EV5V-CT94-0374

OPERATIONAL INDICATORS FOR PROGRESS TOWARDS SUSTAINABILITY

SUMMARY FINAL REPORT

JUNE 1996

Key words : indicators; lifecycle analysis; sustainability; exergy; cost-effectiveness; statistics

RESEARCH TEAM

Coordinator :
J. Krozer Msc.
The Institute for Applied Environmental Economics
Research staff: F. Schelleman MSc. (project manager)
H. Heijnes MSc.
Grote Marktstraat 24
2511 BJ The Hague, Netherlands
Tel.:+31 70 3464422
Fax:+31 70 3623469
Email:tria@knoware.nl

Partners :

Dr. M. Narodoslawsky
Research Staff: P. Eder MSc.
T. Dielacher MSc.
Technical University of Graz
Institute for Process Technology
Inffeldgasse 25
A-8100 Graz, Austria
Tel.: +43 316 8737461
Fax: +43 316 8737469
Email: braunegg@glvt.tu-graz.ac.at

Prof. Schmidt-Bleek
Wuppertal Institute for Climate and Environment
Research staff: Dr. J. Spangenberg
Dr. J. Malley
H. Stiller MSc.
Department for Substance Flows and Structural Change
Döppersberg 19
D-42103 Wuppertal, Germany
Tel.: +49 202 2492132
Fax: +49 202 2492138
Email:J.Spangenberg@mail.wupperinst.org

Prof. R.U. Ayres
INSEAD/European School for Business Management
Research Staff: Dr. K. Martinas
Centre for the Management of Environmental Resources
Boulevard de Constance
77305 Fontainebleau, France
Tel.:+31 1 60724128
Fax: +31 1 60745564

I. OBJECTIVES

Goal of the project

The project "Operational Indicators towards Sustainability" aimed primarily at the development of a set of indicators which can be used to measure and monitor progress towards sustainability and to assess the applicability of four sustainability indicators:
These four indicators are:
- MIPS: Material Input Per unit of Service
- the SPI: Sustainable Process Index,
- PCC: Pollution Control Cost assessment,
- Exergy

The starting point of the project was that sustainability can best be reached by decreasing and minimising the use of materials, energy, land-area and other limited resources in different economic activities, and in the same time, minimising outputs of these economic activities in terms of environmental emissions to air, water, soil and waste-streams.

The general objectives can be summarized as follows:
1. Develop a set of indicators that can be used to assess progress towards sustainability. Examples of parameters/elements that were taken into account:
- total area of land requirement;
- material needs (energy, water, metals, sand, etc.; materials will be specified);
- exergy/energy-input (distinction between renewables and other sources of energy will be made);
- economic parameters (environmental control costs);

2. Demonstrate the application of the indicators in a number of case studies. The results of the case studies will be used to further improve the applicability of the different indicator methodologies. The following case studies were distinguished:
- industrial processes;
- transportation systems;
- product/service oriented case studies: packaging materials/products;
- regional case studies: an Austrian region (Feldbach, and Germany).

3. Evaluation of the case study results.

II. METHODOLOGY

The project was performed according to the following approach:
- collecting available information on the indicators to be studied and the case study topics selected (see figure 1);
- applying the indicator methodologies on the selected topics/case studies;
- comparing the results of the case studies and search for strengths and weaknesses of the indicators;
- based on the results and experiences in the case studies, developing recommendations for a set of sustainability indicators.

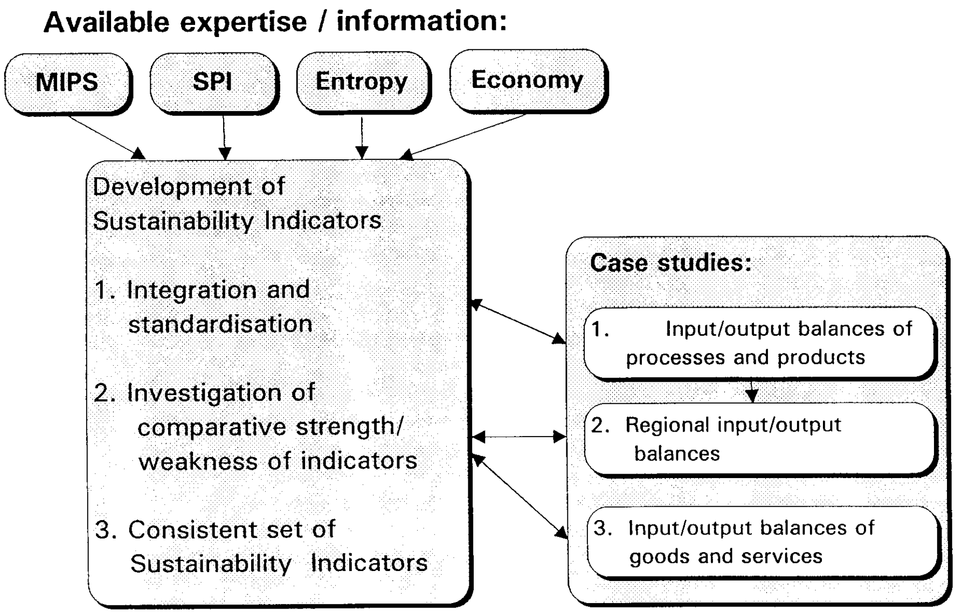

Figure 1: Schematic project approach

The four indicators studied were:

1. Material Inputs Per unit of Service" (MIPS), indicating the flow of displaced materials in terms of masses that are moved in order to provide a specific service.
2. Sustainable Process Index" (SPI), indicating the area which is needed for a sustainable biomass production, viewing the fact that the solar influx for biomass is the only external relation of the closed system of Earth.
3. Exergy which indicates the level of thermodynamic disequilibrium, in popular terms: the available work that can be used for any activity.
4. "Pollution Control Costs" (PCC), shows the costs of controls (abatement measures) to attain the environmental carrying capacity.

Case studies

The four indicators MIPS, SPI, Exergy and PCC, were evaluated and compared by focusing on three case studies:

i) car transport
ii) packaging
iii) regional case studies: only MIPS and SPI.

III. MAINRESULTS

3.1 Car transport

This case study aimed at testing the sustainability indicators SPI (Sustainable Process Index), PCC (Pollution Control Cost) and MIPS (Material Intensity Per Service Unit) in their application to the evaluation of transport. Transport offers unique challenges to an evaluation system as:

- it is an important service with a considerable environmental impact
- it allows the comparison of different technologies that serve the same purpose
- it allows the comparison of renewable and fossil raw material base for fuel.

From the many means of transportation, the project chose to evaluate passenger cars with gasoline, diesel and RME (rape seed methyl ether) fuel, and in addition tractors with diesel and RME fuel.

The case study encompassed (as far as possible) the whole life cycle of the service of transportation by passenger cars. This includes the production processes of steel, plastics and rubber (as materials used in car production), the manufacturing of cars and the production of the various fuels. The database for the passenger car part was drawn from Dutch data. For the RME production and the tractor case, data from Austrian sources were also used. The main results for the transport case are given in table 1.

Table 1: Results of SPI, MIPS and PCC calculations for personnel car transport

	SPI (m2 a/cap km)	MIPS (g/P-km)	PCC (fl/km)
Gasoline	36.30 (3)	1223 (2)	□ 0.049 (2)
Diesel	28.43 (2)	843 (1)	□ 0.066 (3)
RME	8.31 (1)	-	□ 0.037 (1)

For all indicators, the user phase provides the main contribution up to 90% of the indicator value for SPI, 60% for MIPS and 90% for PCC.

SPI and MIPS both rank diesel fuel first. When RME is taken into account, both SPI and PCC put this non-fossil fuel first. Only PCC gives another ranking for gasoline and diesel fuel than MIPS and SPI. The concept of Pollution Control Costs takes into account the economic evaluation of environmental impacts: its value is determined by a combination of the following two factors:

- environmental characteristics
- abatement costs

Evaluation of this transport case with PCC indicated that abatement measures for diesel fuelled cars are yet more costly than for gasoline fuelled passenger cars. Of course this may change in the future, as technological development lower the costs of abatement technology.
Not only the technology ranking, but also the ranking of different stages in the life cycle are similar. All three indicators rate the user phase of cars as the most important in terms of its impact on sustainability.

A recommendation for transport to become more sustainable can be deduced from all three evaluation systems. The main impact in car use is made by the user phase and reduction of fuel consumption is the single most important measure to decrease this impact. A switch to renewable fuel sources is certainly advantageous, however, it will run into considerable restrictions from conflicts in land use.

3.2 Packaging
The subject of the Packaging case was the comparison of the production of beverage cans of steel, aluminum, glass and PVC, using the different indicator approaches.

Of the following stages that are in general comprised in a life cycle approach, in this project data were included on stage I to IV. :

I. Extraction
II. Benefication (concentration)
III. Reduction (melting)
IV. Refining
V. Forming
VI. Assembly/manufacturing

Owing to the limited availability of comparable data, the case study focused on the production of the (raw) materials (stages I to V) that constitute the beverage can body: primary aluminum, oxygen steel, molten and formed glass and PVC. In principle data sets used for the indicator comparison in this report consist of material inputs, energy use, process emissions and emissions related to energy use.
Table 2 gives the results of the indicator calculations for the packaging case. Both SPI and PCC give steel the best ranking.

Table 2: Comparison of SPI, PCC and MIPS for the packaging materials

	SPI	MIPS	PCC
Aluminum	3x	1	6x
Glass	1,1x	1,1x	2x
PVC	5x	-	3x
Steel	1	2x	1

Differences between packaging materials are larger when looking at emissions (as SPI and PCC mainly do) than when focusing solely on the inputs during the production steps taken into account (MIPS).

The main conclusion could be that steel cans offer the most environmentally sound packaging materials with the lowest expected pollution control costs. Tin production, for plating of steel cans, and disposal/usage was however not taken into account in the SPI and PCC calculations. As the differences between glass and steel are relatively small, as well for SPI as for PCC, glass may well turn out to be the most attractive from an environmental point of view if the environmental effects of tin would be taken into account. In that case MIPS, SPI and PCC would provide similar results, ranking glass as the most environmentally sound material.

The number of data necessary to perform useful indicator calculations is rather high. Collection of these data is complicated. Regular indicator calculations to assess progress towards sustainable development therefore remains a complex task, requiring the regular gathering of a wide range of detailed data.
Collection of input and output data may be difficult as companies will consider this information as proprietary information.

3.3 Regional case studies
Two regions were studied in this project: The Austrian Feldbach region and Germany as a whole.
For the Feldbach region, both the SPI and MIPS approaches were applied.

Table 3 gives an overview of the main results and the comparison for the Feldbach region.

Table 3: MIPS and SPI/DA for regional final consumption of goods

Product: Indicator:	Minerals	meat	agri	food	wood	minerals	service	construc- tion	trade	consumptio n
SPI/DA	0,30	0,56	0,14	1,06	0,25	0,46	7,9	1,47	2,5	34,3
MIPS	106	18	9	18	4	19	24	135	1	6

Final consumption of minerals and construction services are the main causes of regional material inputs. The other materials and products are of minor importance. SPI/DA's (DA: Dissipation Area) are required mainly by direct activities of final demand (e.g. of households), and services. Construction and production of minerals only play a minor role as far as DA is concerned instead of their Material Inputs. This is mainly caused by the high inputs required for minerals and construction materials production.

The regional case study shows that in principle, both material input (MIPS) and material output (SPI/DA) are suitable for regional (and national) assessment of sustainability. Regular assessments over time however are essential to allow comparisons over time and to discover trends in material inputs and outputs.

As for the product/service oriented approaches, and for the regional application of the indicator-methodologies, a vast amount of data over the life-cycles of products and services is needed. Another issue to be developed further is the setting of boundaries and definition of the region under study, inputs and outputs to be taken into account and to be (or not) attributed to the region.

IV. SCIENTIFIC INTEREST AND POLICY RELEVANCE

1. The physical base

The physical basis of resources use and production is the key to environmental sustainability. For this purpose, specific sets are proposed to measure the environmental impacts or performances in addition to the regular economic performance indicators. All four indicators limit the sets to highly aggregated parameters (SPI, MIPS, Exergy). Since they are based on the physical values of environment, all four indicators differ from the monetary valuation of environmental qualities based on damage costs, resource scarcity or willingness to pay.

2. Environmental goals

On the economic level, this implies for all four indicators the commitment to the concept of so called 'strong sustainability'. This notion assumes limited abilities to substitute natural by human-made capital or renewable resources, market imperfections like persistence of ineffective technologies, unpriced externalities and intrinsic values of natural qualities (amenities).

3. Materials balance

All four indicators refer explicitly or implicitly to the material balance approach which stresses the notion of mass conservation in environmental management. This notion is rather crucial in quantitative terms because the mass of inputs and outputs in the life cycle must be balanced. Therefore, according to practicability and the specific question asked, throughput can be measured on the input or the output side, but it is crucial to do it consequently, reliably and reproducibly.
All methods refer to a functional unit of activity: 'unit of service'. This requires that physical quantities are assessed in the chain of activities, preferably starting at cultivation or mining and ending with the dissipation in environment, which is essentially a life cycle approach. Clearly, the unit of service can differ. It can be desegregated towards any operational unit in a process or aggregated towards the level of a regional or national product. The common consistency is to proceed bottom up, i.e. from a desegregated level on.

4. Environmental degradation

All indicators cope - directly or indirectly - with the degradation of environmental qualities. The degrees of qualitative specifications differ between methods. All indicators assume that the measurement of the physical properties of compounds is enough to approximate the impacts on nature.

5. Eco-efficiency

The methods aim at improving effectiveness or eco-efficiency with respect to the functional unit. Therefore, whether one prefers any specific indicator or the other, each of them is directly policy relevant. Due to the different assumptions and focal issues of each indicator, any common result would mean a higher level of robustness than an outcome based on one indicator alone.

6. Quantitative approach

All methods are highly quantitative, i.e. the indicators presuppose a translation of the impacts analyzed into some quantitative terms which are the basis to provide proxies for normative policy making. The results are performed in quantitative, preferably uniform values thus neglecting some difficulties that are mentioned by the advocates of the 'post normal science', connected with system uncertainties, low reliability of basic data and untested, experts' conventions about impacts.

General remarks and observations:

The level of detail in the basic data on processes is different in each approach. The MIPS indicator requires only complete input accounts along the lifecycle. The input data are by single processing step but, aggregated data can also be used. The level of detail in SPI and PCC is more or less similar, preferably single processing step but can as well be aggregated on the sectoral or regional level. Both require data on residuals. The exergy requires a high level of detail, with respect to each single compound and process. The mass flows are on a process level and they are strictly balanced.

The meaning of indicators for policy making differs. The MIPS shows how material flows are induced in order to fulfil a specific service. Similarly, the SPI indicates what area is necessary under sustainable conditions. The exergy and PCC show primarily inefficiency of a service. Exergy indicates the physical inefficiency, pollution control costs the economic one. It is possible that large quantitative distorting effects (e.g. much mass displaced) cause limited inefficiencies, and vice versa. Similarly, the differences between MIPS and SPI with respect to effectiveness can be understood by process characteristics, e.g. low-input agriculture can cause much displacement but limited area to compensate residuals. There can be also a difference between physical and economic efficiency because of compound and process characteristics e.g. the exergy yield of PVC processing is rather high but, the residuals are costly to destroy, if needed. Therefore, the indicators are rather complementary to each other.

The relation with the environmental impact assessment differs. The relation between MIPS and Exergy with the environmental impact assessment is only indirect, if any. MIPS claims to cover not primarily directly measurable distortions of the environment, but disturbance potentials(i.e. entropy increases) that will lead to environmental damage. The relation between SPI and the impact assessment is also indirect but, it can be developed rather easily. This relation is more direct for PCC because cost accounts are made for the current and the acceptable environmental impacts.

Problems and constraints:
Regarding the application of the indicators the following issue is most relevant connected with the data requirements for the indicator calculations. A major improvement can be done by an adequate documentation of the basis data, indicators and assumptions, possibly with validation procedure to attain high quality of data and assumptions. The collection manipulation with basic data for the assessments in the life cycle is troublesome because of lacking strictly comparable mass balances, difference in the interpretation of operational units and units of services.

All that can be solved to some extent by the provision of manuals and databases giving mass data but, until now, these kinds of balances are not available for all possible applications.
The development of manuals and data bases with balanced mass data could be a feasible route for the near future. However in the long run, irrespective of the chosen indicators, the differences between producers of data need to be acknowledged and periodical updates must be made and disseminated. Another major issue is to relate these indicators with the 'conventional' indicators's work for the environmental impacts, in particular with the indicators in the framework of Eurostat. It is interesting and important to assess whether the four indicators match the environmental performance indicators. Such comparison will provide more insight in the added value of lifecycle based indicators.