terms of their traits and qualities.

The following indicators are reviewed:

National Accounts Matrix incorporating environmental accounts (NAMEA)
Sustainable Development Indicators (SDI)
Human Development Index (HDI)
Material Flow Analysis (MFA)
Environmental Space (ES)
Life-cycle analysis (LCA)
Total material requirement (TMR)
Genuine Savings / Index of Sustainable Economic Welfare (GS-ISEW)

It complements the description made in Section 3.0 which discusses the status of different indicators in legislation and international policy documents. Readers interested in a factual account of the each of the methodologies are directed to the Annex, which describes the methodology and includes case studies for frameworks other than EF.

5.1 What features are we looking for in a composite environmental indicator

Analysts place a lot of conflicting demands on the traits they would like to see in a single or limited number of environmental indicators. Ideally they would like them to provide a fair reflection of whether human impacts on the environment are getting better or worst from one time period to the next. Unpacking this, the indicator needs to fulfil a number of criteria:

- cover all, or at least all important, environmental issues;
- cover environmental pressures from all sectors of the economy;
- have resonance with politicians and the media;
- be tractable to calculate and update ideally on an annual basis;
- be consistent with the overall framework of environmental pressures; and
- provide an unambiguous message of whether conditions are improving or deteriorating.

These are of course not easy goals for any one indicator to fulfil and indeed some of the methodologies have opted for more than one indicator for precisely this reason.

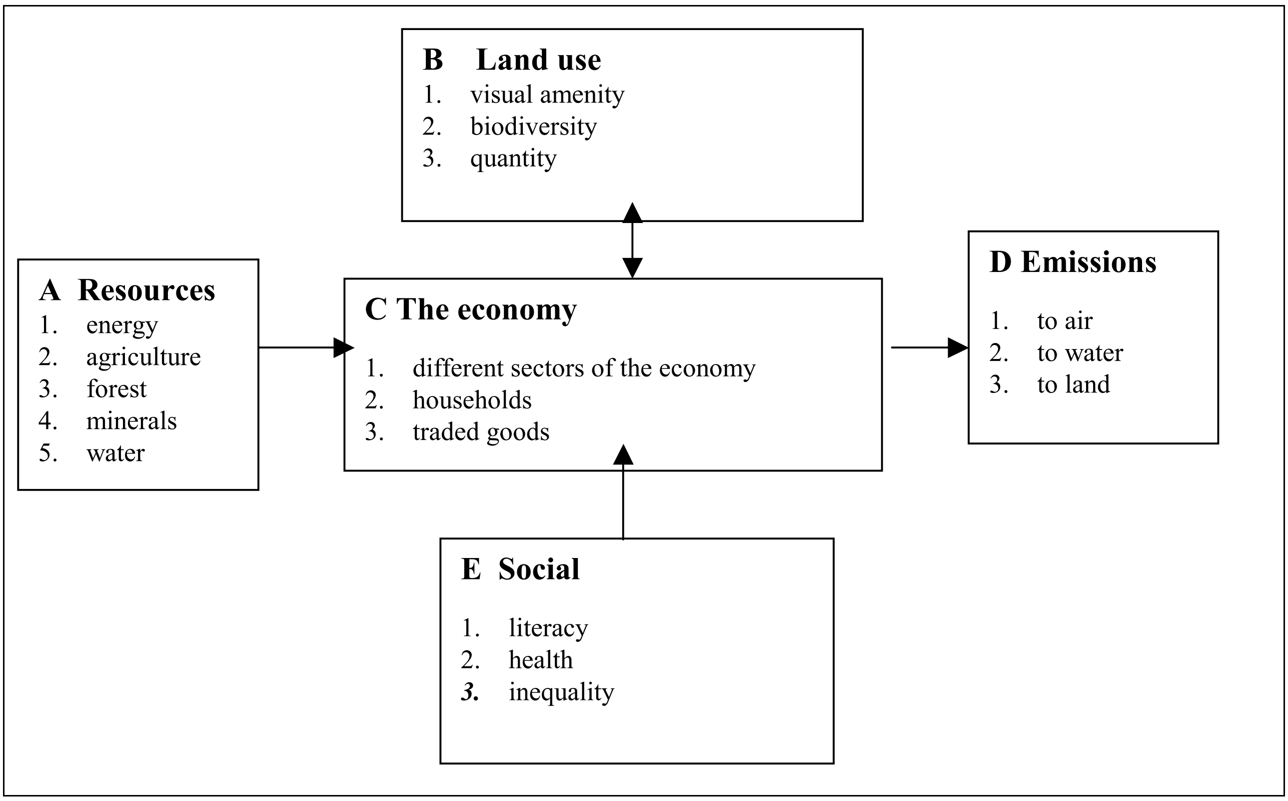
GDP, whose authority and media friendliness is admired by many environmentalists, does not meet all these criteria. It does not cover all economic issues – inflation, equity and interest rates are outside the framework of national accounts. Its sector coverage is also stylised - critics of GDP point out that non-market work undertaken within households (e.g. childcare, housework) is systematically neglected creating a downward bias in economies where the subsistence economy is important. Most controversially critics of GDP say (though we do not necessarily support this charge) that a rise in GDP is not necessarily a good thing since it depends on the *quality* of the increased output. These critics would argue that a growth in arms exports though recorded as GDP actually destabilises the world, without adding to local consumption.

The point of the above paragraph is that it is unrealistic to expect any single environmental indicator to simultaneously satisfy all constituencies and be unambiguously better on all fronts. We are instead talking about a compromise.

Figure 3 shows the main types of environmental, social and economic concerns that are typically covered by attempts to measure and quantify sustainable development. Environmental concerns are normally phrased either as resource scarcity or quantity of emissions. There are also incidental environmental impacts such as loss of biodiversity that do not easily fall within these groupings. These usually arise from land use changes.

Figure 3 lists the basic attributes of each methodology. The list includes only the most important current such methodologies. A great many more have been proposed. Several of the methods shy away from converting all data into a single index. For instance the NAMEA tends to aggregating impacts to a limited number of environmental themes (greenhouse effects, acid rain, water pollution). Very few go so far as to suggest let alone incorporate constraints upon the measure arising from biophysical limits. The two exceptions to this rule are the EF and Environment Space popularised by Friends of the Earth, which trawls through the scientific literature to arrive at "carrying capacities" for the rate at which resources can be extracted or the rate at which emissions can be assimilated.

Figure 3: *The areas of sustainable development policy covered by the alternative indicators*



5.2 The different indicators

Table 5: Attributes of the frameworks used to measure environmental impacts

Methodology	**Single index**	**Target**	**Scale**	**Sponsor**	**Unit of measure**
Ecological footprint (EF)	✔	✔	*N, SN, L,B, P*	*NGO, academia*	*Land area*
National Accounting matrix incorporating environmental accounts (NAMEA)	✗	✗	N	Official	Money, various
Sustainable Development Indicator (SDI)	✗	✗	N, L, B	Official	Various
Human Development Index (HDI)	✔	✔	N	UN	Index
Material Flows Analysis (MFA)	✗	✗	N, SN	NGO, academic	Mass
Environment Space (ES)	✗	✔	N	NGO	Various
Life Cycle Analysis (LCA)	✗	✗	P	Academic, business	Various
Total material requirement (TMR)	✔	✗	N, SN	NGO	Mass
Genuine savings (GS) / Index of Sustainable Economic Welfare (ISEW)	✔	✗	N	World Bank / NGO, academia	Money

"Scale" gives the level of geographic framework has been applied to. N – national, SN - sub-national, L – local, B – business, P – product
"Sponsor" describes the agency that is funded / undertaking the work NGO – Non-Government Organisation

5.3 Performance of the different indicators

This section reviews the different frameworks according to the main criterion listed in 5.1

5.3.1 Coverage of environmental issues (Numbers relate to terms in Figure 3)

The table below lists the environmental issues that each technique has tried to incorporate on a typical and experimental basis.

Table 6: Issues covered by the indicator frameworks

Methodology	**Resources**	**Land**	**Emissions**
Ecological footprint (EF)[1]	**2, 3, 5**	**1,2,3**	***Air*, CO_2**
National Accounting matrix incorporating environmental accounts (NAMEA)	1, *2*, 3, 4,5	*1,2*[3]*,3*[3]	1, 2, 3
Sustainable Development Indicator (SDI)[2]	1, *2, 3, 4,* 5	2, *3*	1, 2, 3
Human Development Index (HDI)			
Material Flows Analysis (MFA)	1, 2, 3, 4		1, 2, 3
Environment Space (ES)	3, 4, 5	3	CO_2
Life Cycle Analysis (LCA)	1, 4, 5		1, 2, 3
Total material requirement (TMR)	1, 2, 3, 4		
Genuine savings (GS)	1, *3, 4*		1
Index of Sustainable Economic Welfare (ISEW)	1, 2	3 (urban)	1

Notes: Numbers in italics have been implemented but are not typical components of the technique

1) EF is not given credit for its 'analysis' of minerals and energy since their scarcity is not addressed

2) SDI relates to indicators typically found in the national Headline Indicator lists

3) Only really handled at the conceptual level

None of the techniques as presently implemented seek to incorporate, never mind unify, all different environmental concerns. Even where the above table gives credit to a technique for incorporating a concern the quality of its treatment varies. No one would argue that the arbitrary 12% of land set aside for biodiversity, as EF assumes, is a good proxy for the pressure society exerts on biodiversity. The two official indicators - NAMEA and Environmental Indicators - attempt to incorporate the most environmental influences but both shy away from producing a single index. However recent work by Statistics Netherlands (Segars R *et al*, 2000) has attempted to produce a single index that straddles all three media (air, water and land emissions) taking account of the relative toxicity of different substances. This very much mirrors and draws upon advances being made in the LCA literature This is in large part due to the greater resources available to national Governments than sponsors of other indicators. It does appear that the price of such increasingly sophisticated methodological developments is that NGOs and the public no longer have the resources to provide adequate scrutiny. The technical complexity of some of the debates in environmental accounting (borrowing from national accounts, resource economics, valuation and LCA) mean that maintaining

Work undertaken by Eurostat under the *Towards Environmental Pressure Indicators* project suggest that to get a coverage of all the major environmental policy concerns something like 60 indicators would be needed. For some issues such as noise, quality of landscape and environmental hazard there is no convincing way of bringing these matters together into a common unit. The only approach to integrating all of these issues into a single indicator is the Policy Performance Indicator (PPI), which scores all the environmental indicators on a 1 to 1000 scale and sums them (*per com* Jochen Jesinghaus). This aggregation is far from ideal. But the alternative is leaving awkward to unify indicators out of the index altogether giving them an implicit weight of zero. There are two difficulties with the PPI approach the first is that the supposed merit of bringing all environmental concerns into a single easy-to-understand measure cannot be achieved because the quality of data do not allow it. Each of the individual datasets have footnotes setting out missing data, inconsistent definitions etc. As a result the amalgamated indicator cannot really be interpreted either over time or over countries. The second issue is of course that of the weights. Is an index that *by assumption* weights emissions of greenhouse gases the same as emissions of ozone depleting substances or noise and then presents the indicator as a measure of *total environmental pressure* really helpful?

Aside from the PPI indicators have not attempted to incorporate all environmental concerns because underlying data are often unavailable (for instance solid waste pollution), because there is no sound methodology for measurement (biodiversity), or because the methodology provides no means of incorporation (EF cannot conceptually handle toxic effects).

Compared to the other single index indicators EF covers a wide selection of environmental concerns in a *consistent* but with a narrow "energy & land centric" point of view. Proponents of valuation would argue monetary techniques are inherently stronger since they could be extended to include any type of environmental concern, be it health, resource scarcity or losses to manufactured assets. We do not believe the techniques command sufficient consensus amongst experts to be used in this way in the forseeable future. We find the basis of aggregation of EF is better than that of TMR. The only other single index indicator is a variant of sustainable development indicators the Policy Performance Indicator (PPI) and the computer software 'the Dashboard' being developed at the Commission's Joint Research Centre which aggregates an eclectic mix of detailed indicators into a single index. This is very much the approach used by the Human Development Index. As presently implemented (with equal weighting) we find the PPI seriously misleading however the approach of assigning weights envisaged by scientists working at the European Commission's Joint Research Centre does address this issue. Nonetheless the idea of obtaining expert of democratic weights for indicators remains far from easy.

5.3.2 Resonance, international comparability and tractability

There is much demand for an indicator that appeals to the public, media and senior officials and politicians. This issue of appeal cannot be separated from all the other issues in the list since an indicator that is poorly conceived or partial in coverage will not be well received. However there are features of an indicator that will tend to promote resonance with a wide target audience. An indicator should:

- be expressed in a unit people understand;
- have a target or constraint so success can be judged;
- be important;
- be comparable across countries and over time.

In these terms EF (calculated for a country) fares well. Land, and the absolute constraint set by the world's bioproductive land and water surface, is easy to communicate. Other indicators suffer from being expressed in less obvious units of measure such as ozone depleting potential (used in the NAMEA and headline indicators) or in units which do not convey any sense of environmental threat (mass of extracted materials – used in TMR). Environmental Space is the only other indicator with targets but the impact of comparing performance against targets has to an extent by weakened by the sheer number of data covered and the arbitrary nature of some of the targets. For instance in "Towards Sustainable Europe Handbook" (Friends of the Earth Europe, undated) it is suggested use of cement should be reduced by 85% from the current level of use by 2050. This type of specific proposal is in keeping with the spirit of Factor 4/10 and articulates the desire for better resource productivity but it is remains to be seen whether such calls for action resonate outside the narrow environmentalist community and act as a spur of policy making.

The Headline indicators have enjoyed a degree of resonance with the wider community. In part this is because of the high level of political commitment of Member States, often spurred on by politicians, have placed in them. To date Member States have not agreed to report a common set of indicators though there is a high degree of similarity between lists. With the development of shorter UN list (though still 59 indicators long!) international comparability is improving.

The NAMEA is not really designed for mass communication. Despite this results from the Dutch, German and UK accounting frameworks have enjoyed limited coverage, because they tend to attribute environmental pressures to particular sectors. International comparability is already quite good and will improve once the revised SEEA manual is released.

Both Genuine Savings and ISEW have attracted interest from the media and policy makers. The World Bank has been calculating the Genuine Savings of developing countries for a number of years. There is a strong feeling the loss of wealth arising from resource extraction and emissions of CO_2 needs to be expressed in monetary terms so that operational divisions of the Bank have an environmental viewpoint when assessing the impacts of loan and Structural Adjustment policies. Results from ISEW studies have attracted attention in part because the ISEW time series depart from the GDP series - showing a fall in per capita ISEW over the past two decades. Critics of ISEW object on methodological grounds to the way the ISEW handles the cost of emissions of greenhouse gases and income inequality.

LCA like the NAMEA is not set up for wide communication. Since it often relies on commercial in confidence data the methodology and sometimes also the results are not widely reported and it can be difficult to gain access to the underlying data for many important LCA studies.

5.3.3 Consistency with the overall framework of environmental pressures

All the indicators place themselves within some kind of environment-economy framework. Most bear some of resemblance to Figure 3.

EF does not explicitly use this framework. It instead treats forest, fish, agricultural, urban and biodiversity land use and carbon sequestration as mutually exclusive uses of land. On this basis this essentially *ad hoc* selection of environmental pressures are aggregated. Experimental EF studies now discuss 'shadow' land use. This extension of the methodology recognises that a plot of land can simultaneously perform more than one environmental function. For instance, an area of forest can provide water catchment services while at the same time providing the above functions. This shadow land is not added to the EF but is presented along side showing a different aspect of land use. In principle there can be many such dimensions, including for instance assimilation of eutrophicating substances, detoxification of air pollution. This means that the framework of EF could be extended more widely while preserving its relationship with land. Of course the price of such sophistication is the current simplicity of the EF idea.

The Headline indicators and the Policy Performance Indicator (a weighted average of other indicators) are only loosely linked to any recognisable framework. The PPI, as presently calculated, is a wide and cheerfully eclectic mix of environmental issues all given the same weight.

Environmental space is also selective in the range of indicators chosen. Stress is given to issues which need political action (such as climate change) areas that are improving (emissions of sulphur dioxide) are disregarded. This reflects the purpose of ES – which is to put pressure on Governments to address perceived environmental problems, rather than provide a rounded picture.

The danger in departing too far from a framework is that the choice and construction of the indicator begins to look selective no matter how rigorous or well intentioned the selection process. This inevitably weakens their impact.

The NAMEA has the most rigorous and complete framework. In principle it seeks to include every environmental issue and experimental projects have analysed issues such as regionalisation (of water accounts), international trade (international flows of resources), modelling of economy-environment interactions, aggregation of pollutants into limited number of themes and land accounts (feeding through to biodiversity and land cover).

Some of the other indicators can almost be viewed as subsets of the NAMEA framework. The TMR stresses resources, MFA contains data on the mass of resources and waste. ISEW and GS take parts of the national accounts (consumer expenditure and net savings respectively) and adjust these for resource depletion and pollution where they can.

Life cycle analysis has a framework comparable in scope to the NAMEA's. As has been mentioned the NAMEA is borrowing aggregation techniques from LCA. Unlike all the other indicators its population of focus is the product rather than the economy.

5.4 Comparative Assessment of EF and other methodologies

This section reviews comparative studies that have sought to compare the different indicator methodologies.

Hardly any empirical work has been done investigating the relative performance of a population comparing ecological footprinting with other indicator methodologies. Two studies were located, one looking at the performance of Scotland in the period 1980-1993 using different indicators (Hanley *et al*, 1999). The second comparing the LCA and EF for packaging has already been described in section 4.3.

Nick Hanley and his colleagues undertook a comparative analysis of seven different indicators, which they classified as either economic, socio-economic or ecological measures. All seven are reproduced below.

Economic	**Socio-economic**	**Ecological**
❑ Green Net National Product	❑ ISEW	❑ Net Primary Production
❑ Genuine Savings	❑ Genuine Progress Indicators	❑ Ecological Footprint
		❑ Environmental Space

Resources available for primary data collection were limited so the coverage of each of the indicators was not as complete as is seen in studies that concentrate on just one indicator.

The coverage was as follows:

Green Net National Product (GNNP): Net National Product (similar to GDP) *less* economic rents earned on North Sea oil and gas extraction, revenue from extracting minerals and forest products, emissions of local air pollutants, costs of loss of wetlands.

The authors were uncertain as to the correct treatment of new discoveries of oil and gas and produce two graphs, one excludes new discoveries, one adds new discoveries to green NNP.

Genuine Savings: Calculated from Disposable income *less* consumer expenditure, minerals, pollution and biological resource use (same as GNNP).

ISEW: consumer expenditure multiplied by the Ginni coefficent (to include inequality effects) *plus* household services, services from household durable items *less* pollution, resource use and time spent commuting

Genuine Progress Indicator (GPI): developed by Cliff Cobb brother of one of the originators of ISEW includes many of the same ideas. It further subtracts loss of leisure time and the cost of unemployment.

Net primary production (NPP): The original methodology was developed by Vitousek *et al*, 1986. The calculation uses data on Scottish food consumption and non-food energy consumption and converts this to mass of vegetation. This is compared to biological Net Primary Production (mass of plant tissue that accumulates over the year) in Scotland.

Ecological footprint: Includes food production, degraded land, forestry.

Environmental space: covered five resources copper, lead, iron, cement and energy.

The results from the study are given in summary form below.

Indicator	Result
GNNP	Increasingly sustainable
GS	Unsustainable, but becoming less so
NPP	***Marginally sustainable, slight improvement***
EF	Marginally unsustainable, little change
ES	Copper, lead, iron, energy unsustainable; cement: sustainable
ISEW	Unsustainable, worsening
GPI	Unsustainable, worsening

Source and result interpretation from Hanley et al, 1999

These results from the different indicators conflict and do not provide decision makers with a coherent 'headline' picture of environmental (and social and economic) development.

To understand why trends are so different it is necessary to understand the manner in which each indicator was constructed and the judgements that have been made in the weighting and aggregation process. GNNP and GS are both based on national accounts and the environmental adjustment is dominated by the oil and gas extraction effect which is itself driven by fossil fuel prices.

The results for NPP and EF are driven by the scale of biological resource demand and fossil fuel energy demand. Neither has changed markedly over time and bother are termed as 'sustainable' chiefly because Scotland is an extensive country with a low population compared to the area of bioproductive land.

The unsustainable ISEW and GPI results both arise from the strong influence of multiplication by the Gini coefficient. This penalises countries where income distribution is deteriorating which was the case in Scotland over the period in question.

The authors conclude the research "…demonstrates that there are many ways to measure sustainable development, each of which provides potentially useful, but different insights for policy makers, academics and the general public." This might be seen as a generous interpretation since to properly understand the differences rather a lot needs to be known about each indicator before hand.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Environmental indicators serve a **communications** function and a **management** function. For ease of communication indicators have to be few in number, and easy to comprehend. To help manage an environmental concern indicators should be closely aligned to policy issues and ideally disaggregated by region and sector so progress by the relevant economic actors can be monitored and influenced for each environmental policy concern. The logic of the former function requires a small number of intuitive indicators. The logic of the latter function leads to a substantial number of indicators that are inevitably difficult to digest and convert into readily communicated 'sound bites'. EF fits more in the former camp.

Of the alternative frameworks reviewed SDI, TMR and GS/ISEW, HDI, headline indicators are communications indicators like EF. NAMEA, MFA, LCA, and sustainable development indicators serve a **management** function and are not strictly comparable. In order to use them effectively they need a greater degree of technical understanding of the framework in which they operate. However the single index indicators will often draw upon data from the multi-indicator frameworks and it is legitimate to think of them together.

EF can be used to focus debate, plot trends over time and make international comparisons. It is an attractive tool for communication to the general public (probably more attractive than TMR, SDI or HDI) because of the footprint metaphor. How it might be directly applied by policy-makers is unclear. In order to reduce the EF and bring the global EF inside the world carrying capacity there are essentially 3 options:

- raise productivity per land area;
- lower resource use;
- reduce consumption.

These are already familiar to people engaged in the resource productivity debates.

EF can and has been applied at many different levels of scale from product and firm to country and world. In principle so could several of the other indicators.

The case for a statistic that summarises many, or all, environmental burdens into single indicators is not universally agreed upon. Many feel it could never be achieved. The main argument for a single environmental index is that it serves a useful **communication** function to be read alongside GDP. GDP has its own critics!

We believe EF has fewer conceptual or practical problems than rival single index environmental indicators such as green GDP, Index of Sustainable Economic Welfare and Total Material Requirement. However EF does not include pollution and is weak on biodiversity. If a single index indicator is regarded as useful, something we support, the following conclusions and recommendations are made.

1. National EFs can be calculated for EU countries with good precision and transparency. We recommend they be calculated on an experimental basis for national and sub-national territories. Excluded environmental issues should be clearly indicated. Such an EF would make a credible Headline Indicator.

2. EF results should be expressed on a per capita basis to permit comparability between countries and over time. The appropriate comparitor is the average area of land per capita at the *world level.*

3. EF's calculation of land use for energy / CO_2 sink services gives rise to overly pessimistic results. More research needs to be undertaken on how the land requirement of viable renewable energy sources might be used in place of carbon sequestration.

4. The use of EF to compare *products* is difficult to support as presently implemented. The methodology emphasises energy and excludes pollution. This will give misleading results when comparing products where the relative balance between the two differs.

5. More conceptual research is needed to incorporate non-biological, non-energy resources and pollution further.

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7.1 Interviewees

Gerard Aubrée	DG Environment, European Commission
John Adams	Head of Sustainable Development Unit - DETR
John Barrett	Stockholm Environment Institute, York
Peter Bartelmus	Wuppertal Institute
Stefan Bringezu	Wuppertal Institute
Nicky Chambers	Best Foot Forward
Mark de Haan	Statistics Netherlands
Kirk Hamilton	World Bank
Nick Hanley	DG Environment, European Commission
Anne Harrison	OECD
Professor Tim Jackson	University of Surrey
Jochen Jesinghaus	Joint Research Centre, European Commission
Duncan McLaren	Friends of the Earth, England and Wales
Ian Moffatt	University of Stirling
Myriam Linster	OECD
Tony Long	WWF-Europe
Craig Simmons	Best Foot Forward
Ronan Uhel	European Environment Agency
Mathis Wackernagel	Redefining Progress

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GLOSSARY

BFF - Best Foot Forward
CSD - (UN) Commission for Sustainable Development
DPSIR - Driving force, Pressure, State, Impact, Response (see also PSR)
EF - Ecological Footprint
ES - Environmental Space
GHG – GreenHouse Gas
GIS - Geographic Information System
GPI - Genuine Progress Indicator
GS - Genuine Savings
HDI - Human Development Index
IPAT - "Impact = Population x Affluence x Technology"
IPCC - Inter-governmental Panel for Climate Change
ISEW - Index of Sustainable Economic Welfare
LCA - Life Cycle Analysis
MIPS - Material Inputs Per Service
NAMEA - National Accounts Matrix including Environmental Accounts
PSR - Pressure, State, Response (see also DPSIR)
PPI - Policy Performance Index
SEEA - System of Environmental and Economic Accounts
SPI -
TEPI - Towards Environmental Pressure Indicators
TMR - Total Material Requirement
WWF - World Wide Fund for nature

ANNEX

DESCRIPTION OF THE ALTERNATE METHODOLOGIES

NATIONAL ACCOUNTING MATRIX INCLUDING ENVIRONMENTAL ACCOUNTS (NAMEA)

Methodology

The NAMEA is a statistical system that organises and holds information on the economy [expressed as an input-output table using the NACE classification of industries] and the environment expressed in physical units. Resources and emissions of pollution are aggregated into a limited number of environmental themes using scientifically derived weights.

The themes typically included in the NAMEA framework include.

- greenhouse gas emissions
- ozone depleting substances
- acidifying gases
- local air quality gases

Background

The Dutch statistician Steven Keuning (Keuning, 1993) developed the NAMEA framework and the first Dutch NAMEA was published in 1994. NAMEA organises information on pollution generation and resource use within the national accounts framework. It is a complex system suitable for holding, modelling and conceptualising interactions between the economy and the environment. Formal NAMEA's have been developed by the statistical offices of several EU countries (UK, Sweden, Germany) and Japan. The NAMEA aggregates pollutants to environmental themes such as climate change, acidification, and toxicity using global warming potentials and similar weighting systems. The NAMEA principal strength is its intellectual integrity and its suitability for integration into economic models – especially input-output models. Environmental accountants are developing a revised manual detailing the construction of NAMEA style environmental accounts, signalling further international standardisation. The NAMEA is not suited to communication to non-technical audiences.

Assessment of the methodology

The NAMEA framework has been developed to organise and depict all major environment-economy interactions. In principle these cover resource use, traded materials, emissions and land. There is no explicit provision for environmental risk or noise. Experimental articles have also been written on spatial and seasonal disaggregation of data (Vaze, 1997).

Though not an aggregate indicator NAMEA can be used as a data source for aggregate indicators such as green GDP. However to date no country has succeeded in integrating sectorally disaggregated data across all environmental media.

NAMEA does not directly incorporate concepts of targets or constraints. Rather it depicts the total pressure on the environment by the economy. NAMEA is conservative in aggregating across different themes and therefore embodies a strong sustainability approach. Aggregation is by scientifically established weights. The four themes mentioned earlier are weighted by global warming potentials, ozone depletion potentials, ionisation potentials and human toxicity (by the Dutch on an experimental basis).

NAMEA has a strong theoretical basis in both national accounts and environmental science. The NAMEA system is quite difficult to understand and interpret but data from the NAMEA especially industrially disaggregated emissions and resource in absolute terms or compared to an industry's economic performance can have a powerful impact in the media.

Studies

NAMEA type studies have been carried out in most European countries at least for emissions of air pollutants. The table below gives a fairly typical output of the UK's air emissions account. Commentators can readily compare the environmental performance with economic performance such as an industry's contribution to GDP - value added.

Table 7: UK NAMEA economic output and air emissions, 1993

Industry Group	Value added £million	Employees 000	Blacksmoke kt	GHG ktC	Acid rain ktSOx
Agriculture	10718	328	2.8	29755	552.5
Extraction	12542	86	2.7	34262	152.1
Manufacturing	113940	3818	34.0	139009	912.0
Energy and water	14404	197	21.2	177651	2499.5
Construction	28851	842	3.7	3284	12.9
Distribution	78924	4698	22.0	12545	55.4
Transport	45990	1299	123.3	50044	552.4
Finance	140248	3434	1.9	2648	8.0
Public admin.	38140	1672	4.2	9070	58.2
Educ. and health	66523	4056	1.7	10605	56.6
Other services	20876	950	44.9	42458	22.6
Households			153.2	153626	599.5
Unattributed			36.3	23562	204.5

source: Vaze and Balchin, 1996

SUSTAINABLE DEVELOPMENT INDICATORS

Methodology

Sustainable development indicators are arguably the most visible manifestation of present efforts to measure environmental pressures. Indicators have been selected by the UN-Commission for Sustainable Development. This list of 59 indicators straddles environmental, social, economic and institutional concerns. Several countries have agreed to trial the UN list. Eurostat is carrying out a pilot exercise compiling data on the indicators for member sates and accession countries. This is to be published in mid-2001.

Two variants of indicators, relevant to EF and other aggregate indicators, are "*headline indicators*" a short list of 6 to 15 indicators, and the "*policy performance index*". PPI is an unweighted aggregate indicator produced by summing up many other indicators all expressed in an index form. The methodology for the PPI consists of the following steps:

- Select the indicators that will make up the PPI [typically there might be 50 environmental indicators]
- Convert each indicator series into an index. This has been done by assigning the worst nation's performance with 0 and the best performance with 1000. All other countries are given an an intermediate value by linear interpolation.
- Weighting each indicator using a Delphi panel (a poll of expert opinion), or some democratically derived weights
- Producing an aggregate indicator.

Background

The demand for sustainable development indicators was articulated strongly in the Agenda 21 document. The UK was the first country to publish a set of Sustainable Development Indicators in 1996. In common with many other such lists that have been developed since then they include statistical series on the environment, economy, social issues (and often also institutional issues).

A common complaint was that a hundred or so data series were hard to decision makers to assimilate. The sheer number of data sets made it hard to interpret whether conditions were getting better or worst. Since then the UN Sustainable Development Commission (CSD) has drawn up a list of 152 indicators which was intended to act as a challenge for UN members. A shorter list has been developed since then.

Critics of SDI argue that the selection and formulation of indicators is arbitrary with little theoretical underpinning. The sheer numbers of indicators make interpretation difficult. Attempts have been made to impose structure upon indicator selection - the best known being the OECD's *driving force-pressure-state-impact-response* model framework.

Statisticians have responded to the second criticism in two ways: by developing a core set of **Headline Indicators**, and a **single complex weighted index** of other indicators. An example of the latter is the Public Policy Index (PPI) which weights different issues according to the views of an invited panel of experts and non-experts. This deliberate dilettantism in selection draws on informed opinion rather than any theory of indicators. This gives the PPI tremendous flexibility. Different datasets are expressed in index form, weighted and added. Indeed *EF* is one of the 13 indicators incorporated within the 'dashboard' index.

Headline indicators and aggregate indicators such as the PPI perform a role comparable to the national EF. Both can serve a powerful communication purpose and are already commanding official support.

Assessment of the methodology

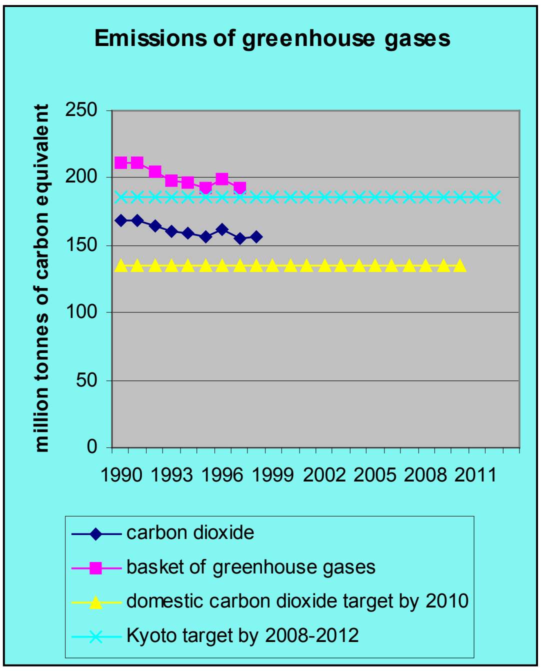
The strength of this methodology is that indicators can in principal cover any environmental concern for which data exist. There is no presumption that indicators have to be measured in the same unit or aggregated to simplify presentation. Headline indicators are intended for ease of communication so ideally are expressed in an easy to understand unit measure ideally with a policy target. The PPI sacrifices simplicity and transparency by adding together a broad range of different issues. At present there are no weights available for integrating indicators within the PPI and so a simple average of all the indicator components is carried out. This has the effect of giving issues such as global warming the same weight as less important issues like noise.

Studies

Figure 4 show the list of UK Headline indicators and an example of one such indicator.

Figure 4: *UK Headline Indicators, 1999*

- total output of the economy
- total and social investment as a percentage of GDP
- proportion of people of working age who are in work
- indicators of success in tackling poverty and social exclusion
- qualifications at age 19
- expected years of healthy life
- homes judged unfit to live in
- level of crime
- **emissions of greenhouse gases**
- days when air pollution is moderate or higher
- road traffic
- rivers of good or fair quality
- populations of wild birds
- new homes built on previously developed land
- waste arisings and management



ENVIRONMENTAL SPACE

Methodology

Environment space (ES) is a multi-indicator methodology that combines specific environmental statistical series with policy targets for 2050 in order to compute distance to target. This tool is used to make the case for policy changes consistent with sustainable development.

The approach selects a limited number of environmental statistics:

- energy
- land use
- water
- non-renewable materials,
- timber

For each of these issues an estimate is made of the global or regional (for non-traded materials such as water) sustainable level of annual use the 'environmental space' for that resource. A per capita fair share in environmental space is then computed, based on a forecast world population of 10 billion in 2050. A nation's target is calculated based on the projected national population in 2050. Current domestic consumption is estimated (taking net trade into account). The difference between the current per capita consumption and the fair share 2050 consumption forms the basis for the national target.

The last stage is to review the policies that need to be put into place to align current consumption to the projected need in 2050.

Background

The concept of environmental space was developed by the Dutch academics Opschoor and Weterings (1994). This indicator unlike others reported here make use of explicit sustainability targets in order to judge environmental performance. Friends of the Earth have trialed a common methodology across Europe in the *Towards Sustainable Europe Project.* The determination of 'sustainable level of resource use' is controversial and the allocation process is often criticised for over-simplifying international trade issues. However the methodology is relatively transparent and sends a potent challenge to policy makers.

Assessment of the methodology

The methodology does not attempt to calculate the ES for the full range of environmental impacts. Effort is concentrated on areas under concern and for which meaningful targets for the year 2050 can be expressed. The indicator is assumes that numerous bio-physical constraints on development exist and does not allow trading off between different issues. No attempt is made to bring different issues into a single index.

The methodology's main weakness is its reliance upon the concept of a sustainable level of environmental space. The idea is that there is some level of environmental pressure that is consistent with sustainability. In the case of climate change this is the amount of global greenhouse gas emission that can released without increasing global GHG concentrations. In the case of some of the other issues environmental space addresses there are no equivalent widely discussed global targets. In the case of aggregates there is an indicative target of 50%

reduction relative to 1990 in use by 2050 (McLaren *et al*) without any clear explanation of why this target is favoured. These targets are given a false authenticity by projecting consumption into the future and recalculating figures to allow for differences in population growth rates in different countries. In the end many of the targets remain arbitrary.

A second issue that has attracted criticism has been the assumption that the environmental space should be allocated to countries purely in terms of their population numbers. In practice this means Northern countries that have consumed more than their ‘fair share’ of global resources have to reduce their consumption while Southern countries might be allowed a limited increase. This is a political re-allocation that relies upon moral ideas of equal access to resources. There is no reference to economic and historical processes that have brought about the present (mis-)allocation of wealth and consumption. The authors make no apology for this facet and indeed ES has been designed to draw attention and question the present international allocation of resources.

Environmental Space has not been investigated as much as some of the other techniques by academics and official organisations. The establishment of targets and the manner in which they are allocated make it unattractive to official statistical agencies.

Studies

Friends of the Earth (England and Wales) have calculated Environmental Space for energy use in the UK (McLaren *et al*, 1998).

The authors suggest that climate change arising from the use of fossil fuels is the most pressing problem associated with energy use. In order to keep global warming to within 0.1°C per decade CO_2 will have to be kept to between 350-400 parts per million by volume. This will require global greenhouse gas emissions to be cut by half by 2050 to 11.1 giga-tonnes or 1.13 tCO_2 per person. In 1990 emissions per person in the UK were 9.5 tCO_2 per person. The logic of environmental space suggests that per capita CO_2 emissions will have to be cut by 88% of the 1990 baseline.

Per capita emissions from the poorest developing countries will be allowed to rise. All citizens would however converge upon the global fair share CO_2 emissions of 1.13 tCO_2. This methodology effectively rejects the flexible mechanisms such as Joint Implementation and Clean Development Mechanism that have been under discussion ever since the Kyoto Protocol was signed.

The suggested cut in emissions for UK citizens is profound and the authors make a number of suggestions about how a low carbon economy can come about by 2050. These include greater reliance on renewable energy, greater energy efficiency in buildings and measures in transport.

GENUINE SAVINGS

Methodology

Genuine Savings measures an economy's 'true' savings over a year. It includes changes in value of social, environmental and economic assets. In practice Genuine Savings (GS) correct "Net Savings" (GDP – Consumption – Depreciation of Produced Assets) for energy, mineral and forest depletion and emissions of carbon dioxide.

GS = GDP - Consumption- Depreciation of Produced Assets - Depletion of Natural Assets

or

GS = GDP – Consumption + Current Education Expenditure – Resource Rents (Depletion of Energy, Minerals and Forest) – CO_2 *damage*

Background

The Genuine Savings concept was developed by David Pearce, Giles Atkinson (at University College, London) and Kirk Hamilton at the World Bank. The approach seeks to include the effects of depleting natural resources and degrading the environment into the measurement of national savings. It exploits progress made in techniques to value environmental resources and environmental accounting and as such is easy to calculate from Green accounts.

The World Bank has calculated Genuine Savings for the period 1970-98 for around 150 countries.

Assessment of the methodology

The current GS methodology incorporates the following elements

1. Resources - Minerals, mineral fuels and forest resources (only deals with net forest depletion, i.e. planting – timber removal, rather than deforestation)
2. Pollution – currently only includes CO_2 because comparable data are available for 150 countries). Work is ongoing looking into the possibility of adding in other air pollution and water pollution factors.

GS uses a monetary valuation to bring together different environmental concerns into a single indicator. For minerals resource rents are calculated by subtracting the region-specific average costs of extraction (including transportation, finishing and a 'normal' return to capital) from the world price (or averaged price). For forest resources rents were calculated on the proportions of different woods found in annual production and average prices. Only rent on that portion of wood production that depletes the commercial wood mass is subtracted from savings. For pollution (CO_2) the global marginal social cost of a tonne of carbon emitted to $20 in 1990 taken from a study in (1994) which is regarded as a conservative estimate.

Education investment includes current (as opposed to capital) expenditures on education including teachers' salaries, book, etc.

There is much professional controversy about both of these valuation techniques. GS does not take account of any toxic substances, and is relatively limited in the level of pollutants integrated into the approach. There is scope for the inclusion of these elements if reliable data on valuation or marginal damage were available. Some examples have been developed at the country level that include water or air pollutants. It does not include any elements of bio-diversity (valuation is difficult) nor considerations of different land uses or erosion (local data are necessary).

The authors regard GS as useful since present omissions make it a conservative indicator of weak sustainability. In other words negative GS is regarded as being evidence of unsustainable economic management. In addition, given that GS does not include many elements of air and water pollution, nor bio-diversity, the current approach overestimates the value of GS. A positive GS, particularly if small, does not necessarily mean development is sustainable. Critics dislike the trade off between man-made and natural goods.

GS currently contains the following assumptions:

- Extraction costs are measured at fixed point in time and held constant in real terms over time. This is a result of data availability and is likely to underestimate GS if extraction costs reduce significantly.
- Use of world prices or averaged global price is likely to overstate resource rents for countries with lower-grade resources.
- Current education expenditure as a proxy for human capital does not take account of depreciation through people dying or technology/knowledge becoming outdated.
- The approach assumes constant global prices for education which is unrealistic, and is likely to underestimate the GS in under-developed countries
- Global damages accruing from CO_2 emissions are charged to the emitting countries
- For some countries regional averages are used for prices or extraction costs

Given that GS rates are highest in high-income industrial countries there is little in the results of studies to suggest that these countries need to alter their resource use or basis of their economy. In contrast ‘mineral-rich’ countries have negative (and unsustainable) GS savings rates. Studies have found that without the inclusion of human capital in the form of education there are only modest differences between the GS rates for high-income and low- to middle-income countries (5% difference). Large investments in education by the most economically successful countries mean that they exceed the genuine savings rates of countries from other income group by around 8%.

GS is easily understood by policy-makers because of the approach of monetary valuation and its relationship to the national accounting framework. In addition it offers a basis for discussions of policy mix balancing resource use, emissions and economic growth. The concept that a country can not continue to consume its assets indefinitely is in itself relatively simple. Using the analogy of a household budget with ‘income’ and ‘outgoings’ it can be explained relatively simply to the layman. The criterion of GS = 0 as a guide to sustainability is attractive. However the details of valuing environmental resources and pollution remain somewhat complicated and it is unclear the extent to which the general public will find the notion of a country’s savings attractive.

Studies

A World Bank (Hamilton and Clemens, 1999)study calculated Genuine Savings rates for around 100 countries for the period 1970-93. The analysis shows that genuine savings are negative in a wide range of countries, and that genuine savings rates were falling in high-income industrialised countries in the early 1990s. In Sub-Saharan Africa genuine savings rates were consistently negative since the end of the 1970s and it is clear that the wealth inherent in their resource stocks is being liquidated and dissipated. The Middle East and North Africa also include some countries with negative GS rates. Adjusting GS to include human capital (i.e. education) move the rates upward and sharpen the contrast between GS in industrialised countries against those in other parts of the globe.

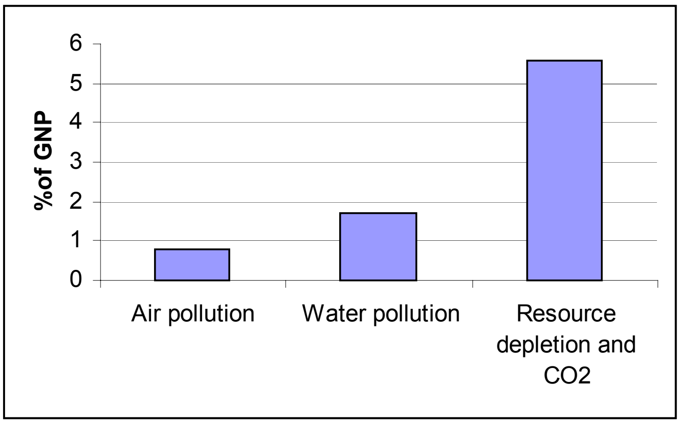
Table 8: Genuine savings rates in developing countries

Country	GS 1980s	GS 1990	GDP p.c US$. 1990	GS 1993
Italy	13.3	16.9	18,141	12.3
Sweden	12.1	16.1	26,397	5.6
Indonesia	2.2	8.2	778	13.8
Mexico	-3	0.9	4,046	3.6
Nigeria	-25.3	-46.4	258	-37.1

Source: Hamilton and Clemens (World Bank) 1999, GDP from World Development Report (2000)

A calculation of the genuine savings in India for 1991 (World Bank, 1997) incorporated pollution damage and the impacts on welfare. Calculations on the average loss in disability-adjusted life years as a result of water pollution coupled with the GNP per capita yielded estimates of the welfare loss arising from water pollution. Using U.S. estimates of willingness to pay to reduce fatal risks arising from air pollution the welfare loss was calculated. The combined air and water pollution represented roughly 2.5% of GNP with damages from water pollution contributing considerably more than air pollution. In contrast depletion of natural resources and the value of carbon dioxide emissions amounted to a reduction in around 5.6% of GNP to the GS rate.

Figure 5: Components of genuine savings in India as a share of GNP



Source: World Bank (1997)

HUMAN DEVELOPMENT INDEX

Methodology:

The Human Development Index (HDI) measures a country's basic human development with regards to longevity (life expectancy), knowledge (literacy rate and education level) and standard of living (GDP per capita). The HDI is a simple average of the life expectancy index, educational attainment index and adjusted real GDP per capita (PPP$) index.

The majority of data come from United Nations bodies or other internationally-recognised bodies. It uses fixed minimum and maximum values to calculate the individual indices within the HDI:

If, for example, the life expectancy at birth in a country is 65 years (and the minimum and maximum values are set at 25 years and 85 years respectively) then the index for life expectancy in this country is:

$$\text{Index} = \frac{\text{Actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}}$$

$$\text{Life Expectancy Index} = \frac{65 - 25}{85 - 25} = \frac{40}{60} = 0.667$$

Background

The HDI was developed by the United Nations as a measure of human development in countries across the globe.

The HDI has been calculated every year since 1990 for the UN's annual Human Development report. It is arguably the most well-known and reported alternative indicator to GDP and is widely quoted and referred to in the media.

Assessment of the methodology

The HDI does not include any environmental concerns but is simply a measure of human development. As a measure of human development it only acts as an average of the situation in a country and does not present information on the inter-group (e.g. male/female) disparities. It also fails to address some basic service such as provision of safe water which are an important component of human development.

The HDI does not have any sustainability criterion. The design of the HDI sets a maximum possible score of 1 as a target. This is based, however, on the maximum and minimum targets, which for income and life expectancy are subjective choices. It is likely that the income maximum and minimum levels will need to be updated in the future. In addition the educational level data only takes into account enrolment in secondary and tertiary education of people of school age. As such it does not incorporate students of other ages who may be investing in education.

The three elements – life expectancy, knowledge and income – are all given equal weighting. This is questionable given that GDP is a proxy for many other parts of human development, however it clearly introduces literacy and longevity into comparisons of human development.

For life expectancy and literacy the index measures the indicators in a linear way on the basis of maxima and minima selected. That is to say that increases in life expectancy from 70-75 contribute to human development in equal measure as progress from 20-25. This allows comparisons between industrialised high-income countries and developing nations in a coherent way but it may not suit comparisons within groups with similar values. The income (GDP) formula is non-linear. As a result, increases in GDP per capita at the top and bottom ends of the scale contribute less to the HDI index than economic growth in the mid-range of the scale.

Although the approach of the index is simple and transparent, such simplicity does not offer much scope for analysis and therefore it is rarely used in academic studies, apart from to highlight the shortcomings of GDP as a sustainable development indicator.

The index is easy to understand for the general public and its annual publication in the Human development report is widely quoted. It provides an insight for the general public into the inadequacy of GDP as a sole indicator of sustainable development, particularly for countries with a similar income but very different HDI values. Its focus on three issues – income, education and health – are the key to its transparency but also raise methodological questions. For policy-makers, the HDI provides a strong incentive to invest in health care and education but otherwise does not offer much material for policy analysis.

Studies

The Human Development Report presented HDI figures alongside GDP per capita for around 100 countries for the period 1975-98. This report finds that 20 countries have experienced reversals of human development since 1990 as a result of HIV/AIDS, particularly in Sub-Saharan Africa, and economic stagnation and conflict in Sub-Saharan Africa and Eastern Europe and the CIS. In addition the link between economic prosperity is not obvious with many examples of countries with similar levels of HDI but very different income levels.

Table 9: HDI and GDP for selected countries

Country	HDI Value	GDP per capita (PPP US$)
Luxembourg	0.908	33,505
Ireland	0.907	21,482
Saudi Arabia	0.747	10,158
Thailand	0.745	5,456
South Africa	0.697	8,488
El Salvador	0.696	4,036

Source: Human Development Report (2000)

Since 1978, the fastest progress has been made by Ireland and Luxembourg within high human development group, Tunisia and China in the medium human development group and Indonesia and Egypt in the low human development group. Denmark, Sweden as well as Romania and several countries in Sub-Saharan Africa have made the slowest progress according to the Human Development Index over this period.

INDEX OF SUSTAINABLE ECONOMIC WELFARE

Methodology

The Index of Sustainable Economic Welfare (ISEW) adjusts Consumer Expenditure (closely correlated with GDP and a proxy for economic welfare) for the following items:

- Expenditure on social investment (e.g. health, education).
- Expenditure on investment
- Environment degradation (defensive expenditures, loss of environmental quality and the accumulation of future costs)
- The value of non-monetarised work (such as household labour)
- Loss of natural capital, including natural habitats and the depletion of natural resources

ISEW multiplies consumer expenditure by the Gini coefficient so that more weight is given to spending by low income families.

Background

The ISEW methodology was first published by Herman Daly and John Cobb in 1989 and aimed to adjust GNP to produce a more accurate measure of economic welfare. It built upon earlier work by Nordhaus and Tobin whose Measure of Economic Welfare (MEW) made additions to and subtractions from the national income to give a better measure of the well-being of the US population (Jackson and Stymne 1996).

Similar indices have been constructed for a number of other countries including Germany, the UK, Austria, the Netherlands, Chile the US and Australia. In the US the approach has been refined and renamed the Genuine Progress Indicator.

Assessment of the methodology

The ISEW framework allows a wide range of different environmental, social and economic concerns to be handled. The key limiting factor in this area remains the ability to give these concerns a monetary valuation. A revised UK ISEW included the following environmental factor[10]s:

- Personal pollution control
- Water pollution
- Air pollution
- Noise pollution
- Loss of habitats
- Loss of farmlands
- Depletion of non-renewable resources
- Long-term environmental damage
- Ozone depletion costs

The ISEW is a relatively complete set of environmental issues. It does not include bio-diversity explicitly although the loss of habitats will impact upon this. The ISEW is a weak sustainability measure since it allows substitution between man-made and natural capital.

[10] (www.foe.co.uk/campaigns/ sustainable_development/publications/indicators/ isewdr3b.html)

Proponents of the ISEW frequently show a graph of the divergence between GDP and ISEW over the past 30 years. The cause for this divergence varies between countries but two issues often dominate the trends. The first is scaling consumer expenditure by the Gini coefficeint which 'corrects for' growing income inequality. The second issue is the manner in which long term environmental damage is handled. This is costed from the cumulative emissions of pollutants rather than a single year's emissions. Many critics find the latter a fundemental error in which the ISEW is calculated.The methodology of valuing environmental and social issues is relatively complicated (though well set out and explained for the technical audience) and opaque to the layman. In addition, the basis of including some contributing elements (such as the sustainability of trade flows and services accruing from durable goods) are difficult for the general public to grasp.

Studies

A study calculated the ISEW per capita for the UK for the period 1950-96 (Friends of the earth, 1997). The study found that although annual GDP growth in this period averaged 2%, the ISEW only grew by 0.6% per year. In fact ISEW increased until 1975 but since then it has stagnated and fallen. The IEW was 22% lower in 1996 than 1980.

Table 10: Components of UK-ISEW 1950-1996 (per capita £1996)

Year	**1950**	**1973**	**1996**
Consumer expenditure	2,435	4,067	6,402
Adjusted personal consumption	2,234	3,751	5,485
Services: household labour	948	1,470	2,368
Public expenditure on health &	89	192	365
Difference between consumer	206	446	1,160
Defensive private expenditures on	14	25	109
Costs of commuting	52	127	206
Costs of personal pollution control	-	8	58
Costs of car accidents	30	43	36
Costs of water pollution	94	73	52
Costs of air pollution	410	464	324
Costs of noise pollution	36	36	39
Costs of loss of habitat	21	40	54
Costs of loss of farmlands	14	24	34
Depletion of non-renewable	332	920	1,812
Long-term environmental damage	292	718	1,321
Ozone depletion costs	8	209	621
Net capital growth	-	382	1
Change in net international position	37	52	41
Per capita ISEW	**1,799**	**2,713**	**2,349**
Per capita GDP	**3,507**	**6,151**	**8,890**

The authors also present the 'threshold hypothesis' in comparison with ISEW calculations from other countries. This states that economic growth brings improvements in the quality of life, but only up to a point – the threshold – beyond which further economic growth brings about a reduction in the quality of life.

The OECD compared different methodologies for calculating ISEW in the USA, UK and Australia and proposed a simplified and harmonised ISEW. There are some differences between the environmental factors included in the different ISEW calculations (see below) or the factor is defined. The largest discrepancies are to be found in social factors where the Australian index incorporates a number of factors such as unemployment, overwork and crime, which are not addressed in the other calculations. The ISEW in the UK and USA increased in line (or more quickly than GDP until the mid-1970s, however since then the growth has slowed significantly in the USA and it has fallen in the UK.

Table 11: Variation in environmental adjustments in ISEWs

	USA	**UK**	**Australia**
Costs of personal pollution control	X	Yes	X
Costs of water pollution	Yes	Yes	X
Costs of urban water pollution	X	X	Yes
Costs of irrigation water use	X	X	Yes
Costs of air pollution	Yes	Yes	Yes
Costs of noise pollution	Yes	Yes	Yes
Costs of loss of wetland	Yes	Yes	X
Costs of loss of farmland	Yes	Yes	X
Costs of land degradation	X	X	Yes
Costs of loss of native forests	X	X	Yes
Depletion of non-renewable resources	Yes	Yes	Yes
Costs of climate change	Yes	Yes	Yes
Costs of ozone depletion	Yes	Yes	Yes

LIFE CYCLE ANALYSIS

Methodology

Life-Cycle Assessment (LCA) is applied at the product, rather than the national level. LCA can be used to compare the strengths and weaknesses of individual products. It provides a standardised methodology to assess the environmental impact that a product has on the environment over the entire period of its life-cycle, 'from cradle to grave'. It aims to address all significant and quantifiable environmental loads. Normally a LCA comprises four stages (SETAC 1993):

1. goal definition and scoping (purpose of the LCA and specifying the products to be compared);
2. inventory analysis (identifying the resource use and emissions during the life cycle of the product);
3. impact assessment (assessment, classification and evaluation of the potential environmental impacts of the loads); and
4. reporting and improving assessment (assessment of the opportunities to reduce environmental impacts).

Different evaluation methodologies include Eco-points for eco-labelling (Swiss approach), the EPS method (Swedish Environmental Research Institute), DTH (Danish Technological Institute) and computer methods such as Simapro.

Background

The energy crisis of the 1970s rose general awareness of environmental problems and one result of this was a detailed system for analysing the energy required to manufacture individual products. LCA was developed in parallel and included not only energy resources, but other resources and also emissions and waste generated by the product. The necessity for a common methodology for LCA was recognised in the late 1980s as LCAs grew more widely used but conflicting results arose due to differing methodologies (UNEP, 1996). Resulting international workshops led to a 'Code of Good Practice' (SETAC, 1993) developed under the umbrella of the Society of Environmental Toxicology and Chemistry (SETAC), a non-governmental professional association.

LCAs are now widely used in the public and private sector for decision-making and policy analysis. They are promoted by UNEP through its Cleaner Production Programme and several large multinationals have jointly set up the Society for the Promotion of Life Cycle Development (SPOLD).[11] LCA is used as the basis of the EU's eco-labelling scheme. In certain product areas the European Commission has developed ecological criteria which must be achieved for a product to receive the official EU eco-label. Products are assessed using LCA against these criteria.

[11] http://www.spold.org

Assessment of the methodology

LCAs aim to incorporate all environmental loads into the assessment of a product over its full life-cycle.

Table 12: Impact categories in SETAC's LCA

Resource depletion • depletion of abiotic resources • depletion of biotic resources *Degradation of ecosystems and landscape* • land use	*Pollution* • global warming • ozone depletion • human toxicity • ecotoxicity • photochemical oxidant formation • acidification • eutrophication

The scope of each individual LCA will depend upon its goals, the level of detail desired and the availability of quantitative data.

The LCA methodology does not contain any sustainability targets. However some valuation methodologies are based on targets for environmental resource use or production (for example Swiss Ecopoints) and therefore could implicitly include sustainability criteria. LCA is usually conservative in aggregation across different environmental concerns however a number of initiatives are being taken to develop this.[12] The valuation procedure is often based upon subjective views of stakeholders or interested parties on the value of different environmental impacts.

The LCA relies entirely on scientific literature and measurement to calculate loads. Techniques such as monetary valuation are not used and there is little aggregation across environmental themes in the basic inventory and impact assessment. The measurement and calculation of the different environmental loads may incorporate some assumptions although it is foreseen that this step will use scientific principles. The 'SETAC Code of Practice' sets out guidance on the quality of data to be used in LCA studies as well as the quality of the study in general. In addition it foresees the development of a peer review process in the LCA.

Studies

UNEP has published an example of an LCA for soy bean oil (UNEP, 1996). Contributions for each of these parts of the process are calculated and an inventory table developed. One by-product of the process is soy bean meal and therefore the environmental loads are allocated between the meal and the oil on the basis of commercial value.

[12] CML et al. (1992)

Inventory table for one tonne of bean oil

	Soy bean production	Steam production	Electricity production	Transport by road	Bean oil production	Total
Energy Resources (GJ)	1.24	1.77	0.68	0.25		3.95
$C0_2$ emissions to air (kg)	97.2	83.3	46.9	23.1		250.5
$S0_2$ emissions to air (kg)	0.71	0.07	0.0058	0.03		0.81
N emissions to water (kg)	212					212
Hexane emissions to water (kg)					1.29	1.29
High risk solid waste (kg)			0.00013			0.00013
Industrial waste (kg)		0.12	0.000052			0.12

The above impacts can be converted into aggregated into themes as shown below.

Environmental loads of the production of one tonne of soy bean oil

	Score
Energy depletion	16.8
Global Warming	6.6
Ecotoxicity	0.22-2.2
Nutrification	1995
Acidification	4.7
Ozone depletion	0

A study (Ecobilan, 1994) compares four LCA aggregation techniques (CML, EPS (Sweden), Swiss Ecopoints and Swiss Critical Volumes) to assess the differences in packaging used to transport tomatoes. The packaging systems compared were corrugated board (CB) and reusable folded polypropylene (PP).

The CML method concluded packaging transport was the major contributor to resource depletion, followed by the material production. There was no clear overall best choice between the two types of packaging. The EPS method, which aggregates emissions and extraction using monetary valuation, found that there were very little real differences between the PP and CB packaging. Emissions to air were more ‘costly’ than emissions to water.

The Swiss Ecopoints method multiplies inventory quantities by *Ecofactors.* These factors are based on the average annual emissions/extraction for the territory and the acceptable level of emissions/extractions. The distribution stage accounted for 60-70% of the score for both types of packaging. CB packaging scored slightly better than PP.

The Swiss critical volumes approach are calculated for air and water emissions by dividing the inventory emissions by a concentration limit value given by local regulations. Air critical volumes are lower for CB than PP but they water volumes are much higher for CB than PP as a result of pulp production. Air critical volumes are, as for the other methodologies, largely dominated by the distribution step.

The authors comment that though the different LCA aggregation methods give similar results when used to compared packaging systems, this does not necessarily mean that the methods are consistent.

MATERIAL FLOWS ANALYSIS

Methodology

The Material Flows Analysis (MFA) framework presents data on the physical mass of materials as they pass from the environment, into the economy and back into the environment as waste. MFA includes the harvesting of primary materials through the chain of industrial processes as they become products and are used. It also follows their flows to their 'ultimate fate' whether it be recycling, reuse, deposition as waste or dispersion into the environment.

Therefore basic material flows balances are based around the following:

Domestic extraction + Imports = Emissions + Exports

Background

Analysis of material flows through the national economy have been around for some time. It is convenient to discriminate between **materials flows analysis** which concentrates on bulky materials such as water, air, food crops, fossil fuels and construction minerals and allied concepts such as physical input-output tables and substance flow analysis. Interest in MFA has increased in recent years driven by the desire to improve the materials productivity of the economy as evidenced in the Factor 4 to 10 debates.

MFA can be used to give (Bringezu, 2000):

- An overview of the material throughput of the economy
- Insight into the material metabolism of the economy by sector
- A basis for sustainability indicators (such as TMR or MIPS), however MFA in itself do not provide any individual indicators
- Data for an assessment of the eco-efficiency of the economy

MFA is closely linked to two other concepts of measuring environmental impacts – **Physical input-output tables** and **Substance Flow Analysis**.

Physical input-output is an extension of MFA that track materials as they progress through the economy. This has only been undertaken with any great success with energy, though efforts have been made with construction material and water. **Substance flow analysis (SFA)** is a term used to describe efforts to track the flow of toxic substances such as chlorine or heavy metals through the economy. It focus is more on chemical transformation of material flows and their detoxification or accumulation.

There is no commonly agreed methodology for MFA and a number of related initiatives have taken place. The German statistical office has written about the MEFIS (material and energy flow information system) cube. Denmark, Finland and Japan have also used the approach in national accounts. The UK statistical office has published data on traded material flows covering energy, agricultural, paper & forest products and mass of metal and non-metallic minerals. Non-European countries such as China, Australia and Egypt are showing an interest in MFA approaches but as yet very little progress has been made.

The European Environment Agency is also supporting the ConAccount initiative which is a network of institutions working in the field of MFA.

Assessment of the methodology

The material flow accounts typically cover

- Agricultural inputs
- Quarried minerals
- Fossil fuels
- Water, Air
- Gaseous emissions
- Waste production
- Emissions to water

Within MFA, different environmental concerns are not aggregated. Information is presented in terms of mass. MFA does not include any assessment of bio-diversity or land degradation, arising from material use. MFA is an accounting framework so there is no explicit sustainability criterion. If used as the basis of calculating resource productivity to judge against factor 4 or factor 10 criteria of resource productivity material flows can provide the raw data to calculate sustainability.

The absence of a sustainability criterion and a disaggregated list of material flows can make MFA difficult to communicate. One strength of MFA is its industrial disaggregation and there are parallels between MFA and NAMEA. The new revision of the environmental accounts manual is to contain a chapter physical accounting techniques such as MFA.

Studies

Wuppertal have calculated a domestic material flow balance (Bringezu, 2000b) for Germany. It includes the physical mass balance of the domestic extraction from the environment, domestic deposits and releases to the environment, imports and exports. The major input and output factors are presented in the table below.

Input (kg/capita)		**Output (kg/capita)**	
Abiotic raw materials	42080	Waste Disposal (excluding incineration)	28463
Biotic raw materials	2748	Soil Erosion	1535
Plant biomass from cultivation	2744	Dissipative use of products (fertilisers, pesticides, etc.)	575
Fishing/Hunting	5	Emissions to air (CO_2, etc.)	12283
Soil Erosion	1535	Emissions of water from materials	7814
Air (O_2 for combustion)	13200	Emissions to water	455
Total	59563	Total	51124
Imports	5805	Exports	2785
Total	**65369**	**Total**	**53909**
		Balance (Net Additional Stock)	*11460*
Water (by used, unused, imports)	597782	Waste Water (by treated, untreated, exports)	597782

Water flows dominate the input-output balance. The domestic input of abiotic (non-renewable resources) dwarfs the biotic (renewable resources) by a factor of 15 suggesting that the use of non-renewable sources still dominates. On the output side, the mass of carbon dioxide emissions into the atmosphere is more than eight times greater than the mass of solid waste disposal.

TOTAL MATERIAL REQUIREMENT

Methodology

The Total Material Requirement (TMR) measures the physical requirement of a national economy - the sum of domestic and imported primary natural resources. It is the total mass in tonnes of primary materials (not including water and air) extracted from nature to support society's activities. It includes materials that the economy disturbs such as mining overburden and eroded. These are termed *hidden flows*.

The calculation of hidden flows is based upon estimates of the overburden removed in mining and where possible national estimates for other harvesting and extraction processes. Estimates of erosion of agricultural or forestry lands in the country of origin are used to calculate the hidden flows arising from imported renewable raw materials.

The TMR can be extended to a product (or service) level through the calculation of the Material Intensity per Service Unit (MIPS). This relates the input of primary materials to the functional unit of a product or service and can therefore be used as an initial screening method within Life-Cycle analyses or potentially for eco-labelling schemes.

Background

The TMR was first calculated by Bringezu and Schütz from the Wuppertal Institute for Germany in 1995. The World Resources Institute Report (1997) determined the TMR for the USA, the Netherlands and Japan and included comparative analyses between the four TMRs. Subsequently the TMR has been calculated in Finland and Poland and research is underway for the UK, China, Amazonia and Egypt. The European Environment Agency is presently funding work to calculate the TMR for the European Union as a whole.

Assessment of the methodology

TMR does not include a sustainability criterion in itself. The Factor 4/Factor 10 methodology could provide a framework within which to set a target for the TMR's development however the aggregation of different substances makes this relatively difficult. Clearly it is not sustainable for TMR to increase indefinitely but there is no bio-physical constraint built into the methodology.

Different materials are aggregated into the TMR solely according to their mass. A frequent criticism of the TMR is that is adds 'apples and oranges' adding masses of hazardous materials such as heavy metals to relatively benign materials such as food. Substantial increases in the mass of hazardous matter would be literally outweighed by comparatively unimportant changes in soil movement. Most TMR analysis do break up the contributions to the TMR into 4 or 5 categories which allows more analysis and interpretation.

'Hidden flows' make up a large proportion of the TMR for a country and their environmental impact are limited. Data on hidden flows are also often based upon estimates.

The aggregation of masses is simple and therefore the concept is relatively easy to understand. The sheer scale of material flows (more than 80 tonnes/per capita in the Netherlands and Germany in 1994) is a powerful 'alert' indicator for the general public on the material basis of modern industrial economies. The 'ecological rucksack' is the mass of materials used to produce a final product that do not form part of the final product themselves.

Studies

The best known report on TMR (World Resources Institute *et al*, 1997) published a report on TMR for the USA, Japan, Germany and the Netherlands (see table below).

Table 13: Total material requirements, 1994 (tonnes)

	U.S.A.	Japan	Germany	Netherlands
Domestic	4581	1424	1367	271
Traded	568	710	406	303
Hidden	16088	3583	4991	701
TMR	21237	5716	6764	1275
TMR/capita	84	46	86	84

Source: WRI et al, 1997

The TMR for all four countries are dominated by hidden flows which account for between 55-75% of the TMR. This is a cause for concern as these are the least well understood of the flows. Of commodity flows, in the Netherlands the mass of traded materials is greater than domestic materials. The opposite is the case in the other three countries. Japan has a significantly lower TMR than the other three industrialised countries studied, however even a figure of around 50 tonnes of material per person per year is nonetheless a powerful signal of human activities' disturbance of the natural environment.

Table 14: Total material requirements by material, 1994 (tonnes)

	USA	Japan	Germany	Netherlands
Fossil fuels	7530	16	2698	68
Metals	1935	7	0	0
Industrial Minerals	417	215	88	8
Construction Material	1889	1103	913	74
Infrastructure	3473	1105	300	51
Renewable	1122	113	199	137
Soil erosion	3710	8	129	2
Total	20075	2567	4328	340

Source: WRI et al, 1997

Fossil fuels make up a large part of the TMR for all four countries accounting for more than 50% of domestic material flows in Germany. Renewable materials make up a significant proportion of the Netherlands domestic material flows whereas in Japan flows Construction material and infrastructure make up more than 85% of domestic material flows.

The data calculated in this study is brought together with other national calculations of TMR for Finland, the EU-15 and Poland in Bringezu (2000a). This study also includes analyses of trends (mostly between 1975-95) of TMR/capita in these countries. The majority of these countries show an increasing TMR/capita over the period. The exceptions are the USA where TMR/capita fell quite significantly between 1975-94. Nonetheless it is still much higher than the average for the EU-15 due to high material flows from fossil fuels (in particular coal).

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