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ECO-EFFICIENCY INDICATORS AS A STEP TO INDICATORS OF SUSTAINABLE DEVELOPMENT?

Paper submitted by the Austrian Ministry of Agriculture,
Forestry, Environment and Water Management [1]

'As early as 1992 the UN environmental summit in Rio de Janeiro stated quite clearly that the main cause of global pollution is the continued use of natural resources at previous levels. Acceptance of this fact by the international community of nations helped promote the discussion of specific measures to ensure sustainable economic development. In this connection, strategies for optimising use of resources as expressed in the debate about "Factor 4" play a particularly important role: Prosperity should be doubled with half the consumption of natural resources and energy.'

This paragraph is quoted from an Austrian publication by which the Ministry for the Environment contributed to the eco-efficiency debate. What we wanted to express was that the concepts of eco-efficiency and dematerialisation were developed as a contribution to implement sustainable development.
Our starting point was the experience that a correct interpretation of an indicator implies the consideration of different factors behind the described phenomenon. For example, an increase in the total amount of waste collected may have various causes: population growth, better collection systems, improved awareness, rise in consumption, growing number of households, etc.

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[1] Prepared by Ingeborg Fiala. The contents of this discussion paper do not necessarily reflect the official opinions of the Austrian Ministry of Agriculture, Forestry, Environment and Water Management.

To illustrate the concurrent development of several indicators we drew diagrams including graphs for various parameters. As it is the long-term development that is of central importance, the individual data comparisons do not show absolute values; instead they show the relative changes compared to the value of the reference year, applying an index with a baseline value of 100. It is thus immediately apparent how the individual economic and environmentally relevant parameters have developed over time and whether, and to what extent, de-coupling has occurred.

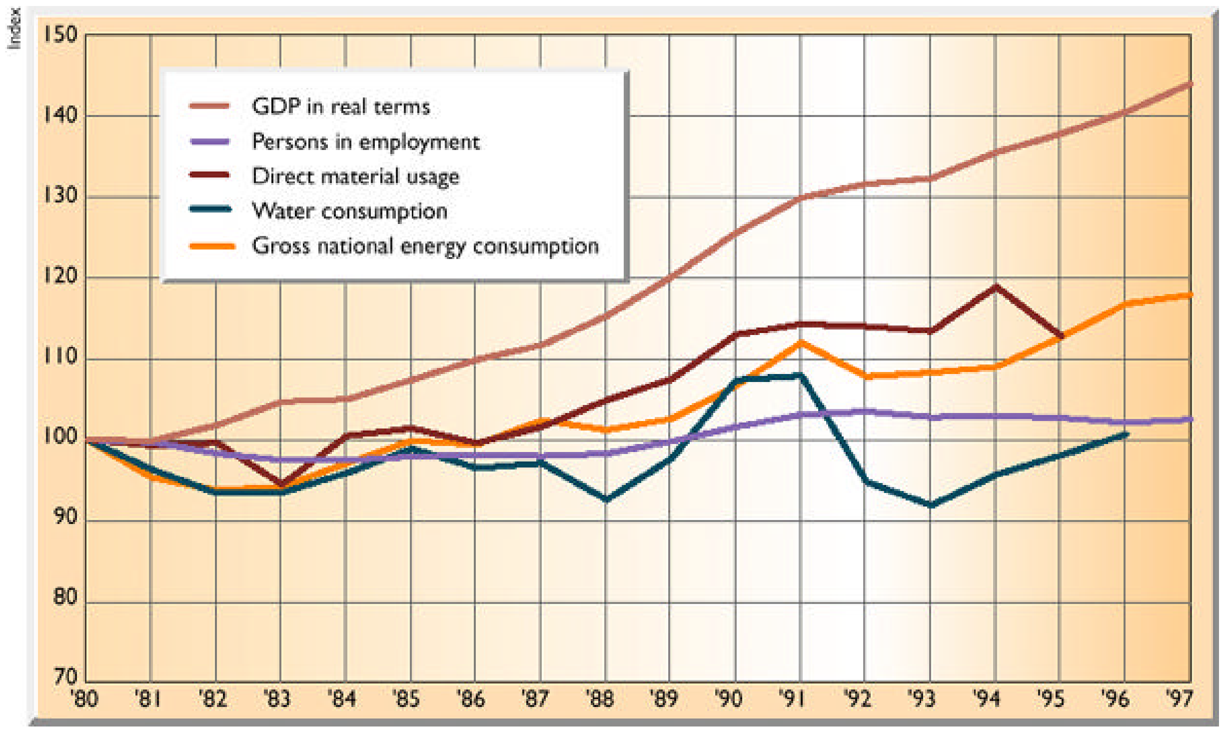
Themes/ sectors chosen and presented separately are:

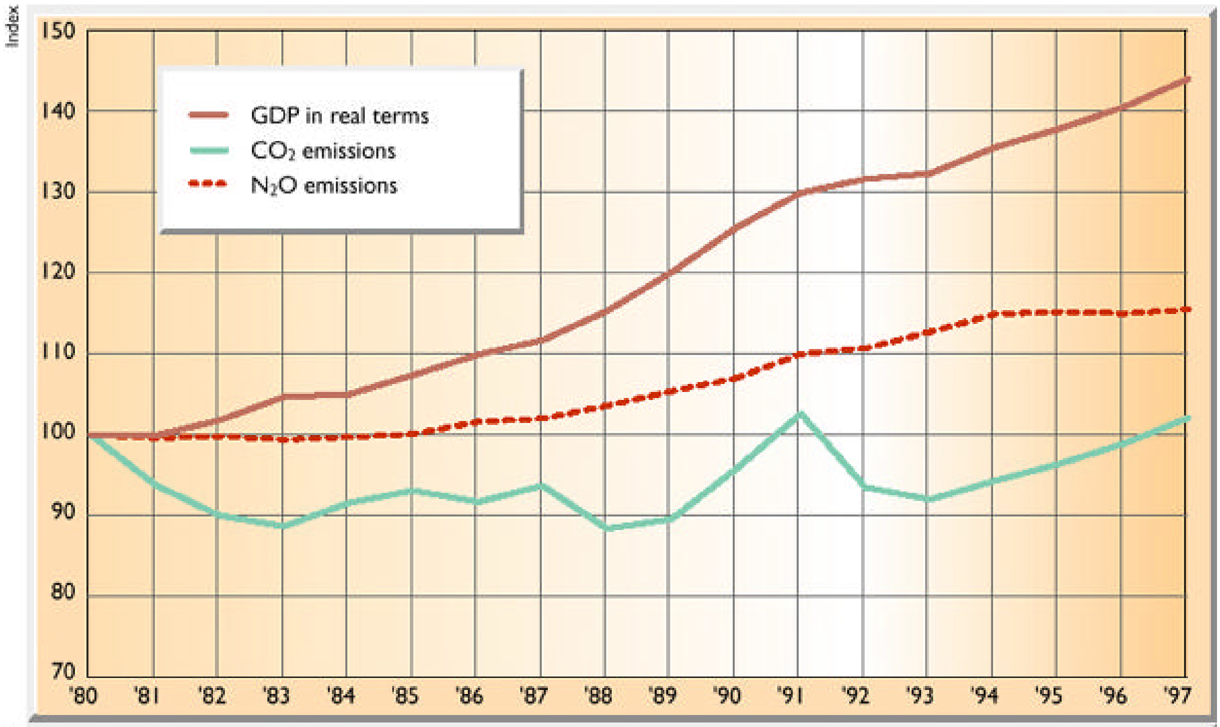
- National economy
- Municipal waste
- Energy
- Agriculture and forestry
- Industry and
- Transport

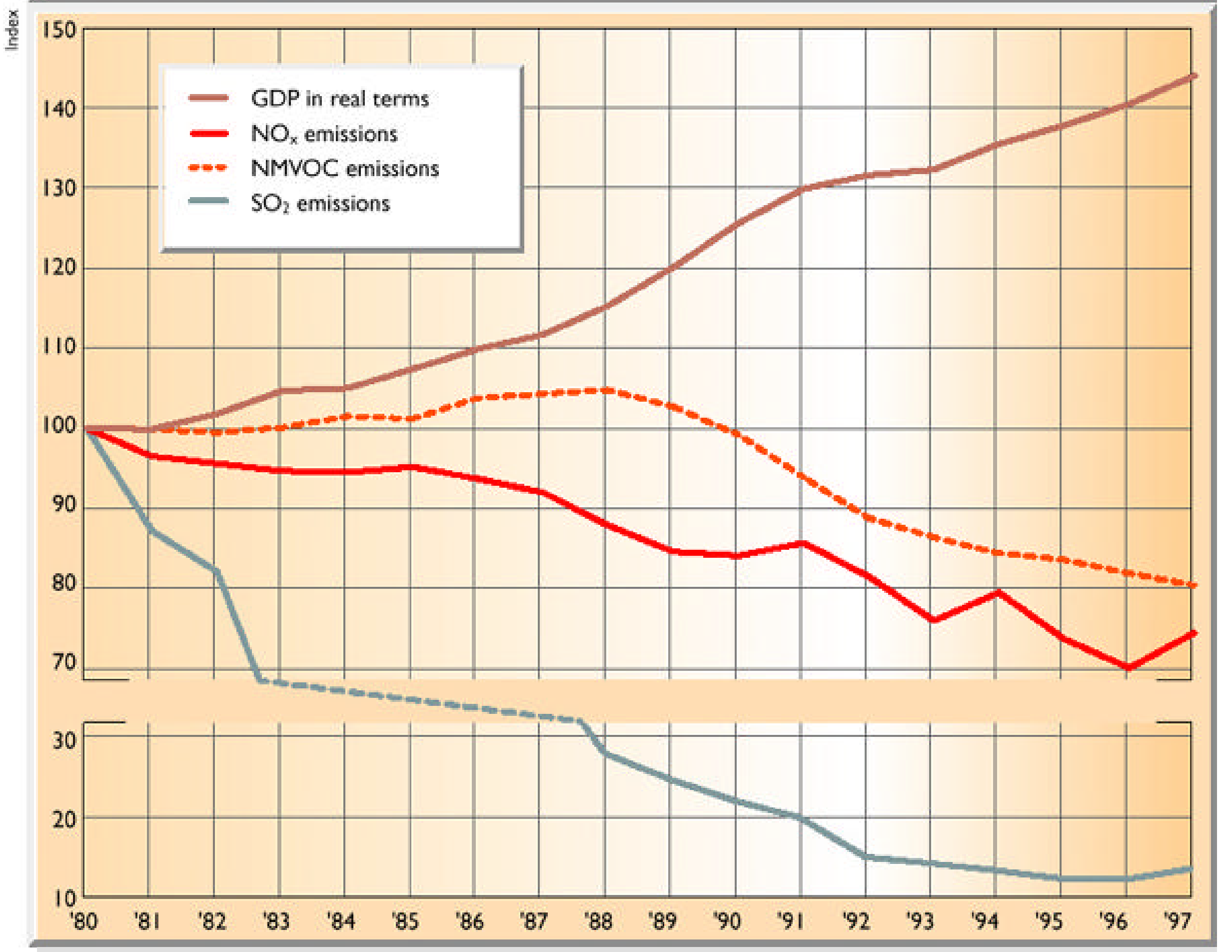
The choice of the individual areas of comparison was largely based on problems related to the work of the Ministry for the Environment. Particular emphasis was placed on those economic areas with special environmental relevance.

The interrelations connections between the pillars of sustainable development were illustrated on the basis of economic, social and environmental parameters.

The diagrams on the "national economy" are provided below:







Sources:

Gross domestic product in real terms and the number of persons in employment: ÖSTAT (Österreichisches Statistisches Zentralamt, Austrian Central Statistical Office).

Direct use of material (statistics include biomass, mineral material, fossil fuels and chemical and other products): Calculations by IFF (Institut für Interdisziplinäre Forschung und Fortbildung, Institute for Interdisciplinary Research and Further Education) -Soziale Ökologie 1998 on behalf of the BMUJF (Bundesministerium für Umwelt, Jugend und Familie, Ministry for the Environment, Youth and Family), Unit II/1, on the basis of ÖSTAT data.
Gross national energy consumption (includes energetic and non-energetic use of all energy carriers taking into account the totals from foreign trade and energy inventory movements): WIFO (Österreichisches Institut für Wirtschaftsforschung, Austrian Institute of Economic Research) Energie Bilanzen 1998; EVA (Energieverwertungsagentur, Energy Recycling Agency), own calculations.
Water consumption: IFF Schriftenreihe Soziale Ökologie, Band 34.
Air pollutant and greenhouse gas emissions: UBA (Umweltbundesamt GesmbH, Federal Environment Agency).

Some general remarks on such diagrams of eco-efficiency indicators:

- On occasions, limits are imposed by the lack of available data and the limited number of values that can be shown in clear graphic form.

- Data of environmental quality cannot be presented in the diagrams related to specific sectors because there is no clear correlation. The impact of e.g., the energy sector on air quality or biodiversity cannot be calculated.

- Obviously the resulting picture for each parameter depends strongly on the year chosen as a starting point.

- The graphs do not give an impression of the real impact a parameter does have on a specific environmental problem. The impact of CO_2-emissions to the problem of climate change is 9-times higher than that of N_2O-emissions which cannot be read from the second diagram. (This method of presenting data only shows relative changes.)

- For the specific diagrams it has to be stated that the data does not claim to be complete. It should be understood as the basis for further initiatives in this field – in particular for the continued linkage of environmental and social indicators to "monitor" sustainable development.

Linking not only economic and environmental but also social data means broadening the classical concept of eco-efficiency, for which a definition is given in the European Environmental Agency’s report ‘Environmental signals 2001’:
‘Eco-efficiency is the amount of ‘environment’ used per unit of ‘economic activity’.’

Further the report states: *'A major goal of sustainable development policy is to decouple the environmental impact of an economic activity from its growth in volume.'* Eco-efficiency indicators – expressed in diagrams similar to those presented above - are used to illustrate whether there is a decoupling of environmental impact and the sectors' economic activity or not. Typically GDP or GNP is chosen as the parameter representing the economic pillar. This implies that GNP is taken as a 'valid' measure of prosperity and individual quality of life/ well being, which is increasingly questioned.

In this definition eco-efficiency is a classical evaluation aiming at monetary values. According to Prof. Willem Riedijk, University of Curacao, this was justified after the world war in the time of rebuilding. What we really should consider is the significance and effect of projects and their impact on fixed goals and targets as well as their influence on sustainability.

The GUA – Gesellschaft für umfassende Analysen GmbH, Vienna – states in the study 'Analysis of the fundamental concepts of resource management, 2000' (commissioned by the European Commission) with reference to Weizsäckers 'concept of de-linking between material use and economic growth during economic development':

> *'However, technological innovation does not necessarily decrease environmental burden, but increase only the efficiency of resource use: A higher population can benefit from the same material standard or a constant population from a higher material standard. There may also be a "rebound effect"; i.e. improvements in efficiency save money to consumers, which can spend the money to consume more elsewhere. Moreover, even increased efficiency will not lower the total environmental burden if population (and therefore the total consumption) keeps growing. Frequently, technology innovations increase the short-term energy and material fluxes, which are often based on non-renewable resources. For example, the dynamic innovation progress in the field of electronic devices and personal computers definitely helps to increase resource efficiency, but newly developed products replace other products in an even smaller getting period.'*

Ayres (Center for the Management of Environmental Resources) also refers these deficiencies of eco-efficiency in its classical definition in the study 'Resources, scarcity, growth and the environment, 2001', commissioned by the European Commission:

> *'A popular environmental slogan these days is `dematerialization'. It follows almost automatically from the notion that large mass flows are environmentally harmful, whence it seems that less harm must follow from reduced mass flow. This is another potentially misleading proposition.*
>
> *Many examples have been presented to demonstrate the supposed trend towards dematerialization in industrial societies. The primary example, of course, is the computer chip. Undoubtedly the size and weight of computer chips, and products containing them, from radios and portable telephones to computers, are much less massive – and use less electric power – than their less powerful counterparts ten, twenty or thirty years ago. To a lesser extent, the same trend can be observed in a variety of other products.*

On the other hand, there are two countervailing trends that are often forgotten. One is the so-called `rebound effect'. To the extent that dematerialization is accompanied by lower costs and real savings to consumers, demand for the products tends to increase. In the case of `mature' products approaching demand saturation, the savings to consumers may be spent on other goods and services, which may or may not be less materials/exergy intensive. However for products that are still rapidly evolving and for which markets are growing, the lower cost of a unit may simply encourage the consumer to buy more of them or to replace them sooner than he/she would otherwise do. This has almost certainly happened in the case of personal computers, digital assistants, cellular phones and so on. It is by no means clear that the total mass of consumer electronic products sold each year is declining.

Apart from the rebound phenomenon, there is another trend that may be working in the opposite direction. Simply stated, as computer chips become smaller and more compact the manufacturing process becomes more and more complex. The ratio of indirect material consumption to material actually embodied in the product is extremely large. A chip weighing 1 gram requires processing in which several hundreds or even thousands of grams of photo resists, acids, solvents and neutralizers are used and discarded. Virtually none of the materials involved are recovered for recycling.

This situation is in marked contrast with conventional metal or plastic products. Stone, glass, clay and concrete products generate very little waste during the quarrying, mining and processing of the materials, and even less is lost during construction. Forest products are also used quite efficiently: wood that is not used directly as lumber is generally converted into fibreboard or paper. Even the wastes are burned as fuel. In the case of paper, most of the waste is at the consumption end. Only in the case of metals is the waste mass during mining, concentration and smelting significantly greater than the mass of the refined product. (This is especially true for copper and even more so for the precious metals.) However, from that point on in the manufacturing process, losses are small and mostly recovered. Again, it is mainly in the final consumption stage that significant unrecoverable losses do occur.

In short, the micro-electronic products that are commonly cited as examples of dematerialization are really illustrations of quite a different and less favorable trend.'

The World Business Council for Sustainable Development (WBSCD) has tried to solve some of the deficiencies of the classical eco-efficiency concept by proposing to consider the environmental burden of a project. This concept and the proposals for practical use are cited in the GUA study mentioned above:

'The World Business Council on Sustainable Development (WBSCD) has developed a broader concept of eco-efficiency, where "Eco" combines a range of economic and ecological values. The WBSCD Eco-efficiency includes a range of performance criteria for innovative companies which are inter alia reducing material and energy intensity of goods and serves, reducing toxic dispersion, enhancing recycling of material of increasing the use of renewable resources.

Eco-efficiency criteria of the World Business Council for Sustainable Development:
1. minimize the material intensity of goods and services;
2. minimize the energy intensity of goods and services;
3. minimize toxic dispersion;
4. enhance material recyclability;
5. maximize the use of renewable resources;
6. extend product durability;
7. increase the service intensity of goods and services.

The WBCSD's working group "Eco-efficiency metrics & reporting" recommends the use of the following ratio as a general equation to measure and report Eco-efficiency:

Eco-efficiency = value provided / environmental burden [value unit/burden unit]'

Pearce (University College London) mentions another critical aspect of the eco-efficiency concept in the study 'A framework for integrating concepts and methodologies for policy evaluation, 2000' (commissioned by the European Commission):

'The obvious problem for the issue of policy guidance is that, while such estimates are interesting, they have no policy meaning. *The reason is actually acknowledged by the researchers. One tonne of material A is not the same as one tonne of material B in terms of environmental importance. The idea of aggregating all materials into tonnes is therefore meaningless for policy purposes. What matters is the 'impact weighted' amount of materials and one cannot know what these impacts are without knowing: the environmental toxicity of the material in question, the assimilative capacity of the receiving environments, levels of exposure and levels of human and ecosystem response to such levels of exposure. Additionally, if policy is to be sensitive to human preferences, the weights must also relate in some significant way to those preferences.* ***TMR totally neglects the issue of whether a given tonne of materials is important or no****t. In terms of the criteria/policy matrix introduced in Section 3, tonnes have been equally weighted in the TMR approach and there is no conceivable justification for this beyond the convenience of being able to add up different tonnes.*

Much the same remarks apply even to very popular indicators, such as the ratio of energy to GDP. Each energy input is not equally important because it depends on what impact the different energy inputs have on the environment. Natural gas is, for example, less damaging than, say, coal.

Indicators of materials intensity are interesting but their use for policy purposes is extremely limited because of a failure to define what the goal is meant to be. It appears to be that one should reduce the TMR of economic activity. But this has no necessary implication for environmental improvement since the mix of materials matters as much as, if not more than, the total. What is needed then is a set of weighted materials and energy input coefficients. The weights could be based on human toxicity (dose-response coefficients), ecosystem toxicity, public opinion, and individuals' preferences expressed in monetary terms. Essentially, what appear to be 'new' indicators come full circle to indicators that have to be weighted by some set of risk factors or preferences. But the notion of dematerialization is a sound one and, indeed, has to be the basis of efforts to improve the environment and to achieve sustainable development.'

An attempt to consider the impacts of the material flow components can be found in 'Bartelmus, Bringezu, Moll: Dematerialization, Environmental Accounting and Resource Management', a study commissioned by the European Commission:

'In order to relate particular material flows to specific environmental impacts, we have to solve two problems, namely how to assess:

- *the specific environmental impacts caused by material flows that have already been recognized as "harmful" and*
- *the environmental impacts of material flows which are not (yet) known specifically, or are not related to specific material substances.*

High –priority environmental concerns of environmental policy such as global warming can be related to associated material flows (e.g. fossil energy carriers and CO_2 emission). All existing knowledge about the property of certain materials and specific substances should be used to derive data for the specific impact per unit of material flow in order to assess the environmental significance of different materials. …

In many cases environmental impacts of material flows are either not yet known or difficult to relate to particular materials. There is no standardized assessment method for most of the potential toxic, nutritional, structural, physico-chemical and directly destructive effects associated with material flows. …

In most cases there is thus only information about the category and volume of the material flows themselves. Any material flow induced by humans may thus reflect indeed a change in the environment and has to be taken as the best proxy for this change. At least, a quantitative flow account will produce indicators that point in the right direction, with increasing material flows indicating increases in environmental impacts.'

An example for calculating the impact of specific components of the mass flow on environmental problems can be found in 'Muilerman, Blonk: Towards a sustainable use of natural resources, 2001', a study commissioned by the European Commission:

'4 Indicators of the pressures on reserves of natural resources

4.1 Type of indicators

There are various indicators that can be used to monitor the use of physical resources and materials. First, of all, there are indicators that represent all the material streams in society, aggregated in one figure. An example is the TMR, the Total Material Requirement (Adriaanse 1997), which aggregates the use of resources by society into one score by adding up all the weights of resources used. This approach has two important disadvantages:

1. *The total score is heavily influenced by the large resource streams and movements of these effectively determine the score, while there is no reason to suppose that these streams are in fact the determining factors in the total pressure on natural resources. The use of sand has a completely different impact than the use of copper, for example. An environmental impact score is needed to indicate this.*
2. *The total score is a sum of natural resources, the pressure on a number of reserves and movements of resources. Figures as different as the use of potatoes and the amount of eroded soil are all added up together. This combination of different units is highly confusing.*

A theoretically more satisfactory approach is to add up all the environmental impacts caused by the various resource streams. However, this places high demands on the method and procedure for aggregating environmental impacts and requires much data. The attempt by Pré (2000) to do this using the LCA method must therefore be viewed as an exploratory exercise. The LCA method used is not suitable for expressing the most important environmental impacts caused by the use of resources, such as loss of biodiversity and the environmental impacts of agriculture. Moreover, the data on the extraction and production of imported raw materials used in Pré study are very sketchy.[2]

Another approach is to use 'key resources'. Instead of looking at the actual extraction of specific resources such as ores and minerals, this method focuses on the use of reserves of a few specific resources that are ultimately essential for the functioning of the earth and human society. These key resources are energy, the use of land and biodiversity. The ecological footprint method is based on the same thinking. It expresses everything as a (weighted) land area (the 'footprint') and has the advantage of allowing comparisons, for example between the use of sand and copper, via the claims made on a few key resources. The disadvantage is that it involves long and difficult calculations and considerable uncertainty. And the definition of 'key resources' is itself a subject for debate. How can the consumption of energy be defined? And how can the use of biodiversity be calculated (see for example Blonk 1997)?

A more practical approach is to identify the resources streams that make up a substantial part of all resources used and the environmental impacts caused by the use of resources. The WWF takes this approach with its six indicators for consumption (WWF 1998): grain consumption, marine fish consumption, timber consumption, consumption of 'drinking' water, and CO2 emissions. This report draws partly on the issues selected by WWF.

4.2 Consumption indicators for the Western world – the Netherlands as example

Production and consumption activities require different indicators of resource use. Consumption indicators are designed to reflect developments in consumer demand. The final use of resources, such as land, fossil fuels and biodiversity, and other environmental impacts can be obtained by combining these indicators with data on the environmental efficiency of production (such as energy consumption and emissions from production processes, materials reuse and losses from the production chain). Production indicators reflect production activities within a country and are more suitable for monitoring the environmental efficiency of specific production activities.

The OECD (1999) has developed a number of indicators for monitoring changes in the sustainability of consumption. This list of indicators, along with the WWF methodology, is used in this report.

The indicators shown in Table 7 provide a good impression of the use of resources by the Dutch population.

[2] The Pré study does provide insight into some environmental themes and a number of interesting conclusions are drawn. One third of the pressure on the environment exerted by consumption in the Netherlands takes place abroad. The study also shows that the Netherlands is a recipient of environmental pressures exerted by consumption in the EU region (particularly Germany) because of the country's geographical situation and economic structure.

Direct indicators	Contribution to environmental impacts from consumption			
	Land use	Damage to biodiversity	Greenhouse effect	Ecotoxicological impacts
Fossil fuels	<1%	<1%		
– total fossil fuels			80%	Approx. 65% of acidification
– direct energy consumption for passenger transport			20%	
– direct domestic energy consumption			20%	
– indirect energy use by consumers			40%	
Wood				
– total wood	56%	15%	10%	
– consumption of non-certified tropical hardwoods		15%	3%	
Food				
– total food	36%	75%	30%	Approx. 90% eutrophication and pesticides
– meat consumption	13%	60%		
– consumption of dairy products	8%			
– consumption of vegetable oils	10%	15%		
Metals	<1%		5%	Heavy metal emissions and accumulation
– use of steel				
– use of aluminium				
– use of zinc				
– use of copper				
Indirect indicators	Indicates:			
– household waste	Use of articles with a short life			
– building and demolition waste	Loss of materials due to changes in the housing stock			

Table 7: Indicators for Dutch consumption and contribution to environmental impacts (Vringer 2000, Blonk 1992, Ros 2000, De Vries 1994, Blonk 1992)

Important criteria for the choice of indicators are:
- *Contribution to the environmental impacts of Dutch consumption*
- *Provides insight into the losses (‘leaks’) from the production–consumption chain*
- *Availability of data*

Direct indicators

The material categories – fossil fuels, firewood, food – make a very high contribution to environmental impacts in the Netherlands. At the moment, Statistics Netherlands (CBS) and RIVM monitor these directly in only a limited way. With a few calculations, good consumption figures can be derived from the statistics (Vringer 2000, Koster, 2000, Kramer 2000). The use of metals is a good indicator of losses from consumption, derived from net primary use after consumption (Blonk 1992, Spapens 1998). The use of zinc and copper leads to an increase in the use and emissions of cadmium because this is a by-product of their extraction.

Indirect indicators

Both the amount of household waste and residual building and demolition waste are monitored. Trends in the amount of household waste (or packaging waste) produced says much about changes in the use of products with a short life, and the composition of household waste also provides an insight into the use of metals. The amount of residual building and demolition waste is a global indicator of the materials efficiency of changes in the housing stock.’

Muilerman and Blonk call ‘the challenge facing the Western world’:
‘First, that of achieving a fair distribution of resource use’, and
secondly ‘to produce raw materials within acceptable local environmental and social conditions, and in doing so contribute to meeting global sustainability targets.’
They recommend to monitor the indicators in table 7 of their report.

In conclusion, there seems to be accordance that broadening the concept of eco-efficiency would be helpful on the way to SD-indicators. The scientists recommend to consider the impact of the diverse materials used and propose some assumption methods. Following those recommendations in preparing indicators of sustainable development an indicator model considering human needs and their impacts could be helpful.