LCA Methodology: Ecometrics

Ecometrics for Life Cycle Management

A Conflict Between Sustainable Development and Family Values?

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Abstract

Metrics are a prerequisite for the successful monitoring and management of progress toward goals. Within the context of sustainable development these "values" are stakeholder dependent with the interests of the individual, society, the environmental infrastructure and intergenerational liability differing significantly. These stakeholder priorities may also be mutually inconsistent or simultaneously unattainable. Therefore, a set of scale- and value-specific indicators will be required to represent the priorities of individuals, religious organizations, political and public interest groups, non-government organizations, firms and industry associations, as well as national and international institutions. Restricting the number of ecometrics, or creating aggregated sustainability indicators, risks disenfranchisement and invalidation respectively.

Over the past three decades a series of *microecometrics* have been developed to account for the impact of human activity, technology or products over regional, national, and sub-continental scales. These include life cycle energy consumption, dematerialization, waste minimization, as well as design for environment and eco-efficiency indicators, the latter two combining technological or economic aspects respectively with environmental factors. *Metrics which evaluate the impact of a service, or the utility provided by a product, are lacking.* A series of global measures, or *macroecometrics* have also been defined and include the average annual temperature as well as atmospheric compositions and concentrations, sea level, and earth based resources such as topsoil quantities. The validity of microecometrics as measures of global phenomena can be established through life cycle impact assessments which evaluate the "system's" response to effects of products or services throughout their life cycle. However, the link between microecometrics and macroecometrics, their validity as indicators of sustainability, the subjectivity of sustainable development *per se* as a value, and the relationship of metrics and sustainable development with family values has not extensively been addressed. This paper summarizes recently proposed ecometrics, calls for the recognition of the subjectivity of indicators, the distinction between ecometrics used for internal corporate reporting and external decision making, and the establishment of a representative multistakeholder debate.

Keywords: Ecoindicators; environment; family values; intergenerational debt; life cycle assessment; sustainable development; values

1 Introduction

1.1 Sustainable development is a value

The environment is a system whose complexity rivals arguably that of only the human physiology. One could, therefore, question how one measures the environmental state or its "health". For example, are indicators required which reflect current conditions, such as global temperatures or concentrations, or will metrics with predictive powers, akin to a barometric readings, be definable? This debate is important and fuels the current disagreements between stakeholders such as religious and environmental groups, since measurement and reporting influence behavior. These also represent values. Therefore, while the augmentation of *the quality of life of individuals or families*, the preservation of the well-being of the human *population*, the maintenance of an *environmental* infrastructure and *intergenerational responsibility* may be values which the majority of people, or societies, can agree to, their ranking will almost certainly be stakeholder dependent. Furthermore, although it has not been stated to date, sustainable development *is* a value and can be contradictory with other beliefs. Therefore, the premise that sustainable development will, or "must", be beneficial for everyone, alienates some shareholder groups from participating in discussions. In this sense, the parties advocating sustainable development, through their normative statements, have not yet acknowledged the right of other interest groups to their values.

One could question if, and if so how, one can measure the environment, the sustainability of species as well as individual and collective welfare, all the while recognizing that the very act of deciding what we measure is subjective. Related to this is the identification of the ultimate clients for such evaluations: families, societies, future generations, or the ecosystem, to name just a few. Therefore, it seems quite reasonable, and justifiable, that the stakeholder groups whom have not participated, or been invited, into the sustainability debate (e.g. religious organizations), could feel that some of the environmental aims are contradictory with their fundamental beliefs. Furthermore, the values of certain religious and political organizations are not novel, or responses to the sustainability movement, but rather inherent in the founding documents and priorities of their respective nations.

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1.2 Metric aggregation

One can argue that systems cannot reasonably be characterized by a single index. Furthermore, aggregated metrics, while useful in actuarial, financial and, perhaps, quality of life computations, certainly cannot be unambiguously applied to multi-stakeholder decisions which involve the weighting of relatively uncertain qualitative information. Aggregated indices can also require periodic adjustment, as is seen in the changes in the typical "basket of goods" which constitute the basis for the consumer price index. Furthermore, composite indicators tend to be reflective of short term events and lack the proactive predictability one would desire in a sustainability metric. Therefore, without entering into the semantic[1] debate as to the terminology we are implying that a *set* of macroecometrics will be required to permit us to monitor the global environmental state. Microecometrics, while subjective, can nonetheless be validated through approaches such as life cycle assessment. They can also be used to adjust the behavior of the stakeholder group(s) subscribing to the metric.

1.3 Sustainable development's lack of authority

The question as to which stakeholders, if any, should be authorized to act for the public is at the heart of the politico-religious debate. Furthermore, the recent flurry of North American and European bank mergers have created international institutes with the same competitive potential as the majority of nations. If, as has been proposed, ecoindicators are used as credit screens, then there will exist a microeconomic risk that arbitrarily defined metrics, or values, can be used as filters which discriminate in terms of access to capital according to fundamental stakeholder belief. This is analogous to the macroeconomic cash crises facing developing countries as the World bank imposes its conditions, or values, in terms of social restructuring, on loan availability. It is unlikely that the access to credit will be decoupled from the values of the dominant, now global, institutions. However, this author is recommending that we recognize that this bias does exist and penalizes certain stakeholders.

1.4 Economic and environmental time scales

The economy and financial markets can serve as examples of the utility, and daily functioning, of families of metrics. Cumulative measures such as the money supply indicate the amount of currency in various forms of liquidity in the economy while, on the firm level, ratios such as the price-to-earnings data are used to represent investor confidence and shareholder value. Metrics can also be redundant. For example, the Dow Jones Industrial Index, while biased to thirty large multinational manufacturing corporations, generally leads broader based indices such as the technology based NASDAQ and the entrepreneurial Russell 2000. In retrospect historical trends in the indices become obvious and, over the long term, the metrics often mimic each other. However, on a daily basis, the approximate time constant for monetary activity, the indices often move in opposite directions indicating that the means of averaging and data normalization are additional factors to consider in the establishment and validation of metrics, and may themselves be stakeholder dependent values.

One index of the environmental state is the global average temperature which shows, with the exception of a plateau in the mid-twentieth century, a steady rise over the past 150 years. However, annual fluctuations are significant and decades are required to observe trends. Nobel laureate Mario Molina has recently shown that the effect of the CFC production ban (Montreal Protocol, 1990) can now be atmospherically observed in terms of a plateau in CFC-11 concentration [1]. He offers this as the first example that human activity can positively influence a measurable global environmental parameter. However, CFC-11 has a half-life of fifty years and the carbon cycle is orders of magnitude longer than the human life expectancy. Therefore, temporal aspects must be considered when one creates or averages ecometrics whether use for private or public sector decision making. There is also the issue of ecometric lag to consider [2] which represents the time required to incorporate environmental indices into routine statistical studies and reports.

1.5 Ecometrics

This paper reviews the micro- and macro-ecometrics which have been recently proposed, or reevaluated. The list tabulated herein is a "snapshot" and one should recognize that microecometrics in particular will develop through a variety of industrial, governmental and academic exercises over the next decade. Many of these are already in place including the World Business Council for Sustainable Development's Ecoefficiency work group [3], the President's Council on Sustainable Development (USA), the Ecometrics committee within the Japan Life Cycle Assessment society [4] as well as a series of Ecometrics workshops [5]. Additionally, internal corporate committees are evaluating ecoindicators for performance tracking and decision making as is evident from recent environmental reports.

1.6 Subjectivity of metrics and stakeholder rights

A collection of ecometrics is not controversial *per se*, although there is some judgment involved in scaling the index (e.g. per capita or per unit of GDP) as well as in the boundary definition. However, if an attempt is made to prioritize such a list, for example as a means to move toward sustainable development, the result becomes subjective. The use of a metric also requires data collection, the act of which depends on stakeholder dependent interpretation and filtering. Therefore, we recommend that *those working on defining potential ecometrics decouple themselves from the sociopolitical process involved in determining the suitability of indices*. One could also question if the freedom to define metrics, given the values they imbibe, should not be constitutionally recognized as are, in some countries, freedom of religious preference and speech.

1.7 Needs for ecometrics

There is an immediate need for ecometrics in order to make corporate and macroeconomic allocation decisions as well as to communicate the progress towards "ecoefficiency" [6].

[1] Various groups utilize "metric" or "indicator" as a suffix, with a variety of prefixes proposed, though "eco" is the most common.

Furthermore, Total Quality Management, and commitments to continuous improvement, require metrics. ISO standard 14031 also addresses the evaluation of a firm's environmental performance and their management system. What kind of indicators will those seeking international standardization use? Will they be flow based metrics or will they seek to measure impacts on local environmental regions? This paper will discuss recent progress in measuring the environment, categorize the status of current projects in the ecometric area, and make recommendations as to underrepresented areas in the sustainability and ecometric debates.

2 Discussion

Tables 1 and 2 (→ *Appendix*) provide a non-exhaustive list of recently proposed ecometrics. Macroecometrics include those related to material and energy flows, climate, emissions, sociopolitical and population-based attributes and cost-based indices, while microecometrics have been defined over a more limited, generally product- or firm-based range, as will be detailed in the following section. It is evident from Tables 1 and 2 that the proposed indices *can* be measured. However, some data will require international aggregation while microecometrics are often based on confidential corporate information. Given the divergent continental preferences voiced at the recent climate summit in Kyoto, and the consensus to reduce CO_2 emissions over the coming 15 years [32], the organizations which tabulate and validate ecometrics becomes an issue, as does the question of whom is responsible for this selection. Over the short term, while global trends are difficult to distinguish from data fluctuations, prompting debate over tendencies, *the identification of the appropriate direction for improvement would be a significant step toward sustainable development.* If we will need to establish valid metrics which locally monitor the environment and are valid indicators of global environmental states, several caveats must also be considered. For example, in reporting one always seeks a balance between the volatility in the data versus the lack of short term tendencies in moving average based calculations. Furthermore behavior is modified by metrics and it has been established that the organization and screening of information influences perception of what is being measured [33]. Finally, it should be recognized that metrics are subjective and may have implicit, non-transparent, value systems.

2.1 Macroecometrics

Table 1 (→ *Appendix*) shows macroecometrics for global energy input and demand, material utilization, climate and weather-based events and overall emissions. These imply, either explicitly, or implicitly for climate-based metrics, that reduced consumption and dematerialization is, to some extent, required for sustainability, though the thresholds for required action remain undefined. Furthermore, one cannot specify the system's (Earth's) proximity to these "limits". Even with these uncertainties, the aforementioned macroecometrics are the least subjective of the list in Tables 1 and 2 (→ *Appendix*). In contrast, the sociopolitical measures can include national political goals in the calculation. Similarly, the tabulation of annual "adverse" effects requires a definition, or value system, which influences not only the calculated metric but the data to be collected. The series of financial based measures are unambiguous. However, if data collection is incomplete, their validity as an ecometric must be questioned. The same is also true of energy and material based ecometrics.

Macroecometrics can be established which qualitatively represent global sustainability in a relatively unambiguous manner. These would include material and energy demand, concentrations of certain species and climate data. However, the threshold levels which indicate above or below which action is required, and the intensity of an action[2] for a given effect should be debated, as they are now, in the arenas of national and international affairs[3]. Nonetheless, the macroecometrics can be qualitatively linked to sustainable development. While this may seem a meek statement, the same cannot be claimed for microecometrics, where even the direction of the change is context dependent, as will be discussed in the following section.

2.2 Linkages between micro- and macroecometrics

An example of the difficulty in linking microecometrics to global environmental effects is the use of the percentage of recycled parts as a measure of the environmental burden of the automobile. Certainly, in a product where the use phase presents the dominant burden, an indicator which reflects production and end of life cycle (disposal) issues is, while perhaps still valid, likely not critical. Furthermore, even if the metric "percentage recycling" or another such as vehicle energy consumption is validated as representative of the overall burden of the automobile, it is the *transportation service system* burden which needs to be sustainable and not the vehicle as a product. Therefore, while automobiles are more energy efficient and of lighter weight then 40 years ago [2], the overall burden of the transportation infrastructure has, arguably, increased considerably. Therefore, under such conditions, the microecometrics "percent recycled components" or "energy efficiency", while intuitively satisfying, are actually metrics of non-sustainability. This example, while certainly not general, illustrates that *service-based microecometrics should be considered as alternatives to ecoindicators of products.*

The relationship between microecometrics, which are likely the most tempting to measure in the private sector, and macroecometrics, or global indicators, must be established. One method to accomplish this is life cycle assessment which could be employed as a means to validate proposed microecometrics. For example, Sweden determined that it was less of an environmental burden to burn plastic drinking bottles than to wash and re-use them. In this analysis, life cycle

[2] The preferred, individual or collective, response to a given metric is stakeholder value dependent.

[3] The extension of macroecometrics to indices of sustainable development will require a definition of sustainability. Such a specific definition has, to date, been avoided. While this builds consensus towards sustainable development as a goal, it hinders the acceptance of action toward sustainability by some stakeholder groups.

energy and life cycle atmospheric emissions were the most burdensome and hence emerge as key microecometrics for this product line, or service (delivery of beverage). This implies that *microecometrics will be product or service specific and require a systems-based valuation, and periodic reevaluation.*

2.3 Microecometrics

Challenges in integrating environmental performance across business functions have been encountered even by organizations pioneering the use of ecoindicators. Furthermore, many firms have chosen environmental performance indicators based on data which they are either required to collect, for example toxic release inventory, or are relatively easy to obtain. Indexing has also become "cultural" within enterprises and many companies find it useful to aggregate. Given these observations it is not surprising that microecometrics (→ *Table 2*, see Appendix) focus on material or energy reduction and reuse, closing the loop or product-based statistics[4].

Microecometrics are typically expressed in units of material or energy consumption, production, discharge, waste or byproducts, numbers of employees, cost and reuse/recycling statistics. The figures are, more often than not, scaled per unit of production or sales[5]. Clearly, while scaling is necessary for standardization, the choice of the denominator is a value judgment and will influence the validity of the metric. Furthermore, the decision as to what to include in the numerator as a "key substance" or component of Toxic Release Inventory and "hazardous" waste is also subjective, even if established by multistakeholder committees[6]. Nonetheless, if a sufficiently large number of micrometrics are tabulated, perhaps even using historic data to move backward in time, the validity of a micrometric for a product/service, and as a measure of global sustainability *could* be determined. Clearly there is a tradeoff between simplicity and completeness [33]. Therefore, the recommendation is to accept that a specific microecometric is subjective, and to require it to be transparent and validated over the long term through life cycle assessments and correlations with macroecometrics. That is, not to filter data, or metrics, rapidly but to accept time as a component of the debate. As stated in the introduction, one philosophy which could be adopted is the collection and tabulation of ecometrics such that generations, and their stakeholder groups, present and future, can use the indicators which are deemed most appropriate given the environmental crises which are prevalent, or anticipated. In such a light, ecometrics tabulate intergenerational currency or exchange. However, we are, at present, unable to establish a link between eco-efficiency and either macroecometrics or sustainability.

It is not the purpose of this paper to evaluate the metrics proposed. Those listed herein have, and likely will continue to, serve as a basis for the generation of modified indicators, as has been observed at recent workshops [4]. Can we say which ecometrics are needed to enable a family-based, collective, organizational or national movement toward sustainability? At this point perhaps not, at least uncontroversially. However, it has been the opinion of various forums that filtering ecometrics at this point may be more harmful than beneficial. Until, and this may be decades, it can be agreed amongst the stakeholders which course of action will be required for sustenance of the individual, family, population, environment, future generations, or any other value one may aspire to, our greatest service may be to elaborate, to the best of our abilities, a set of ecometrics which will likely increase in number with time, and to tabulate them. The following section discusses current efforts toward ecometric resolution as well as the actors involved.

2.4 Current status

Overall, the efforts towards the development of metrics can be categorized as:

- Microecometrics, or ecoefficiency indicators, are aimed at the profitability and environmental responsibility of institutions on a global scale and focusing on societal goals.
- Macroecometrics measure long term global effects and are oriented towards the environment and intergenerational responsibility as a dominant value.
- Sustainable development metrics, while not yet established, require thresholds to determine critical levels of global variables. The emphasis is on intergenerational values.
- Individual quality-of-life measures represent, in the 20th century "developed" countries, a nuclear-family orientation. While qualitative and quantitative metrics exist to indicate trends in, for example, the standard of living, how these relate to sustainability, or even collective welfare and environmental maintenance, has not been discussed.

Figure 1 relates the scale to be considered (local to global) to the specific goal or value. A series of microecometrics have been developed for issues largely related to the collective wellbeing of the human species or society[7]. These indicators generally correspond to industrial variables which can be collected, most readily, on a facility-specific or local basis. However, while micrometrics can be measured an life cycle impact assessment[8] is required to establish their validity as sustainable development indicators. In contrast macroecometrics which represent global attributes such as temperatures, compositions and con-

[4] Microecometrics are proliferating much more rapidly than macroindicators. These will require validation if the metric is proposed for use for in multistakeholder decision making frameworks.

[5] Most of the proposed microecometrics are, *de facto*, extensions of life cycle inventory data. This implies that relatively significant time and human resource commitments will be required in the data collection stage. This may reduce the acceptance of metrics by some organizations, particularly those who employ streamlined life cycle management and design for environment approaches in place of more comprehensive life cycle assessments.

[6] Some investigators have called for ecometrics, and the data which comprise the statistic, to be transparent specifying the forum/agency that has proposed averaged and normalized the indicator.

[7] It has been argued that the maximization of the wellbeing of "society" is context dependent and that even the optimal tendency for metrics may differ in developed and "developing" regions [5].

[8] Life cycle impact assessment is an established, though still evolving tool. Nonetheless, it provides a means to forge this local-global link.

centrations require long periods to measure and distinguish from historical baselines. Furthermore, the critical level of the majority of macroecometrics have either not been determined or lack consensus. Therefore, *macroecometrics are not predictive*. This, and the general *lack of validation of specific microecometrics* are the forefront of the debate regarding movement towards sustainability. It is this controversy which risks disenfranchising several interest groups which are generally underrepresented in sustainability debates, particularly religious organizations.

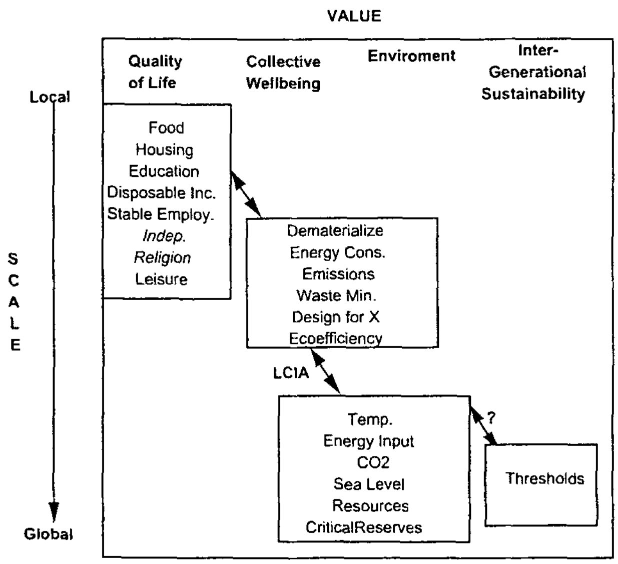

Fig. 1: Categorization of the scale and values involved in the ecometric and sustainable development debates. The question mark designates linkages which have yet to be established.

3 Conclusions

One may question who needs, or will require, ecometrics. It has been argued herein that individuals, societies, the environment and various generations are all stakeholders. One may measure the environmental "health" through traditional macroecometrics (temperatures, compositions, concentrations) and these represent the current state of the ecosystem. However, they are not predictive indicators. Links are also required which validate microecometrics and tie sustainability thresholds to global conditions. Therefore, until metrics can be validated, the human population collectively runs the risk of moving towards non-sustainability, even if sustainable development can be agreed to as a goal. The author of this paper recommends the following course of action:

1) The recognition of the inherent **subjectivity of ecometrics**.
2) The **distinction** between ecometrics used for "internal" organisational accounting and ecometrics employed in "external" multi-stakeholder decisions.
3) The **acceptance** of homogeneous stakeholder groups to define internal ecometrics for their own uses.
4) The establishment of **representative stakeholder debates and review processes** for external ecometrics.
5) The **validation** of proposed external ecometrics using systematic assessments across a products, technologies or service's life cycle.

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Appendix

Table 1: Various macroecometrics proposed over the 1992-98 period

CATEGORY	ECOMETRIC	DETAILS/JUSTIFICATION	SOURCE
Energy	*Energy Input to Globe*	–	Muzutani, 1996 [7]
Energy	*Energy Demand*	Referred to as a "Screening Indicator": 65% of gases, 90% of SO_2 and 85% of NO_x are due to energy related activities.	Christiansen et al., 1996 [8]
Material	*Materials Intensity per Service Unit*	Simplified idea that "dematerilization" is better. All inputs are added according to their mass.	Christiansen et al., 1996 [8]
Material	*Environmental Quantities*	Amount of productive topsoil, fertile forests, ozone and fish stocks.	Schmidheiny, 1996 [6]
Material	*Maximum Sustainable Yield*	"Highest number of trees, fish, nuts or any other renewable resource that can be harvested year after year".	Schmidheiny, 1996 [6]
Global Measures	*SPI*	Equal Space Consumption.	Cramer, 1993 [9]
Climate	*Weather Data*	Examples include: Number of Extreme Rainfall Events, Number of Hurricanes.	Topping, 1997 [10]
Climate	*Climate Response Index*	Global Temperature relative to a moving average.	Karl, 1995 [11]
Climate	*Environmental Impact Classes*	Examples include Global Warming Potential, Ozone Depletion Potential, Nitrification Potential, Photooxidant Formation, Acidification and Eutrophication Potential.	Heijungs et al., 1992 [12]
Emissions Based	*CO_2 Emissions*	–	Yamagiwa, 1996 [13]
Socio-Political	*Indicator of "Weak" Sustainability*	Macroeconomic and Environmental Examination of Measures of Sustainability.	Pearce et al. 1993/7 [14]
Socio-Political	*Effect Category*	Includes Sweden's Political Goals.	Bauman et al., 1994 [15]
Human Population	*Exposure & Risk Metrics*	Incidence of annual Adverse Effects to Humans.	Fiskel, 1996 [16]
Cost Based	*EPS*	Cost of restoring biodiversity, production, human health, resources and aesthetic values following changes to the system.	Steen & Ryding, 1992 [17]
Cost Based	*Abatement Costs*	Costs for abating emissions according to national goals.	Kroon et al., 1994 [18]

Table 2: Various microecometrics proposed over the 1992-98 period

CATEGORY	ECOMETRIC	DETAILS/JUSTIFICATION	SOURCE
Energy	*Energy Use*	Renewable energy consumed during the life cycle.	Fiskel, 1996 [16]
Energy	*Energy in Transportation Infrastructure*	Total or scaled (J/km) energy.	Graedel & Allenby, 1997 [19]
Energy	*Energy Consumption (Scaled)*	Energy Used per Unit Product.	Correa, 1997 [20]
Energy	*Energy Intensity Index*	Energy Used per Service Unit	Lehni, 1998 [21]
Energy	*RER Energy Rate*	$= \frac{\text{Total Energy Consumption (GJ/y)}}{\text{Employees} \cdot \text{km} + \text{Chemical Products (t)} \cdot \text{kc} + \text{Pharma/mixing products(t)} \cdot \text{kp}}$ km = 100 GJ/employee · y kc = 100 GJ/ton of product from chemical production kp = 6 GJ/ton of end product from mixing, pharmaceutical operations.	Glauser and Müller, 1997 [22]
Material	*Material Use*	Life Cycle Material Use for a Product or Service.	Lehni, 1998 [21]
Material	*Materials Productivity*	Mass of Products and Byproducts per Mass of Material Input.	Lehni, 1998 [21]
Material	*Ecopoints*	Ratio of critical to actual flow for a given substance summed via a weighting scheme (value system).	Jolliet, 1996 [23]
Material	*Key Substances*	Quantity of key substances such as heavy metals, nitrogen compounds, organic chlorides, greenhouse gases, emitted.	Weidenhaupt & Hungerbühler, 1997 [24]
Material	*Summary Parameters*	Examples include: Total Organic Carbon, Volatile Organic Carbon, Chemical Oxygen Demand.	Weidenhaupt & Hungerbühler, 1997 [24]
Material	*Source Volume Metrics*	Includes Product Mass, Percent of Product Disposal of or Incinerated, and Fraction of Packaging Mass.	Fiskel, 1996 [16]
Material	*Water Usage*	Water consumption during product and use (for electric products).	Fiskel, 1996 [16]
Material	*Water Consumption (Scaled)*	Water Consumption per Unit Product.	Correa, 1997 [20]
Material	*Eco-efficiency*	$= \frac{\text{Product Quantity}}{\text{Raw Materials Input}}$	DiSimone and Popoff, 1997 [25]
Discharge	*Toxic Waste*	Toxic Release Inventory: average annual total releases and off-site transfers in pounds per million dollars in sales.	Kiernan and Levinson, 1997 [26]
Discharge	*Hazardous Waste*	Toxic Release Inventory: average annual total releases and off-site transfers in pounds per million dollars in sales.	Kiernan and Levinson, 1997 [26]
Discharge	*Spills*	Biennial reporting of average annual total RCRA waste generated at federal (US) permitted facilities in tons per million dollars in sales. Does not include WW.	Kiernan and Levinson, 1997 [26]
Discharge	*Pollutant Releases*	Categorized Discharges	Lehni, 1998 [21]
Discharge	*Material Border Metrics*	Hazardous waste generated during various life cycle stages (production, use).	Fiskel, 1996 [16]
Discharge	*Non-ProductOutput*	Non-Primary Material Generation	Lehni, 1998 [21]
Discharge	*REIF: Environmental Impact Factor*	$= \frac{\text{Waste air + Waste to incineration + Effluent to WWTP + Waste to Landfill}}{\text{kg of end product}}$	Glauser and Müller, 1997 [22]
Discharge	*Waste Ratio*	$= \frac{\text{Waste}}{\text{Product + By Product + Waste}}$	Zosel, 1992 [27]
Discharge	*Enforcement*	Total number of enforcement actions per billion dollars in sales.	Kiernan and Levinson, 1997 [26]
Loop Closing	*Recovery and Reuse Metrics*	Percent of Recycled Materials used as Input to Product.	Fiskel, 1996 [16]

Table 2 *cont'd*

CATEGORY	ECOMETRIC	DETAILS/JUSTIFICATION	SOURCE
Financial Based	*Economic Metrics*	Life Cycle Cost Incurred by Manufacturer, or Life Cycle Cost Savings Associated with Design Improvements.	Fiskel, 1996 [16]
Financial Based	*Life Cycle Profit*	Value chain over complete product life cycle.	Steger, 1996 [28]
Financial Based	*Environmental Risk*	Credit Rating (e.g. Moody's). Environmental risks could be incorporated into credit ratings.	Schmidheiny, 1996 [6]
Financial Based	*Eco-Productivity Index*	Turnover per Input of Key Materials, Energy, Water and Packaging	Novo Nordisk
Financial Based	*Resource Productivity*	$= \frac{\text{(Economic Value Added)} \times \text{Product Life}}{\text{Material (Consumed-Recycled) + Energy in Production, Use and Recycling}}$	Sony Europe
Financial Based	*Cost-to-Durability Ratio*	= Purchase Price + Material Cost + Energy Use + Disposal Cost per year of Product Life	Lehni, 1998 [21]
Financial Based	*Value Added per Resource Unit*	Value Added to National GDP per unit of Water or Energy Consumed	Correa, 1997 [20]
Financial Based	*Variance in Profit*	Less environmentally burdensome firms tend to have smaller quarterly and annual profit swings.	Meyer, 1997 [29]
Aggregated Indicators	*Eco-indicator*	Numeric Valuation of Various Impacts	Goedkoop, 1995 [30]
Aggregated Indicators	*Sustainability Risk Index*	Rates Investment Risk according to the Potential for Global Warming, Ozone Depletion, Materials Intensity, Toxic Release, Energy Intensity, Water Use and Environmental Liabilities	Storebrand, 1997 [31]

Conference Announcements: *In*LCA

The International Conference and Exhibition on Life Cycle Assessment: Tools for Sustainability

- Date: April 25-27, 2000
- Location: Crystal City Hyatt, Arlington, Virginia, Washington DC Metro Area
- Contact: InLCA.CI@epamail.epa.gov

Sponsored by the USEPA's National Risk Management Research Laboratory
National Center for Environmental Research and Quality Assurance (USEPA)
Institute for Environmental Research & Education
Environmental Quality Management Institute

LCA is being developed and applied internationally by corporations, governments, and environmental groups to incorporate environmental concerns into the decision-making process. It is being widely adopted as a means to evaluate commercial systems and develop sustainable solutions.

Presentations and discussions during *In*LCA will focus on approaches that integrate environmental, economic, and social values for decision-making, with emphasis on LCA applications and case studies. The conference will bring together practitioners and decision-makers. peakers will discuss how LCA can be used to:

- *create* marketing advantages
- *improve* environmental decision-making
- *save* organizations money
- *organize* environmental management systems
- *measure* environmental performance and progress towards sustainability
- *communicate* within and outside of organizations.

Fee:
$175 – Early Registration
$200 – Registration after 2/14/00
$150 – Government and Students