Commentary Articles

Ecometrics

Identification, Categorization and Life Cycle Validation

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Abstract

Indicators which reflect environmental, economic, health and safety issues, have been categorized as microecometrics and macroecometrics. The former, generally flow based measures, have been developed for local, firm-wide or product based assessments. Microecometrics include materials intensity, energy consumption and emissions data, often from life cycle perspectives. They are, generally, intensive and are scaled with respect to unit of production, GDP or per capita, though other normalization factors have been proposed. In contrast macroecometrics tend to be extensive and represent global conditions such as temperatures and environmental concentrations. Ecometrics are subjective and reflect the dominant value of the individual, family unit, stakeholder group or firm. As such overaggregating or reducing the number of ecometrics for given applications, such as the rating of investments or access to credit, presents potential conflicts. Furthermore, while eco-indicators used for internal corporate reporting should not, necessarily, be validated, those microecometrics which involve external reporting, or multiple stakeholders, are arbitrary if not derived from, or based on, comprehensive life cycle approaches.
This paper summarizes ECOMETRICS'98, a workshop held in Lausanne, Switzerland in January 19-20, 1998. It discusses ecometric needs of various users including consumers, designers, private sector decision makers as well as politicians and policy makers. A discussion regarding appropriate microecometrics for industrial sectors including chemical, pharmaceutical, insurance, finance, electronics, manufacturing and consumer products is also summarized.

Keywords: Eco-Indicators; Ecometrics; Life Cycle Assessment; Life Cycle Management; Sustainable Development

1 Introduction

Ecometrics are indicators which reflect either an environmental attribute, such as a concentration or temperature, or an effect which is anticipated to have an environmental consequence, such as a discharge, the selection of a given material, or the use of a product. Often economic, technical and societal factors are embedded into these measures. Ecometrics have been proposed for applications in areas as diverse as ecolabeling, new product design, marketing, internal and external corporate reporting, and credit screening. Clearly, specific indicators for given decision makers, industrial sectors, products and services will be required. While other recent publications [1] have summarized ecometrics proposed over the past five years, this contribution discusses the need for ecometrics among potential users, subcategorized by product and service.

This division permits the ecometric question to be evaluated from the perspective of designers, consumers, as well as policy and decision makers. Furthermore, given that the burden of a product, or service, is primarily determined in the conception stage, the utility of various types of ecometrics will be analyzed with respect to various industry sectors including chemical and pharmaceutical, insurance and finance, electronics and manufacturing and consumer products.

Two general categories of indicators require definition. "Macroecometrics" typically are resource and flow based measures which represent current, or historic, global situations such as temperatures, atmospheric concentrations, sea

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water levels, top soil quantities as well as accumulation based indices such as mean energy input. These can be correlated with "microecometrics" which, by comparison, are oriented to a given product and industry and may indicate consumption through the life cycle as measured by material and energy intensity or waste and toxic release emissions. A subset of microecometrics, commonly referred to as eco-indicators, can be used to evaluate firms according to environmental criteria [2]. Clearly the latter are much easier to measure. However, the question of how they correlate to global measures remains uncertain although a link does exist between macro- and microecometrics with global temperature, for example, being itself an indicator of CO_2 equivalents. It is largely for this reason that recent papers [3] have concluded that ecometrics used on local or product/service-based scales require validation with systematic methods such as life cycle assessments[1]. Furthermore, the local to global link is critical. For example, certain ecoindicators such as the percentage of recycled parts or energy consumption during use of a product can actually represent non-sustainable practices if, as is the case with the automobile, the product has become more life cycle efficient but the burden of the transportation service, as a whole, has increased considerably over the past several decades.

This contribution summarizes the discussion of a workshop entitled ECOMETRICS'98 held in Lausanne, Switzerland January 19-20, 1998, the goal of which was to unite industrialists, academics, policy makers and representatives of public stakeholder groups to evaluate the requirements for a set of indices aimed at the environmental, economic and technological interface. This paper discusses the need for a collection of product and service specific microecometrics and their correlation and validation as indicators of global impacts.

A family of ecometrics are required to model any dynamic, complex system. For example, daily indices represent shareholder value in various global stock markets. However, even for unambiguous monetary values, the act of aggregating data leads to specific indicators with apparently contradictory tendencies[2]. Clearly, when the environment is added to the equation, the situation is not likely to simplify. Furthermore, a key issue in establishing ecometrics is achieving a balance between, on the one hand, simplicity and transparency with the ability to provide meaningful validated information.

2 Discussion: Ecometrics Needs

2.1 Decision making needs

Ecometrics have been developed to provide condensed information to a variety of decision makers, each with specific requirements. They can be sub-divided into four groups.

1. **Intensive Ecometrics** are scaled relative to a unit of production or function. Examples include greenhouse gas emissions, relative to population, geographic or economic statistics, energy consumption per functional or operational unit (e.g. floor space), material resource requirements and hazards, risks or liabilities per unit operation. Endocrine disruptive emissions per unit of production are also intensive.

2. **Extensive Ecometrics** are couched in absolute terms without reference to a unit of production or service. Purely extensive ecometrics include the security of material and energy supply and the "residual risk" for a given option under consideration. The intensive ecometrics listed above, if unscaled, also become extensive. ISO 14000 permits a firm-specific list of significant extensive impacts.

3. **Improvement Scorecards** refer to some baseline performance. They are useful in monitoring progress towards a goal, such as zero emissions or CO_2 reductions.

4. **Eco-Efficiency Indicators** have a financial or business performance reference as a denominator. Such measures are expected to grow in importance as sustainable strategies are further embedded in general business practices and strategies [5]. Eco-indicators are related to a firm's, or industry sector's, performance and can be expressed in terms of the fraction of a target category or economic value added. Intensive eco-indicators include the environmental and social costs per unit of production or value added and the life cycle impact per unit of revenue or profit.

The characteristics of the decision maker and the context in which they operate are important in the development and selection of metrics. The majority of measures identified to date have been eco-indicators, for the internal use by a firm [1,2], or extensive macroecometrics. It is much less clear what kinds of metrics will be useful, for example, in consumer choice. It should be noted that the manner in which the ecometrics (numbers) will be used, except in cases where comparisons are being made, depends on the value systems or other meaning-giving structures of the users. It is also essential to identify these value systems in designing a metric and the procedures by which they are enumerated and employed. Therefore, it follows then that "users" should be involved in the ecometric development process

2.2 Marketing, labeling and consumer needs

Several issues need to be considered in selecting ecometrics according to *consumer needs*. For example, the consumer may be interested in information on environmental impacts related to products (labels), companies (annual environmental reports) or his or her own behavior (e.g. traveling). Similarly *marketing needs* may be expressed in the view of marketers considering the "green image" of the product or

[1] Ecometrics which have been derived from Life Cycle Assessments are commonly referred to as Screening Indicators [4].

[2] Furthermore, while ecometrics have generally been proposed to reflect environmental attributes, others include economic and social impacts.

company. Marketers may also seek to influence potential customers as well as offices, administrations or the public in general. Additionally, various types of *labels require* condensed information, often related to the product life cycle or environmental impact. According to ISO/DIS 14020ff [5,6] three types of labels exist which require different information to be communicated:

- **Type I** labeling can be relatively time consuming since a third party validation is involved (see, for example, the EU-label requirements). It also has to be questioned if the multiple criteria can be communicated to the public, or any other interested audience, and how to set the criteria for excellence in one product group. Furthermore, the level of excellence often becomes a standard with time and thus the criteria, and thresholds, have to be adapted regularly. Due to data incompleteness, it is also often difficult to relate the ecometric (criteria) to life cycle impacts.

- The perception, and validity, of **Type II labels** has been questioned due to the lack of involvement of third parties. However, their acceptance could be enhanced if ISO principles are followed to set up the label.

- **Type III labels** are thought to be the less time consuming for the producer to establish. Furthermore, for consumers, or other users, it communicates concrete, simple information for the purchase decision. Like Type II labels it has been questioned if the perception of such a label is sufficient if no third party is involved. Again, its acceptance should be enhanced if ISO principles are followed to set up the label.

Ecometrics are applied in the definition of labeling criteria as well as to establish exclusion hurdles for given product groups. Labeling criteria should, rigorously, be based on a life cycle perspective [7], in order to avoid undesired tradeoffs. However, due to time, monetary and information constraints a simplified LCA approach based on expert knowledge has been advocated. This specifically will involve the rapid assessment of the key impacts and stages in the life cycle, thereby reducing the scope of the inventory collection. In order to provide labels of excellence for, for example, the top 10-20% of products in a group, exclusion criteria can be defined, though the threshold will be quite controversial, particularly in competitive industries. These criteria will require revision as a function of time due to technological and process improvements.

Ecometrics used in labeling should be transparent, concise, informative, not overaggregated while providing the necessary information to the desired audience. This is clearly a daunting and subtle task, and one for which the various stakeholders are not likely to agree. Given this, families of metrics will be required to be used in parallel[3]. These are required at both the assessment and communication level. While it is obvious that environmental burdens require multiple indicators to provide a comprehensive information summary, the means of illustrating the conclusions should also be considered. For example, consumers often prefer condensed information in the form of graphics while a manufacturer or retailer may desire more quantitative information, such as improvement potential. Furthermore, some label-criteria may be provided in the form of a Life Cycle Inventory level, such as an ingredient mass. Others will require a more comprehensive assessment including life cycle energy consumption and toxicity evaluations.

Another option is a stepwise aggregation of information which can fulfill the requirements of various audiences. Furthermore, labeling criteria must be product dependent which is reflected in the ecoindicators used and their combinations. Ecometrics are also likely to be geographically sensitive. For selecting the appropriate ecometrics in labeling ISO/DIS 14020 [5] provides basic information in the form of nine principles. The current policies in various countries also provides alternative examples, some better than others, of labeling practices.

2.3 Designer needs

For the purpose of this discussion a designer is defined broadly as a person involved in a creative activity related to the development of a new product or service. Therefore, designs could include business organizational layouts, strategic planning as well as facility or process development. Regardless of the type of design, indicators are required to provide information early in the design phase. Ideally these intensive microecometrics should be based on a life cycle perspective and be limited in number so as to not overwhelm the designer and the time available to incorporate environmental information into the process. If one wishes to couple environmental aspects into design, the ecometrics should support a designer's creative process. Therefore, the microecometrics must be capable of being interrogated so that key life cycle impacts or stages could be identified. **Table 1** lists some microecometrics which have been proposed for designers along with their associated life cycle input and output flows. A short list of intensive microecometrics for designers includes:

- life cycle material usage per unit of service
- life cycle energy usage per unit of service
- ratio of scarce and non-renewable resources, to plentiful and renewable resources per unit of service
- non-product output per unit of service

ECOMETRICS'98 [8] concluded by recommending the establishment of intensive microecometrics for environment,

[3] If multiple metrics exist which are not independent it will be necessary to establish their relationship.

Table 1: Intensive microecometrics for designers

Category of Intensive Microecometric	Specifics
Environmental	Pollutant releases to air, water and land need to be distinguished
Health and Safety	Mortality and morbidity should be examined separately as should reversible damages
Impacts on Humans	Consumer environmental requirements and expectations should be included
Impacts on Ecosystems	Mining overburden an the impact on ecosystem vulnerability should be considered
Impact on Resources	Should include upstream materials efficiency
Value Added	Uncertainty should be considered
GNP Generation	Benchmarking is needed. The usage, relative to capacity, is another factor to consider
Material Usage	Purity, renewable and recycled content, concentration and disposability are variables in material quality
Energy Usage	Entropy, exergy and water use for hydroelectric power should be included
Emissions	Product, nonproduct, as well as hazardous, nuclear and biodegradable waste should be distinguished
Transport Distances	Capacity utilization should be considered, along with the return voyage
Product Durability	A timeframe should be specified for metrics and any life cycle calculations they are based on
Social Aspects	Social aspects such as community accountability and the use of child labor should be considered as collective human impacts

health and safety, as well as societal attributes. These have not been developed to date. A service metric expressing the effectiveness of the desired functionality and durability was also deemed to be useful. The incorporation of intensive business related microecometrics, also known as eco-indicators, should also be considered.

2.4 Political and policy related needs

Ecometrics deal with consequences including the effect of environmental trends on the distribution of welfare and institutional designs at the national and international levels. While economic indicators such as employment, inequality indices, migration rates, credit flows from developing to developed countries, financial system instability and the interest rate in developing regions[4] are generally extensive, social and ecological ecometrics could be intensive. For example, education levels and the percentage of the population level living in rural area could be scaled with economic (e.g. per unit of GDP) or resource-based criteria. Furthermore, ecological macroecometrics such as the energy and energy mix, land and water availability as well as resource consumption could be scaled per capita or based on economic statistics. The conversion of data to intensive ecometrics remains non-controversial provided the extensive ecometrics on which they are based are also reported. However, the quality of data employed, the collection and filtration of information, and the time frame used to aggregate the information requires discussion. The last point is acute for less developed countries since fluctuations in the quality of life can be as damaging as the absolute living standard.

Government policy instruments include traditional command and control and taxation approaches as well as tradable permits. Policies can be influenced by the extensive quality of life indicators tabulated by organizations such as the World Bank. These include energy consumption, land use and desertification, population and conservation of resources, including water. However, one should recognize that the policy makers will only be able to use a subset of the data collected and that links between economic and social administrative would enhance ecometric utility. Furthermore, contrary to present IMF policies which see development and transitions from planned economies as requiring a single remedy, applicable to various continents, geographical factors are important for ecometrics. For example, using marginal utility theory one can show that it is reasonable for the same ecometric to move in opposite directions in various parts of the world [9].

On the political scale, several questions related to microecometrics have hindered their acceptance. For example, it is uncertain how intensive microecometrics, so often tabulated in corporate reports, represent global phenomena. Furthermore, it is yet to be established how long term macroecometrics can be employed by policy makers whose term in office generally rests between four and twelve years. The question of whether supplying, or restricting, credit in relation to a country's environmental performance can close the

[4] If interest rates in developing countries are higher than the norm, decision makers have an incentive to convert environmental assets into economic assets.

development gap implicates the debate as to what is an appropriate environmental discount rate. Historically, one can also question if the shift from non-industrialized to industrialized societies implies that non-industrialized regions are, de facto, non-sustainable.

3 Product and Service Based Microecometrics

3.1 Chemicals and pharmaceuticals

This common industry group can be subcategorized into firms whose primary business is related to chemicals, biotechnology or the genetically modified organisms. All of these have negative public perceptions. For example, there is a high level of public fear and distrust and intense NGO pressure on producers of certain chemicals such as chlorine. Several countries have also either banned or have scheduled referendums debating the future of genetic engineering. In contrast, the pharmaceutical industry is generally perceived in a positive light. Within the chemical industry one needs to distinguish between chemicals which are used as materials versus those that are "effects". In the latter group, it is the product itself which creates the pollution.

Intensive microecometrics are required for the operation of the process plant. These would generally be scaled per unit of production and include emissions to the air, land, surface and ground water. Human toxicity, the toxicity pathway (food, drinking water and inhalation), and ecotoxicity would also be important considerations. Greenhouse gases and ozone depleting substances should likely be accounted for separately. Ecometrics will also be required throughout the product life cycle, particularly in the extraction, use and disposal phases, though in some regions transportation can also be a significant stressor. Clearly metrics will have to be transparent if they are to be used in product or process development, or in a precautionary manner to identify risks. It has been suggested that metrics capture the decline in negative aspects associated with a product, such as emissions, as well as the growth in positive aspects through process reinvention and chemical substitution. ECOMETRICS'98 concluded by recommending the development of a multidimensional matrix which incorporates both quantitative and qualitative inputs [10].

3.2 Insurance and finance

Environmental and sustainability measures are included by several financial institutions as investment, insurance and credit screens. These guidelines generally include corporate ecology related issues, as well as environmental management and policy. The industry is seeking to develop a risk rating from Z to AAA, similar to Moody's credit rating. Computation of the rating would be based on subjective judgment that includes the quality of management, structure of the environmental policy within the company and its operating environment. More measurable attributes would include known liabilities, costs for pending legal actions, and financial statements including legal and remediation expenditures.

In the context of insurance and lending, client risk has been expanded to include, generally extensive, macroecometrics. These include the history of regulatory compliance, the quality of environmental management and the inclusion of environmental criteria in investment, insurance and credit business. Qualitative indicators such as external certification would also compliment traditional pollution prevention indicators such as emission releases. Financial institutions are interested not only in a firm's history and current management commitment but also its anticipation and identification of pending environmental issues, leading to both risk and business opportunity. The environmental ranking of firms by sectors is occurring within the context of environmentally oriented investment funds.

Corporate, and perhaps even municipal and national, environmental performance could become a criteria to obtain credit. With the globalization of the financial institutions the adoption of selected ecometrics imposes on the borrowing community a set of values which one must accept in order to obtain financing. This is akin to the World Bank's social conditions on loans to countries. Therefore, the rate of development, either economic, technological, social or environmental, is likely to become a supranational issue. The loss of autonomy of individual countries to define their environmental preferences has not, to date, been debated.

3.3 Electronics and manufacturing

Key aspects in the electronics and High Tech manufacturing industries include life cycle energy consumption, emissions, and materials management [7]. A number of consumer products are now rated in terms of energy consumption per unit, and consumers are being made aware of the toxicity and ease of disposability of materials that make up the product. It is essential that these factors continue to be included in the intensive ecometrics used by the manufacturing sector. Given the short product life cycle of many technologies in this sector financial indicators also must compliment ecometrics. In addition to the metrics defined in **Table 1**, rapid product turnover necessitates consideration of product dissassemblability and upgradability. The short life cycle also makes it critical to introduce streamlined and abbreviated, yet meaningful, LCA-based metrics that designers can incorporate into the product design and development cycle. Particularly unique to electronics manufacturing are the life cycle impacts of wear and tear on tooling and solvent substitution in cleaning and degreasing operations [7].

Industries with rapid product design cycles require intensive macroecometrics, often scaled relative to supply. For such industries, bottom-up approaches for metric definition and data acquisition are viewed positively. The ECOMET-

RICS'98 workgroup proposed a conceptual intensive aggregated macrometric as the ratio:

$$Metric = \frac{Total\ \ Life\ \ Cycle\ \ Risk}{Total\ \ Product\ \ Risk}$$

The risk term in the previous equation includes financial and liability costs as well as qualitative estimates of human, environmental, and residual risks. The metric could be adapted to include multiple cycles. It is clear that from a consumer's perspective the closer the value of this metric to unity, the more acceptable is the product being evaluated. It is more difficult to identify what the ideal value should be from a manufacturer's perspective.

It should be noted that a number of factors need to be made explicit when using this and other metrics to evaluate cost.

- When considering recyclability and reuse of materials, their relative availability is a key factor. Regional influences, such as the infrastructure available for recycling also play important roles.

- Computations need to be normalized by established product functionality. However, this is a non-trivial process.

- How the cost of recycling is distributed between the manufacturer, customer, and government needs to be addressed.

3.4 Consumer products

One can elect to define consumer "products" functionally as any good, or service, delivered to the ultimate user. These "consumers" could therefore, include, manufacturers, the public, municipal, regional and national governments, retailers, NGOs, as well as financial institutions and insurance companies. Ecolabelling and product comparison are the main requirements of public consumers. In contrast, governments, as consumers, are supporting metrics which provide for cleaner industries and tax "dirtier" corporations, to evaluate the environmental performance of products in relation to standards, as well as for enforcement and in benchmarking. Governmental funding agencies also require metrics to set research priorities. NGOs need ecometrics, particularly in order to prioritize issues, influence the political process and communicate information to the public.

Consumer products require microecometrics which indicate health and safety particularly during the use and transportation stages of the life cycle. These include acute and chronic toxicity as well as flammability and corrosivity. Additional environmental impacts during the use stage, which could be quantified into indicators, include water use and pollution, noise, energy consumption and air pollution. A seldom mentioned factor is the environmental impact of a misused product. Producer information should also compliment material content and manufacturing practices. This includes the extent to which the producer implements extended producer responsibility (EPR), the application of environmental monitoring and performance within a firm (e.g. EMS) as well as identification as to where the product was made. The use of life cycle concepts to identify intensive macroecometrics such as global warming potential, ozone and resource depletion and biodiversity impacts can also be scaled per unit of product, or service, delivered.

Thus far consumer products have been a driving force for ecometrics. Given the multitude of possible substitutes available, consumers require simple, independently validated, reliable information. In many cases these ecometrics can be qualitative, indicating the direction of improvement, for example. Certainly there is a gap between perception and actual impact of many products. Therefore, ecometrics can be used, and misused, for communication and education. One problem which will likely arise is the conflict between nationally defined ecometrics and multinational products. In this sense, one has to question if multinational organizations are concerned about the ecometrics as potential trade barriers.

4 Ecometrics Resolution

Microecometrics are not sustainability metrics and may not even be correlatable with global phenomena or macroecometrics. It may also be difficult for any ecometric, or eco-indicator, to be predictive and, if not, the possibility for intervention is reduced. Furthermore, there is, either implicitly or explicitly, a value system that governs any measurement. Given these caveats, the aforementioned regional, product and user-specific requirements for ecometrics, and the need for validation via multi-stakeholder panels, ECOMETRICS'98 concluded with the following recommendations.

Ecometric Subjectivity: *Macroecometrics have been suitably defined. Although the linkage between microecometrics and macroecometrics, or eco-indicators, needs to be established in a more systematic manner in order to validate the latter, a sufficient number of extensive macroecometrics exist. This list is not controversial as a set, however, any basis to reduce the number, or create intensive ecometrics reflects a value which will likely be stakeholder dependent [2] and, therefore, requires an enfranchised debate [1].*

Application of Life Cycle Concepts: *A streamlined life cycle impact assessment, with highly cost effective inventory component, should be used in an iterative manner to develop matrix-based micrometrics for prioritization and communication. This matrix, which could include qualitative information and financial data, should satisfy corporate level reporting to external stakeholders and show the consequences of choices.*

5 Conclusions

Any measure which summarizes a complex phenomena must achieve a balance between simplicity and uncertainty. Ecometrics, which are essentially comparative tools developed to suggest improvements, are no exception. ECOMETRICS'98 concluded with a recommendation that metrics be developed based on function rather than products. Clearly, the context is also essential in the definition, or selection, of an appropriate metric with the user and purpose of the analysis required. As with most debates, a consensus is usually reached on further questions rather than resolution. In the ecometrics area two practical questions arose.

1. *Can intensive microecometrics improve the information exchange throughout the supply chain so as to carry out assessments more comprehensively?*

2. *Can multi-stakeholder peer reviewed microecometrics improve the cooperation among the industry and government sectors?*

The overwhelming opinion of the multistakeholder ECOMETRICS'98 forum was to validate microecometrics by employing life cycle concepts. However, practically, representatives of industry and public groups alike, discussed the need to conduct life cycle assessments without rigorous life cycle inventories. In regard to the latter it should be mentioned that SETAC-Europe has working groups attempting to find practical applications for LCA in decision making, and to define an implementable set of Life Cycle Management tools.

Intensive microecometrics are akin to temperature readings, reflecting the current state. When evaluating how to define such measures, one invariably poses questions such as "what time is it?". Macroecometrics, and the link of microecometrics to sustainability, require predictive measures, much more similar to a barometric reading. The development of these global thresholds and measures is more philosophical, and certainly subjective and value dependent. The relevant analogy in such cases is "what is time?".

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Conference Announcement: 9th Annual Meeting of SETAC-Europe

May 25-29, 1999, Leipzig, Germany

The organisation of this international meeting is shared by the SETAC-Europe office in Brussels, the UFZ Centre for Environmental Research in Leipzig and the University of Leipzig. The conference site will be the auditoria of the University of Leipzig which is located in the centre of Leipzig. The main theme "Quality of the Life and Environment in Cultured Landscapes" reflects the need to take into account ecological as well as economic and social aspects in developing concepts for a sustainable development of societies.

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