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Indicators, Green Accounting and Environment Statistics— Information Requirements for Sustainable Development

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Summary

Since the "Earth Summit" in Rio de Janeiro 1992 the term "sustainable development" determines the third and current phase of environmental policy. A precise and commonly accepted definition of sustainable development (s.d.) is still missing. There are, nevertheless, some elements in the philosophy of sustainable development which—even if they are still vague—could be used as guidelines for a framework of "green" accounting and sustainability indicators. Based on theoretical considerations, the German Federal Statistical Office has developed a framework for an Environmental Economic Accounting System. The objective is to add meaningful modules to the traditional System of National Accounts which are designed to quantify the external (environmental) effects of economic activities. The framework could already be realised and published to an extent that is relevant for actual policy making in Germany.

Key words: Sustainable development; Environmental external effects.

1 Sustainable Development

The awareness for environmental problems has generally grown since about 25 years ago the first Club of Rome report and the "oil crisis" became hot spots of the public debate. Meanwhile, the perspectives from which environmental problems are discussed have been modified or supplemented considerably: within a first phase during the seventies people were primarily concerned about the depletion of natural resources, i.e. a scarcity problem on the input side of the economy. In the eighties the degradation of nature by polluting substances and waste (the undesired outputs of economy) were added as environmental themes. Since the "Earth Summit" in Rio de Janeiro of 1992 the term "sustainable development" determines the third and current phase of environmental policy. A precise and commonly accepted definition of sustainable development (s.d.) is still missing. There are, nevertheless, some elements in the philosophy of s.d. which—even if they are still vague—could be used as guidelines for a framework of environmental accounting and sustainability indicators. These elements are:

(a) Sustainability (keep capital intact!) and development (increase your income!) have to be balanced out. Neither isolated sustainability nor pure development are successful long-term concepts.

Behind that guiding principle the following characteristics are hidden:

(b) Globalisation: today's economic, social and environmental developments and problems tend to untie from national boundaries.

(c) Long time scales: cause-effect-relations of environmental problems tend to extend and to untie from periodic boundaries.
(d) Uncertainty: damages from environmental deterioration cannot be precisely measured but only predicted in terms of risk and probability.
(e) From an economic point of view environmental damages are caused by external effects of individual production and consumption decisions, and they often affect natural elements which have the character of public goods.

The tools for diagnosis (statistics, science) and therapy (politics, science) have to be selected with respect to the size and character of the problems. Global issues must not be treated with measures which have been developed for local or regional questions.

(f) Traditionally environmental politics used command and control instruments. As in sustainability problems are very complex, those instruments have partly to be substituted by economic instruments (e.g. tradable permits or eco taxes).

Closely connected to s.d., but independent, is the call for an integrated assessment of environmental issues. The separation of environmental problems in isolated (political and scientific) boxes is seen as one of the major obstacles for further progress in that field.

(g) From the cradle to the grave: outputs of residuals stem from inputs of resources. Depletion and degradation must not be seen separately. Even if the objective is to reduce pollution, it is necessary to start preventive politics at the input side of the society, i.e. at the consumption of raw materials and energy. Furthermore, a systematic approach has to be followed when it comes to the inventarisation of nature (bio-diversity, etc.).

Achievement of sustainability objectives requires resource management to assure the maintenance of essential environmental functions as well as economic capital stocks. In this way, the legacy of the past—natural and economic capital—is transformed into the welfare base for the future, laying the foundation for a high and sustainable national income (Radermacher, 1994; Bosch, Brouwer & O'Connor, 1997; Faucheux & O'Connor, 1997). Economic resource management must then fulfil two complementary functions: the delivery of an ecological welfare base through assuring maintenance of key environmental functions; and the delivery of an economic welfare base through production of economic goods and services.

Summarising: the typical mix of insustainability consists of external effects, public goods, a global context, slow processes, complex systems and uncertainty. The consequence is that the requirements from sustainable development cannot be simply fulfilled with a statistical accounting concept which has been tailored for market goods, national economies, short term processes and which is based on a linear descriptive model. Finally, an integration of sustainability problems would cause not only marginal but structural changes of the core (market) system. It would, therefore, not be realistic to assume that an easy adjustment by subtraction of some correction values could solve or reflect problems of that size in an appropriate manner. S.d. can only be defined and achieved by a complicated restructuring process of the society including the fact that the final results of that process cannot be anticipated by (scientific) assumptions and (statistical) surveys or estimates.

2 Determination of the Statistical Concept

2.1 Objectives of Indicators for Sustainability

Consequently, the quantitative results of "Environmental Economic Accounting" or "Sustainability Indicators" (SCOPE 1996) must be interpreted as representations of possible margins for the manoeuvre to sustainable development, and inputs to policy debate in this sense. This reflects the fact that the validation of analysis for policy support depends not only on standards of theoretical rigour and internal coherence, but also on external societal considerations (see O'Neill, 1993; Holland, O'Connor & O'Neill, 1996). It is convenient to distinguish five broad sets of considerations which are interlocking:

- scientific adequacy: do the description and evaluation methods deal well with the important features of the natural world and its characteristic processes of change?
- social adequacy: do the methods furnish information in ways that respond to stake-holders' needs which support social processes of decision making?
- economic rationality: do the suggested courses of action that emerge from the valuation process respect economic efficiency, in the sense of appearing to be a reasonably cost-effective way of arriving at the envisaged outcome?
- statistical adequacy: are the empirical measurement and subsequent aggregation procedures consistent with the guiding theoretical precepts, and do they conform to norms of reliability, coverage or representativeness?
- budgetary realism: can the proposed approaches be expected to yield reliable and useful information (judged in terms of the four sets of considerations above) within the limits on resources that can be committed to the research?

The bringing together of scientific, social, and economic considerations in real time, as a sort of interdisciplinary dialogue, social learning and conflict resolution process, furnishes a basis for prioritising and revising actions in the environmental domain.

2.2 Multiple Criteria Decision Support for the Development in Complex Systems

The behaviour of complex systems like nature and society cannot be completely predicted. On the contrary: feedbacks and nonlinearities may lead the development of such systems through abrupt changes or through partly stable situations towards surprising new positions. Hence, it would not be realistic to expect from scientific models or statistical figures that they are able to mirror the structure and development of those systems perfectly. This is a matter of principle and not only because of a marginal lack of capacities, etc.

An important precondition to understand complex systems in a more sound sense is the distinction of hierarchical scales (see Müller, 1992). A society and an economy consist of many layers which participate in the decisions and drive the development forward. For simplification figure 1 illustrates only three types of these layers. The acting subjects within those layers are mutually dependent: politicians depend on their voters, market subjects on regulations of the government, etc. That means firstly that the description of such a system which is restricted to the perspective of one specific layer tends to be biased. For instance, the traditional point of view of engineering and environmental protection is distorted in the sense that it is implicitly assuming that there is an almost omnipotent manager on the macro (government) level which at the same time has in his hands all the necessary information. Contrary to that position, mainstream economic theory is micro oriented which means that it assumes that all decisions can be derived from individual utility functions ("preferences count!") and management rules which follow theoretical models efficiency. It seems that none of these two positions can reflect the actual form of decision processes in a society at least approximately.

If it comes to the question how sustainability can be defined and which tools can be used to steer the process of society's development into a more "green" direction, these assumptions concerning the decision processes are highly relevant. On the one hand it would be of no value to set targets which are out of reach for the actual status and potential development of a society. On the other hand a fatalism, which only believes in pure market power does not take into account that there are legislative rules or other (even informal) regulations which define the limitations of individual decisions and

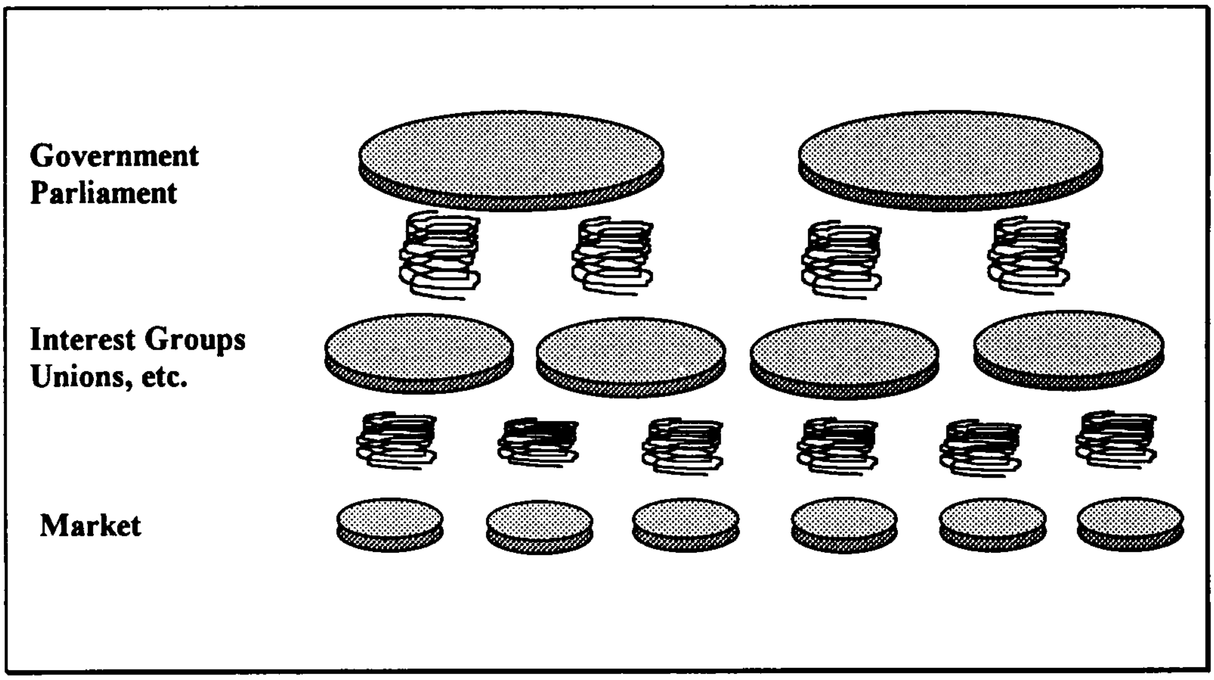

Figure 1. *Scales in the decision processes of a society.*

which emerge from social debate on higher levels in the political hierarchy. Development towards sustainability, hence, is a result from processes in the self-organising and complex system of society.

2.3 Statistical Capability: "Trade-offs" Between Data Quality and Boundary Conditions

Information plays a major role in the development of complex systems. It influences the direction of the development and it acts as an interface between the various layers and groups within the system. Information about environmental damages leads to new political debates, to new rules or to a new system of taxes, price regulations, etc., and finally to changes in economic decisions. So far, information is a precondition for any type of politics. However, it must not be neglected that information itself depends on the status of the system. Or, simply speaking: the production of information needs money which has to be spent by society. Hence, we find ourselves in a circular argumentation (see Radermacher, 1994): obviously, a society with low awareness of environmental problems will have a low willingness to pay (WTP) for environment statistics and will set low environmental standards. In such a situation it is unrealistic to suppose high quality of statistical information. Hence, the beginning of the story is "poor information" which, however, must be oriented towards improving the awareness, which then leads to higher WTP and standards, and so on.

Data quality consists of some components which are all relevant for the question (see Radermacher, Schäfer & Seibel, 1995): does the figure measure what it is expected to measure? First of all the equivalence of theoretical terms (e.g. income in economic theory) and statistical definitions (income in a specific survey) is most important. However, in addition to that correspondence there are in principle, some factors which determine the suitability of statistical figures: are the data up-to-date? Does the classification provide enough detail? Are the results reliable? The aggregation of all these interrelated factors is called "validity" which is a complex definition of data quality.

It is essential to understand that statistical figures—like other economic goods—can be produced and delivered in very different quality and with very different costs. Hence, it is a task for negotiations between data producer and data user to find out an "optimal" quality: the quality of a working system

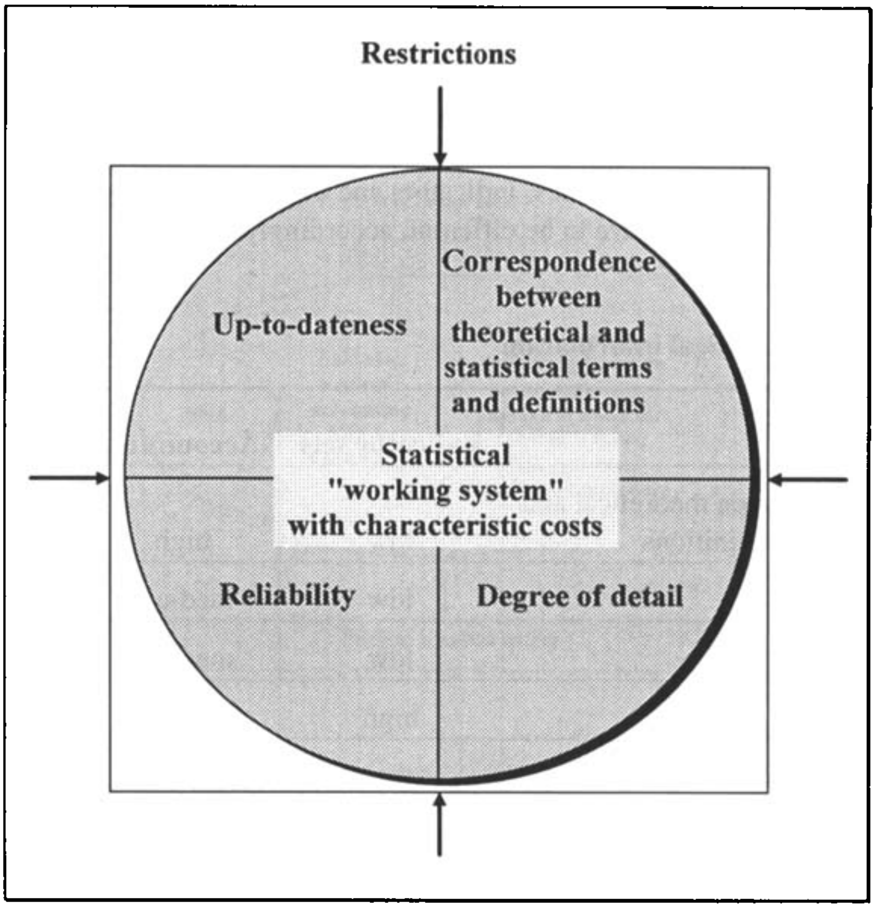

Figure 2. *Components of a statistical "working system".*

can only be enlarged if the necessary budget is available. This point is of higher importance to the extent that it stresses the fact that a conceptual framework also has to reflect the actual financial capability, administrative restrictions, etc. In a realistic description of today's situation one must suppose that the budget is too short to fulfil all requirements of all users. Hence one has to decide where to save money. A trade-off between different components of validity is unavoidable. A conceptual framework that can be useful in practice has to reflect not just theoretical criteria of coherence but also actual financial capability, administrative restrictions of implementation etc. It would be without practical and political value to elaborate a theoretically sophisticated concept which cannot possibly be fulfilled with real data. Limited budgets for green accounting and indicators represent society's small collective willingness to pay. It is evident that, under these conditions, the first concepts and figures produced must be far from being perfect. But again, it seems to be important to understand this as a starting point within a dynamic political process. Creating awareness for the general potential of green accounting and sustainability indicators can aim at improving the budget which again allows to provide better quality, and so on.

2.4 The Menu of Environment Statistics

Before we will briefly outline the concept of the German Environmental Economic Accounting it is necessary to remember the specific role of statistics within the processes of societies towards sustainable development mentioned. Statistics provide quantitative (ex post) models of the actual situation. Their task is not to set standards/political targets and their task is neither to simulate future/hypothetical situations. Hence, there is a need for a close co-operation between statistics, scientific research and the political setting of standards. Furthermore, there are different working areas within statistics which must be well co-ordinated: basic statistics, accounting and indicators. In particular with respect to the very limited financial and personal capacities, it seems to be unacceptable that double work would be done in the development of basic statistical systems, accounting concepts and indicator sets. Basic statistics, indicators and accounting provide information for different utilisations. Their qualities have to be different, accordingly:

Quality profiles of statistical information

Quality aspect	Indicator sets	Accounting	Basic statistics
Correspondence between theoretical and statistical terms and definitions	low	high	high
Degree of detail, scale	low	medium	high
Reliability	low	medium	high
Up-to-dateness	high	low	different
Comprehensiveness with respect to a complex issue	high	high	low
Systemic basis of the concept	low	high	low

Frequently, the three different types of statistical approaches are interpreted as three levels of an "information-pyramid" (Hammond, 1995). Since indicators are not necessarily linked to a high level of aggregation, this metaphor is not entirely sufficient from the viewpoint of statistical methodology. Nevertheless, it seems to be applicable and meaningful for sets of macro-indicators, like the environment indicators of OECD, vs. accounting systems, like the SEEA, and frameworks of basic statistics, like the FDES (see Bartelmus, 1997).

Separate user groups and user needs require a menu of statistical data which observe one specific item from selected angles. In that context, accounting can and should be used as a tool to improve consistency and performance of the production and analysis of statistical figures in general. To fulfil this broadly defined function in the field of environment-economy-interactions, an accounting approach must not be restricted to an extension of the rigourously formal rules of national economic accounting. Only a minority of environmental themes can be pressed meaningfully into a linear scheme of opening stocks, flows and closing stocks. Consequently, an environmental accounting system has to be constructed on the basis of a wider set of methods. The challenge of such a modular and pluralistic approach is then to find a balance between conceptual consistency on the one hand and a reflection of the reality on the other.

Consequently, it seems to be meaningful to distinguish between a narrow set of environmental accounts, being in line with the main concepts and formal rules of national accounting, and a set of tables, accounts or even maps which are more loosely linked (via identical classifications, accounting units, etc.) to the System of National Accounts (SNA). The SNA itself should integrate those environmental goods which are of short-term and national economic interest (in figure 3 this is indicated by an asterisk). It is obvious that this proposal is different from the actual SEEA handbook (United Nations, 1993) in the sense that it underlines the limitations to providing answers to environmental problems from the very beginning. A consequence of this is to deny the existence of an "Eco-Domestic Product" which is meaningful, descriptive and comprehensive. Being less

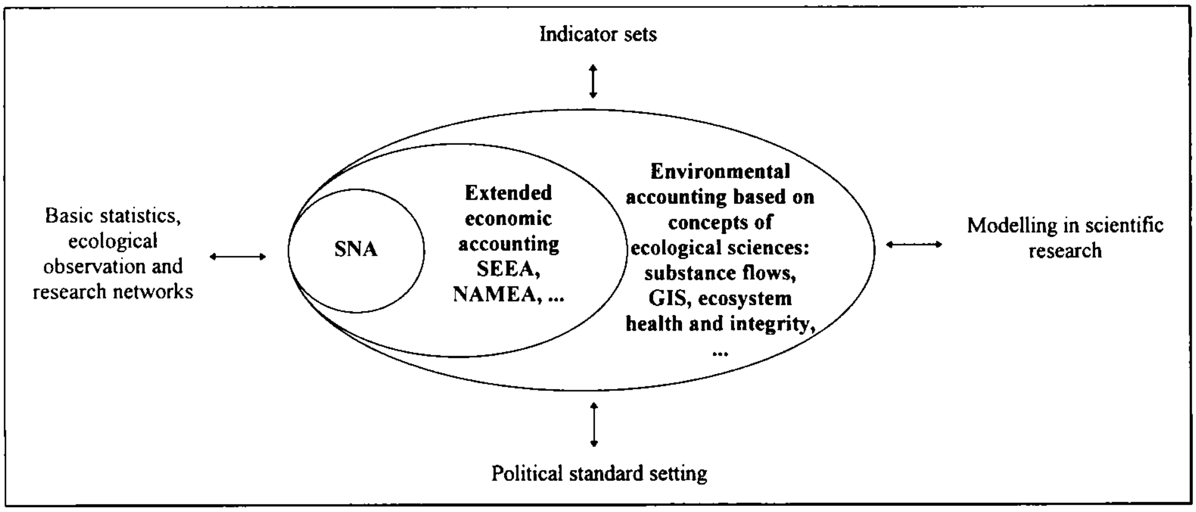

Figure 3. *Scope and context of environmental accounting.*

ambitious concerning the endogenous monetarisation of environmental elements, this approach emphasises the major role that accounting can play as part of actual decision processes. It opens the door for complementary modules where the SEEA—being closely linked to economic accounting—has limitations. Those shortcomings are, in particular, the dominance of the national scale (global or regional issues can rarely be integrated), qualitative changes (biodiversity, etc.) and changes in distributions (e.g. spatial restructuring). Nevertheless, the SEEA already provides a framework of modules with high importance for the implementation of green accounting systems in National Statistical Offices.

2.5 The Valuation of Nature

After having elaborated the role of information within the decision processes of societies, it seems evident that the question how to put values on natural goods and services, has to be solved accordingly. At the beginning stands the generally accepted understanding that environmental functions are scarce. However, though scarcity of environmental functions definitely exists, it cannot be quantified in a direct manner, because there is normally no market where, for example, climate and biodiversity units (or the respective services they provide for the economy) are traded. Consequently, if ecological elements cannot be traded themselves corresponding economic goods have to be constructed which are able to represent them as realistically as possible. Keeping natural capital intact is the fundamental objective of sustainability. Within the world of economic accounting, the Hicks' income concept represents the same axiom (constancy of capital). The meaning of constancy has to be specified in the form of quality goals. These goals have to define what is interpreted as "constant" concerning the complex dynamics of ecological systems. Obviously, this is primarily a task for natural sciences and political decision processes. Given that such quality goals have been set (on a local, national and partly on a global level), the next question is what they mean for the activities in a specific country and period of time. An answer to this question can only be given by negotiations about the distribution of "rights to pollute" between the different countries. The results of those negotiations then can be called "sustainability standards". They define targets in terms of emissions and are oriented towards the economic activities and the origin of the environmental burden. Sustainability standards correspond to "rights to pollute" in a specific country and period of time. Under the precondition that economic measures are selected for the realisation of those standards, they define economic goods and economically measurable scarcities. Hence, there are two problems to be solved before an economic evaluation can take place:

- the identification of anthropogenous impacts within the complexity of ecological dynamics, definition of quality goals (stock oriented!), and
- the synchronisation of spatial and temporal scales, definition of sustainability standards (flow oriented!).

This is the first chapter of the story. Obviously, it has not been written in the philosophy of neo-classical economics and optimal growth theory. Whether neo-classical models can provide some support for this debate can, however, be doubted (Daly, 1992).

2.5.1 The micro-economic evaluation

Sustainability standards (rights to pollute) define scarcities in an absolute sense. The price of those rights could (in principle) be detected on real markets by the emission of tradable permits. In theory the price can be deducted from a micro-economic model (figure 4). It has to be pointed out that in this model the sustainability standard can be interpreted as a kind of supply function (the supply of rights to pollute), whereas the marginal cost curve corresponds to the aggregated micro-economic costs of the demand side. Under the assumption that the standard can be achieved by improvements of technologies this model represents the short term equilibrium on separate markets of emission standards. Abatement costs can then be interpreted as indicators for the distances to goals. In a retrospective calculation they represent monetary equivalents for negative external effects caused by economic activities of the period and country under consideration. These indicators are a first iteration towards a corrected national income figure.

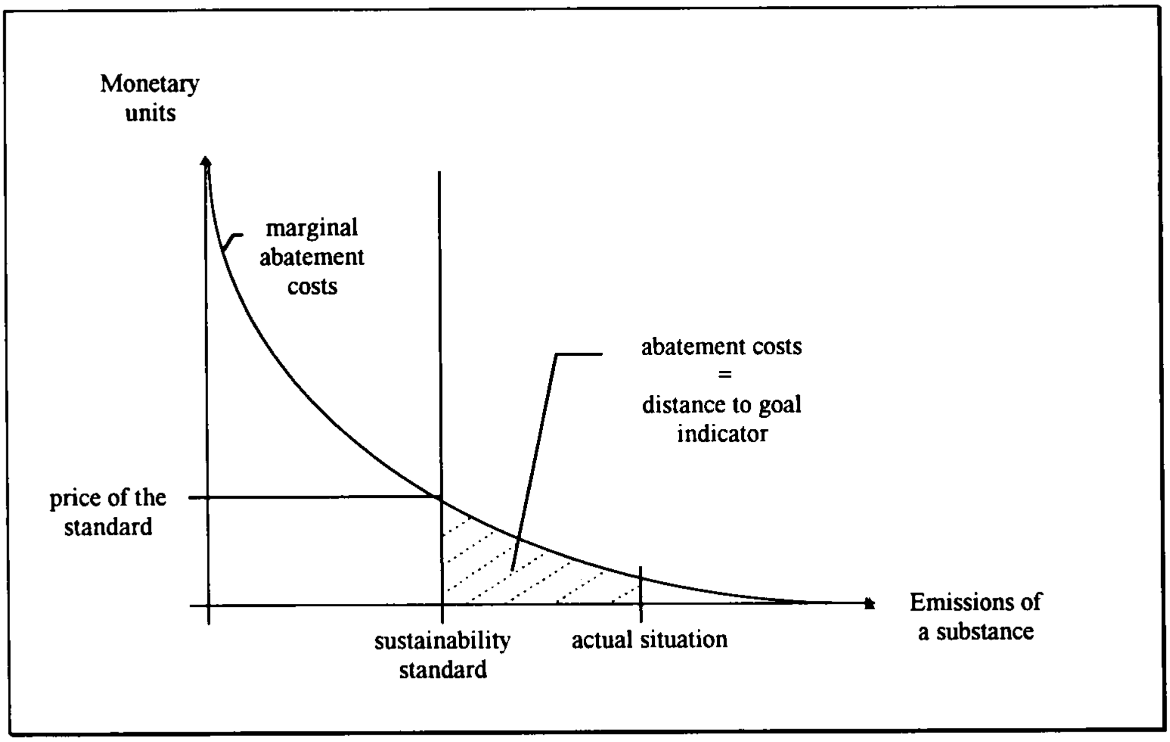

Figure 4. *Micro-economic abatement costs.*

An "Eco Domestic Product" (EDP) could, in principle, be calculated by a simple subtraction-procedure of all these indicators (= adjustment of the calculation of national aggregates). Because of a lack of finances and relevant data sources, such a calculation can in no way be comprehensive. Furthermore, the meaning of such a calculation is very arbitrary and vague. It can therefore not be recommended as an "official" statistical figure.

2.5.2 *The macro-economic evaluation*

It is evident that the micro-economic approach is not sufficient for an adjustment of national income figures, if considerable indirect economic effects have to be taken into account. The adequate conceptual approach seems to be a simulation of an economy which has (hypothetically) integrated the additional set of products (rights to pollute), defined by the sustainability standards. Such a modelling approach should start from the short term prices of standards and tackle the problem of structural changes. Again, the problem of scale (spatial and temporal) plays a major role for the design of adequate models (see Meyer & Ewerhart, 1998). The result of this modelling approach could be an EDP which is defined as the Gross Domestic Product (GDP) for a hypothetical sustainable economy (= calculation of national aggregates for adjusted economies).

2.6 *A Note on International Trade and Unequal "Ecological Exchange"*

Within the concept of sustainability the aspect of global interlinkages between national activities plays a major role. The Rio Conference 1992 for the first time linked two separated policy fields: environmental protection and development aid. Global environmental problems can be properly treated only on a global political scale and with an explicit internalisation of social and economic aspects in developing countries. Hence, it must be an important task for a statistical concept of green accounting to represent the international trade in different categories of goods and services and the corresponding "trade"—actual or imputed by origins—in environmental burdens. A purely national focus could lead to completely wrong signals and conclusions. A highly developed country with an essential share of service industries, banks, insurances, etc. may look perfectly sustainable in a separate national ecobalance because it has succeeded in exporting the polluting production industries. The statistical trends over the last 30 years are, in fact, widely in accordance with such a pattern of "unequal" development: an increasing amount of total international trade combined with a decreasing share of imports of raw materials into the industrialised countries and a decreasing share of toxic pollutants.

The treatment of this item in a statistical system has to start with the physical side. In addition to balances of domestic material/energy flows and land use changes, the corresponding effects have to be calculated which are linked with imports and exports of raw materials and goods. Ecological "rucksacks" can—in principle—be calculated by a combination of life cycle analysis (for the pressures of the excavation/production of raw materials) and input–output analysis (for the international trade of goods, which are already composed of different raw materials). Since international input–output tables which are up-to-date and of high quality are not available, this sort of work is still in a very early state of development. In Germany, for instance, some institutions have established a working group for co-operation in material and energy flow accounting, including particularly international trade.

The monetary side of the problem is even more complicated and still has to be elaborated conceptually. Some guidelines seem to be clear, however. Starting with the easier (and from the ecological point of view, more attractive) scenario that green accounting would be implemented all over the globe, it seems reasonable to set the flow standards with respect to the direct pressures of economic activities. This is equivalent to the assumption that indirect pressures connected with intermediate consumption were already taken into account within the preceding production activities (and internalised as cost elements). In this framework, each country is responsible for its own production sphere. Consequently, the international negotiations of pollution permits have to consider the contribution of countries to the global production of goods. This seems to be an utopic requirement. The alternative, however, seems to be even worse: a concept which would be based on (global) cumulative pressures per activity would presuppose that a cumulation of gross pressures which are induced by an activity could be carried out, with high quality and without any double counting, etc. Evidently, this is by no means a realistic assumption. However, the consequence of a "net" concept is that a separate monetisation of external effects in one country cannot be a sufficient solution for global sustainability. It is therefore (again) necessary to complement the monetary accounts by physical accounts showing the international interlinkages.

3 The Framework for Environmental Economic Accounting

Based on these theoretical fundaments, the German Federal Statistical Office has developed the framework for a "Green" Accounting System (Radermacher, Schäfer & Seibel, 1995; Radermacher, 1998a/b; Radermacher & Stahmer, 1998). The objective is to add meaningful modules to the traditional System of National Accounts which are designed to quantify the external (environmental) effects of economic activities. Figure 5 describes the different modules and their relation to decision making and target setting.

In Germany, the collection and evaluation of environment related data has already a long tradition. Basic environment statistics (waste, water and environmental expenditures) have been carried out since the early seventies (Baltes & Nowak, 1974). Geographical information systems and remote sensing are applied for land cover/use statistics since about ten years (Radermacher, 1993). The concepts of satellite systems in the field of environmental accounting have been developed by accountants of the Federal Statistical Office in the eighties. Since 1989, there has been a special division for "German Environmental Economic Accounting (GEEA)" in the department for economic and environmental statistics. This new division is now responsible for the whole field of integrated economic and environmental accounting. The framework could already be realised and published to an extent that is relevant for actual policy making in Germany. However, the questions of aggregation and evaluation are in a stage of research and development.

3.1 Methodological Concept

German Environmental-Economic Accounting has been set up in such a way as to provide answers to questions of economic and environmental policy at every stage on the way to the final system. For evaluating the efficiency of natural resource handling within the framework of structural and environmental policy, it is of fundamental importance to know how the use of raw materials, energy and land changes within the sectors of the economy over time, and what, in contrast, the emissions into the natural environment turn out to be. Highly aggregated indices of the state of the environment indicate qualitative changes in a standardised form and reflect the effects and benefits side of environmental protection measures. The costs side and the current burden on the economy is recorded for environmental protection activities which are actually being carried out. Abatement costs of additional preventive measures complete the picture, helping to weigh different "standards" (target values) for individual serious pressure factors against each other and to decide in favour of one of them. Figure 5 presents the entire concept of the German Environmental-Economic Accounting.

As indicated by the different symbols, the various subject fields are characterised by a pluralism of specific methods: in some subject fields methods of economic statistics and accounting are used to balance the material flows caused by the economic sectors and the environmental protection activities

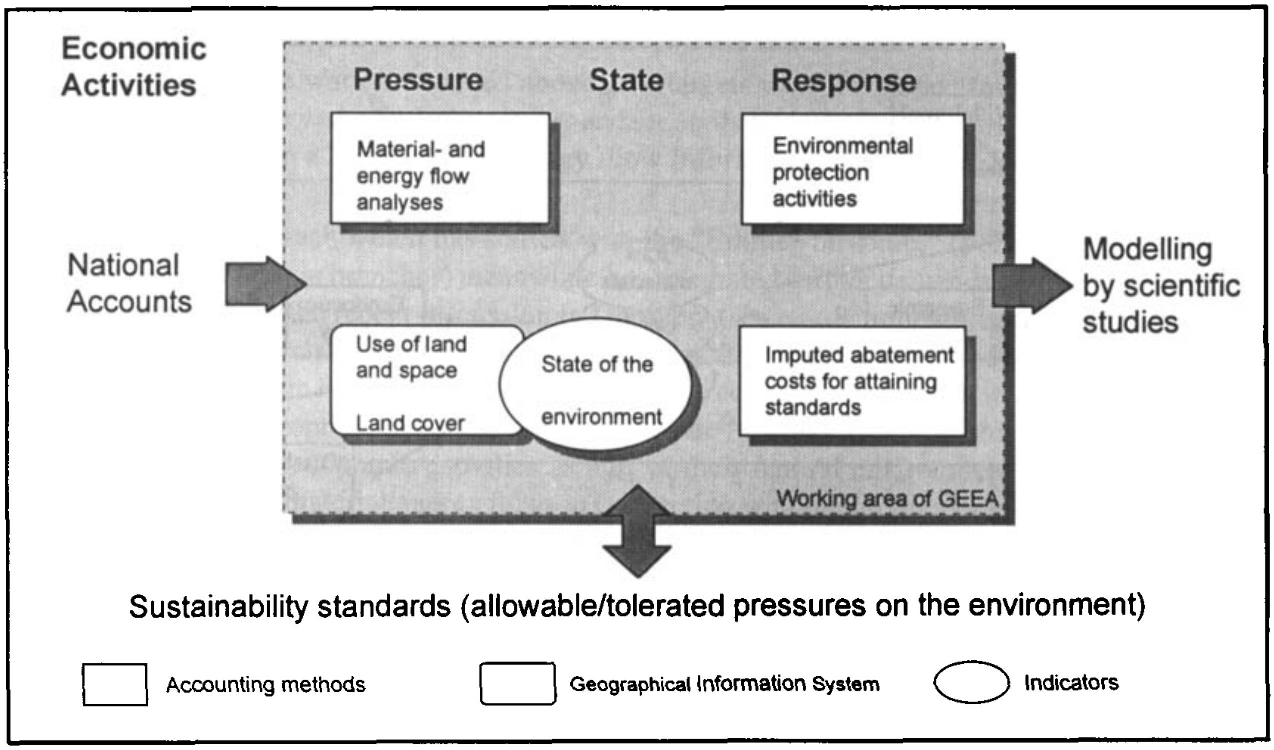

Figure 5. *German environmental economic accounting.*

taken. In those subject fields dealing with immaterial pressures and physical restructuring arising from a modified distribution of land uses, physical intervention, etc., the methodological instruments used are remote sensing and geo information systems. Finally, in the subject field "state of environment" the objective basically is to condense measuring and monitoring data, which are available in an isolated form, both with regard to space and contents, so as to provide suitable indicators. The entire working area of Environmental-Economic Accounting does not include the setting of standards. For establishing such standards, however, information from Environmental-Economic Accounting explicitly aims at providing factual data, where available, on costs and benefits of alternative standard values for the process of political decision-making.

3.2 One Selected Issue: Material and Energy Flow Accounting

As a methodological part of GEEA, the material and energy flow analyses use the natural sciences as a background to enlarge the material flow concept of the economy into the "industrial metabolism" (see Baccini & Brunner, 1991; Ayres & Simonis, 1994; Strassert, 1991).

Characteristics of the concept are (see figure 6):

- Nature is taken into account by putting an additional asset/stock account both on the input and the output side of the system of national accounts.
- The border between the economy and nature is defined explicitly: raw materials are extracted from the nature and residues are discharged into nature.
- The vector of goods and services in the system of national accounts is supplemented by raw materials and residues.
- The material and energy flows within the system borders (e.g. domestic economy, activities of production and consumption, technical processes) are calculated by taking the law of conservation of material and energy into account.

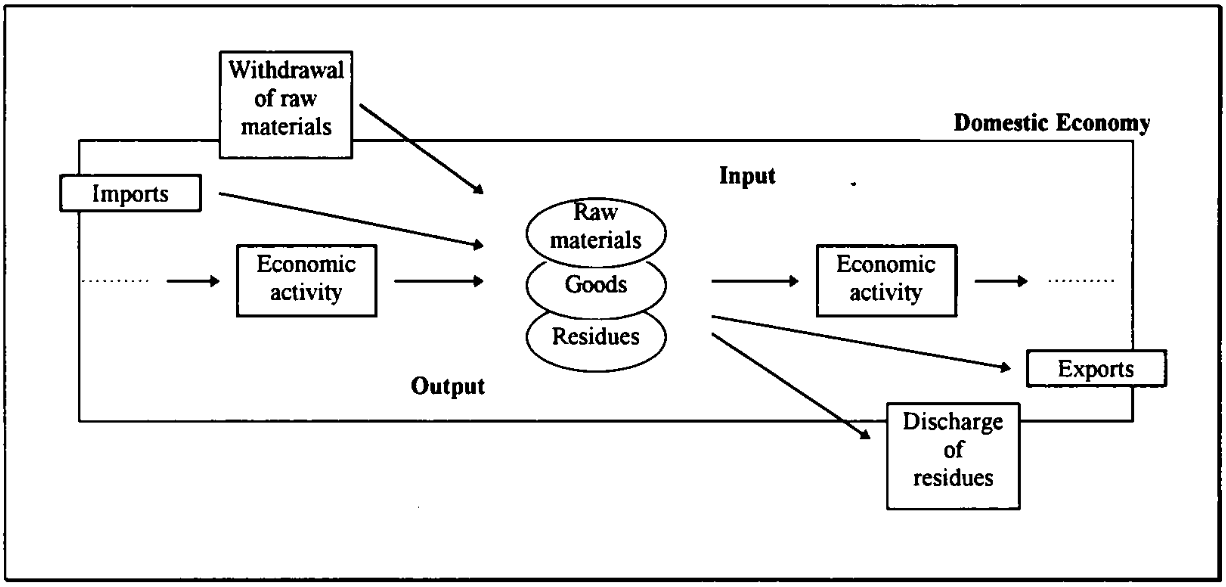

Figure 6. *Material flow through the domestic economy.*

Within the system borderlines, raw materials (material and energy) will be transformed into products or groups of products and environmental burdens e.g. air emissions, waste and waste water. Depending on the system borderlines, economic activities can be interpreted as a technical network aiming at the production of goods and services. In relation to GEEA, it is relevant to cover the material and energy flows caused by activities of the domestic economy (Radermacher & Stahmer, 1998).

The results of material and energy flow accounts in Germany are based on previous work e.g. the investigation of the consumption of raw materials (Radermacher & Höh, 1993) and the structure of air emissions for branches (Thomas 1996). They are preliminarily comprised in the publications of material and energy flow accounts (e.g. StBA, 1998). On the highest level within the hierarchy of accounts, the total material flow through the entire economy is quantified for 1960, 1990 and 1994 for Germany, which represents the withdrawal and the discharge of materials in total ("economic metabolism"). Detailed information of the environmental-economic trends for the former territory in these years can be gathered from the publication by Kuhn, Radermacher & Stahmer (1994). Such an expression of material flow accounts is also published regularly in the Statistical Yearbook of the German Federal Statistical Office (e.g. StBA, 1997). With a similar approach, the resource flows for four important industrialised countries (Germany, Japan, the Netherlands and the United States of America) was recently published (see WRI *et al.* 1997), which opens the possibility to compare the material flows in those countries.

Furthermore, for the first time a complete Physical Input–Output-Table (PIOT) for 1990 has been set up which brings together the material accounts of the domestic economy e.g. raw materials extraction, flows of commodities in the production and consumption activities, and discharge of residuals (air emissions, waste and waste water) into nature (Stahmer, Kuhn & Braun, 1997). In this account the activities of the domestic economy (former territory of the Federal Republic) are divided into 58 branches of production, an additional branch of environmental protection activities (including recycling) and consumption activities of private households. The tables also show in physical units the inputs and outputs of gross fixed capital formation (equipment and construction), stocks and nature. Nature serves the domestic economy with raw materials and at the same time absorbs residues from the economic activities. The material flows are broken down by nine types of raw materials, 49 groups of commodities and eleven sorts of residues.

On the basis of the work mentioned above, two targets were developed for the next steps: firstly improving the data on waste and waste water and secondly bringing together all the results of material and energy flows into a Material and Energy Flow Information System (MEFIS; see Radermacher, 1998a).

The German approach which has started with the "Emitter-Structure" (polluting substances in a breakdown of economic branches) meanwhile has integrated further demands from another group of users. Stimulated by the recent discussion in Germany (see e.g. Schmidt-Bleek, 1994) and Austria, (see e.g. Fischer-Kowalski, *et al.*, 1997) it became clear that a set of purely "reductionistic" indicators which measure specific impacts at the output side of the economy is not sufficient as decision support for a preventive environmental policy. A more "holistic" view is needed enabling us to describe the "physical reality" of economic activities as part of their natural environment in order to improve the understanding of material/energy flows in connection with the production of goods and services. These analytical goals require a higher degree of integration and consistency (in a physical sense). Hence, it was necessary to adjust the methods of material flow analysis which so far had been developed and used for single products/substances (a micro-economic perspective) for an application in a macro-economic context. An adjustment is needed, since it is by no means possible to quantify all material flows of an entire economy with that degree of detail and that preciseness which is state-of-the-art for instance in substance flow accounting. A specific quality mix of information has to be determined.

Two examples may exemplify this: firstly it has to be decided how to deal with a very complex reality, i.e., how to reduce and to simplify complexity in order to achieve measurability? Material flows through an economy are a complex matter as they imply multiple hierarchical scales which can be taken as reference points for an observation (scales of economic units, scales of regions, scales of substances, etc.). Even if we decided to account only for flows through the total economy and the entire national territory, we would still have to determine which materials or substances had to be integrated. This depends on the selection criteria which again are a function of a widespread understanding of environmental relevance. In Germany it has been decided to follow a top-down-approach, starting from the total of material and energy flows and then trying to distinguish those flows as far as possible with respect to their economic, environmental and regional relevance (see figure 7).

Secondly, the borderlines of the accounting system have to be defined. Here we have decided to delimit the system "economy" in correspondence to the physical flows. That means that a flow between two economic activities is part of the economy even if this flow has no economic value (e.g. the discharge of sewage water into the drainage system).

3.3 Availability of Data on Environmental Burdens

As part of the material and energy flow accounts, three types of environmental burdens are examined on the output side: air emissions, waste and waste water. The calculation method for air emissions is based on the energy balance, which is compiled by the working group "energy balance", and on the technical emission factors determined by the German Federal Environment Agency (UBA). This method is largely standardised. Compared to that, the method to calculate the amount of waste and waste water is in the development stage, and was used for setting up the first Physical Input–Output-Table in Germany. Basic data for this method are mainly the statistics of the German Federal Statistical Office; the statistical data on waste and waste water are ascertained as a rule every three and four years, respectively. Because of the different times of ascertainment, it is at the moment not possible to show the material flows in all the three areas of environmental burdens

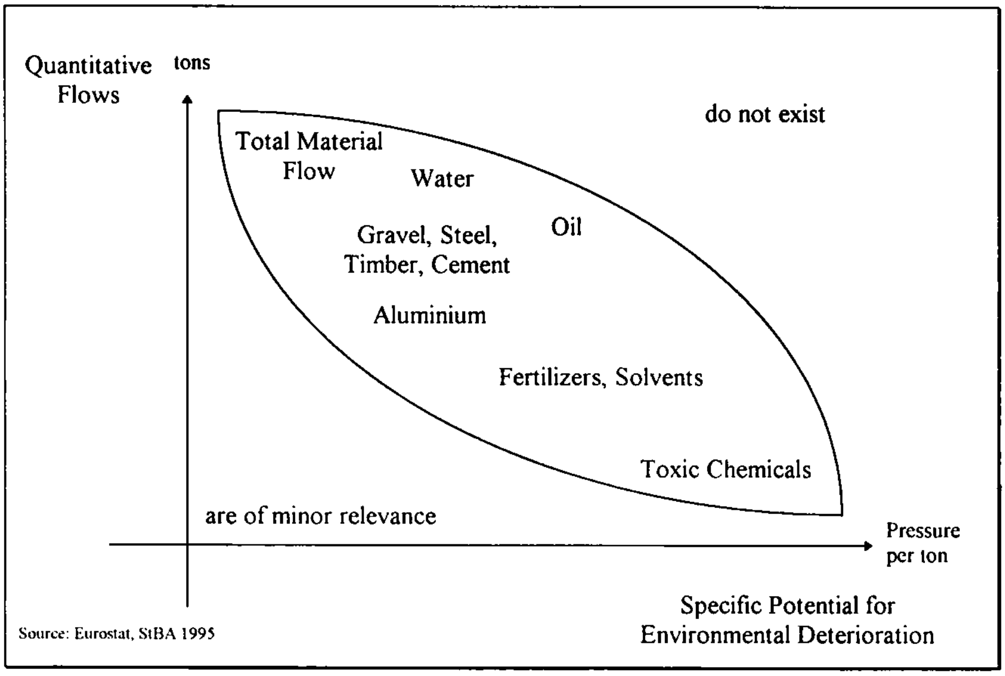

Figure 7. *Scales of material and substance flows.*

for the same year. In this context a method to assess the amount of waste and waste water for a specific year or in a time series has to be developed. A corresponding study on waste is carried out at the moment; the result of this study should make it possible to assess the amount of waste in various categories.

The following types of direct and cumulative air emissions were calculated for the most important branches and the private households for 1993 (Germany): nitrogen oxide NO_X, sulphur dioxide SO_2, carbon dioxide CO_2 , methane CH_4, dinitrogen oxide N_2O, carbon monoxide CO, particulate matter and NMVOC (non methane volatile organic compounds). Cumulative emissions are calculated as the sum of direct and indirect emissions. The investigated emissions from the processes are the direct result of a specific economic activity of a branch, and therefore they are defined as direct emissions. The emissions resulting from the domestic or foreign production of intermediate goods (included is also the purchase of electricity from suppliers) are defined as indirect emissions (StBA, 1997a).

3.4 The Linkage of Indicators and Accounting

3.4.1 An example: indicators for greenhouse effect and acidification

Environmental indicators are calculated by aggregation of physical pressures within the same category of effects or environmental subjects, respectively. As a rule, the physical flows of a given effect are aggregated by multiplying them by a corresponding equivalent factor. On the basis of the available data on air emissions the indicators of greenhouse gases and acidification were calculated, following the recommendations of the International Panel for Climatic Change IPCC (StBA, 1997a). To calculate the indicator of the greenhouse effect, the air emissions of CO_2, N_2O and CH_4 are weighted and aggregated on the basis of $CO_2 = 1$. This means that the quantity of N_2O emissions is 320 fold and the quantity of CH_4 emissions is 24.5 fold compared to CO_2 emissions. The result is the greenhouse gas emission expressed in CO_2 equivalents. To calculate the indicator of the acidification effect, the air emissions of NO_X and SO_2 are aggregated on the basis of $SO_2 = 1$ by multiplying the quantity of NO_X by a factor 0.7.

3.4.2 Results

By means of environmental accounting, direct air emissions of greenhouse gases and acidification gases as well as their cumulative emissions can be connected with the related economic figures of gross value added at market prices and gross output. Regarding the direct emissions, both value added and the number of persons employed can be presented. Four fifth of the greenhouse gases in Germany—with a total amount of more than one billion tonnes—are emitted by production activities. This share is even higher in the case of acidification gases with a total amount of five million tonnes. Three quarters of the direct emissions of greenhouse gases and acidification gases from all production sectors are caused by just six production sectors. Less than five percent (greenhouse gases) and less than three percent (acidification gases) of the respective air emissions from production activities are emitted from each of the other production sectors.

Generally, only a few production sectors are responsible for the largest quantities of the direct emissions and so contribute the largest shares to the respective environmental effects. At the same time, the effect of those production sectors on employment (share of employed persons) and on economic performance (value added) is in inverse proportion. The exception to this rule is constituted by the government services. Their share in the emissions is also comparatively high, one of the reasons being their activities in waste disposal and waste water treatment. Their contribution to value added and their share of employed persons exceeds their contribution to the direct greenhouse effect as a result of their main activity being services.

The general attempt of such kind of calculations is to extend the economic functions of production and consumption by an integration of environmental indicators. Although the results are presented in a combination of monetary and physical information, they can be used as an input to political decision processes. Their major value added in comparison to isolated environmental indicators is the potential to quantify the ecological effects of economic activities and, *vice versa*, the economic effects of environmental policies. Furthermore the results can be used to improve dynamic modelling on the field of environmental economics (Meyer & Ewerhart, 1998).

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Résumé

Depuis la conférence mondiale de Rio de Jaineiro en 1992 le "development durable" est le mot clé de la troisième phase de la politique de l'environnement. Il n'existe cependant pas encore une définition précise et largement acceptée du développement durable. Il est quand même possible de dégager quelques éléments d'une philosophie du développement durable, qui—bien qu'encore vagues—peuvent être utilisés comme cadre de référence pour les "comptabilités vertes" et les systèmes d'indicateurs de développement durable. A partir de ces considérations théoriques, l'Office Fédéral de la Statistique en Allemagne a développé un cadre de Comptabilité de l'Economie et de l'Environnement. L'objectif de ce système d'information est d'ajouter à la comptabilité nationale des modules pertinents qui quantifient les effets externes de l'activité économique. Le système est en partie déjà réalisé et des résultats importants pour la politique de l'environnement en Allemagne sont régulièrement publiés.

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