Issues in Ecobalances

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Overview

- Vision
- Inventory
- Impact
- VI / Chem Systems Study

Vision of Ecobalances

- Minimize Adverse Impacts on the Environment
- Product Planning and Risk Management
- Maintain and Improve Quality of Life
- Maintain Sustainable Business Growth

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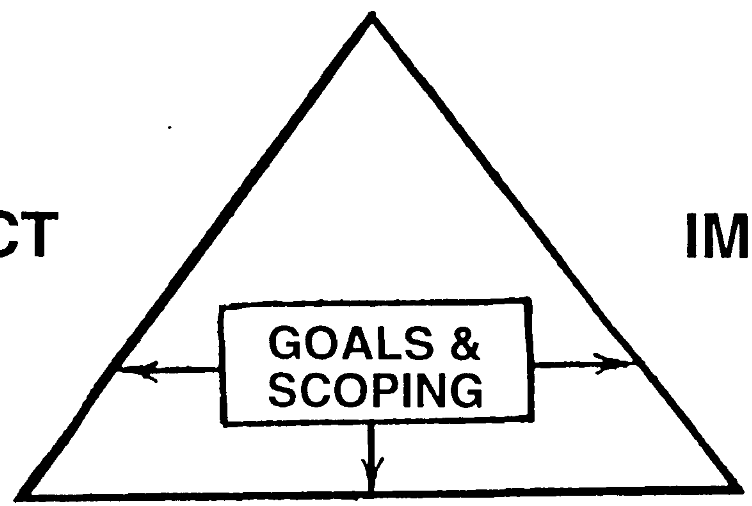
Ecobalance Methodology

IMPACT

IMPROVEMENT



INVENTORY

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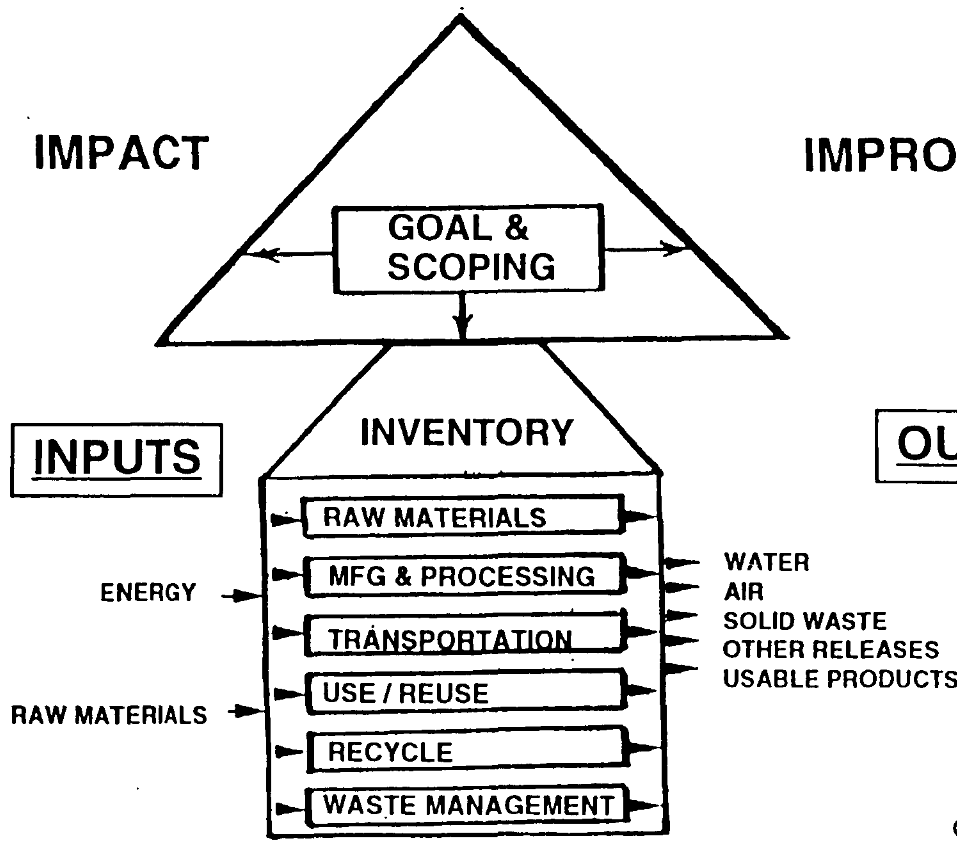
TRIPARTITE CONFERENCE

Inventory Database



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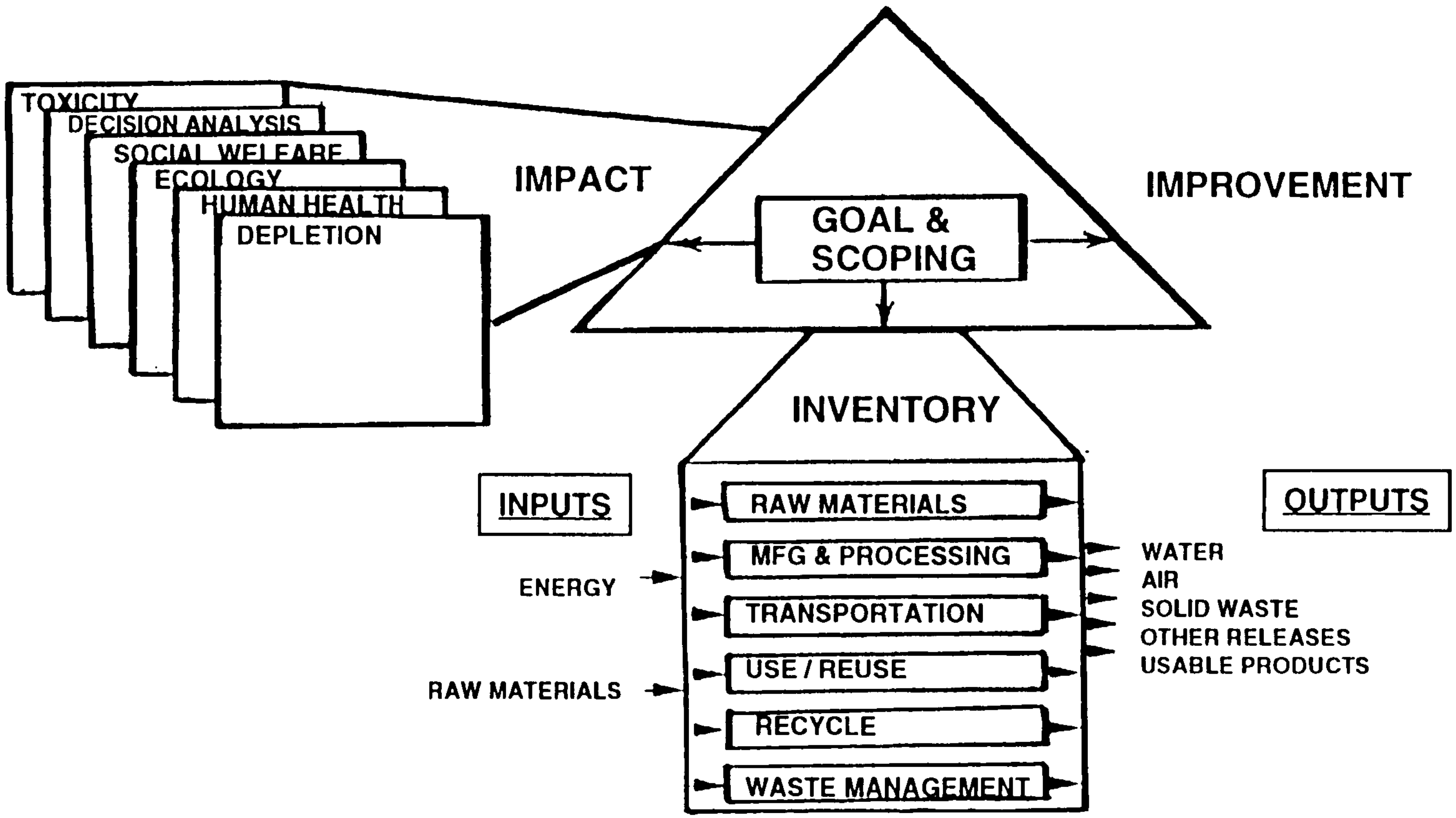
SEPT 2 - 4, 1992

Impact Assessment



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Impact - Stressors

STRESSORS:

Properties that may lead to adverse human or environmental conditions and can provide a linkage between inventory data and impact.

- Toxicity
- Accidents
- Climate Change
- Ozone Depletion
- Oxidants
- Acidification
- Radiation
- Nutrients
- Biological

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VI / CSI Packaging Ecobalance

- Prepared by Chem Systems Inc. for The Vinyl Institute.
- PVC Applications Studied:
  - 32 ounce Household Cleaner Bottles (PVC, Glass HDPE)
  - 32 ounce Food Oil Bottles (PVC, PET)
  - Thermoformed Blister Paks (PVC, PETG)
  - Rigid Folded Cartons (PVC, Bleach Kraft Paperboard)
  - Flexible Film Meat Wrap (PVC, PE coated Butcher Paper)

CTL007217

Data Sources Utilized

- Chem Systems Technology Database
- U.S.A. Government Energy Reports
- USA 1988 Toxic Release Inventory Report
- 1989 EPA Science Advisory Board Report

Ecobalance Computer Modules

Natural Gas Processing
Natural Gas Production
Fuel Module
Petroleum Refining
Oxygen
Utilities
Ethylene
Ethylene Oxide
Ethylene Glycol
P-Xylene
Terephthalic Acid

Benzene
Methanol
Dimethyl Terephthalate
Hydrogen
Cyclohexane Dimethanol
Chlorine
PVC
Plastics Fabrication
HDPE
LDPE
PET

PETG
Kraft Pulp
Butcher Paper
SBS Paperboard
Ammonia
Nitric Acid
Adipic Acid
2-Ethylhexanol
di-octyl Adipate
Cyclohexane

VI / CSI Ecobalance Conclusions

- PVC generally requires less energy than the alternatives
- PVC creates substantially less carbon dioxide
- Inventory data variation makes impact assessment difficult
- Inventory methodology and databases need standardization
- Impact methodology has not been developed
- Use ecobalances to improve products and processes
- Do not use ecobalances to "micro-manage" economy

Additional References

- "COPPE INFO BACKGROUNDER - ISSUES IN LIFE CYCLE ASSESSMENT," Council on Plastics and Packaging in the Environment, September 1991

- "AN LCA ON PVC PACKAGING - A NEW LOOK AT METHODOLOGY AND USE OF LCA'S," Ron Cascone, Chem Systems Inc., September 1991

- "NEW LIFECYCLE STUDY SHOWS ENVIRONMENTAL BENEFITS OF VINYL," Nora Jacobs, Edward Howard & Company, May 1992

- "VINYL PRODUCTS LIFECYCLE ASSESSMENT - A REPORT PREPARED FOR THE VINYL INSTITUTE," Chem Systems Inc, March 1992

COPPE

BACKGROUNDER

Issues in Life Cycle Assessment

What is the Issue?

Environmental professionals, policy makers, and the general public are very interested in having the means to accurately and comprehensively measure the environmental consequences of products and packages. These include the raw materials, energy and emissions related to each step of a product's lifecycle. One developing procedure for doing this is termed "product life cycle analysis," "ecobalance," "cradle-to-grave" or "life cycle assessments" (LCA).

Such studies can be valuable tools for evaluating the environmental consequences and opportunities for making meaningful improvements in a product, process, or activity. However, the concept can benefit from further development. Additional research will enhance our understanding of how to conduct life cycle assessments and how to better interpret the results.

Of immediate importance is how LCAs are used while the methodology is being further developed and refined. More to the point: should legislators and solid waste officials consider LCAs—as they are currently conducted—to formulate public policy?

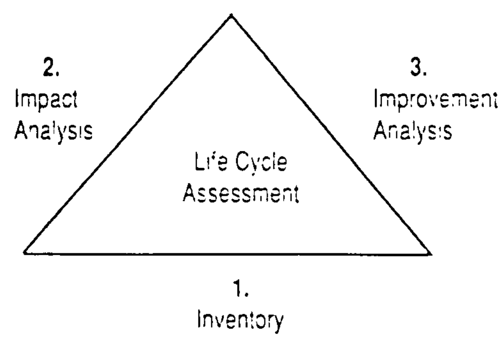
What are 'Life Cycle Assessments'?

LCAs are an objective, three-part process used to evaluate the environmental impact of a product, process, or activity. The first step involves an inventory of energy, resource use and emissions during each step of a product's "life," starting with the extraction of raw materials from the ground and continuing with the various processing, manufacturing, fabrication, and transportation steps, including the acts of consumption, disposal, or recovery for recycling.

The second step involves measuring and assessing the environmental impact of the energy, materials use and emissions inventory. Step three evaluates opportunities and areas for improvement.

Most LCAs conducted today focus on the inventory component only. These studies are useful sources of information on resource usage and environmental emissions, and can serve as the basis for improvement analysis. To date, LCAs have been effectively used to evaluate packaging options and thereby reduce energy use and solid waste.

A complete life-cycle assessment consists of three separate, but interrelated components.



Most attempts to develop life cycle assessments have focused on the inventory component. Considerable research is needed to develop the impact and improvement analysis.

Life Cycle Inventory. An objective, data-based process of quantifying energy and raw material requirements, air and water emissions, solid waste and other environmental releases incurred throughout the life cycle of a product, process or activity.

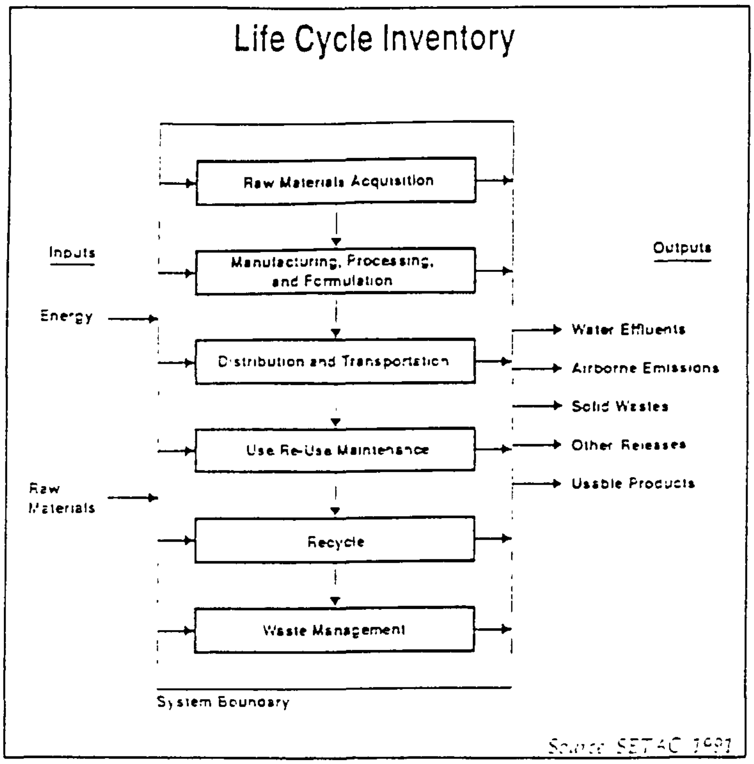
Life Cycle Impact Analysis. A technical, quantitative, and/or qualitative process to characterize and assess the environmental effects of energy, materials and emissions identified in the life cycle inventory. The assessment should include both environmental and human health considerations.

Life Cycle Improvement Analysis. A systematic evaluation of opportunities to reduce the environmental impact associated with energy and raw materials use and emissions throughout a product's, process's or activity's entire "life."

Source SETAC, 1991

However, such studies do not qualify all environmental consequences of a product. In 1990, leading LCA experts meeting in a workshop sponsored by the Society of Environmental Toxicology and Chemistry (SETAC) proposed a technical framework for measuring each step of a life cycle inventory (*see figures*).

The major life cycle inventory stages are 1) raw materials acquisition, 2) manufacturing, processing and formulation, 3) distribution and transportation, 4) use/re-use/maintenance, 5) recycling; and 6) emissions and waste management. In general, each stage receives inputs of materials and energy and outputs materials or energy and waste emissions.



Source: SETAC 1991

Resources needed to construct buildings and manufacturing equipment are generally not included in LCA studies. To do so would require averaging these resources over a very large number of items produced during the life of the equipment, and therefore would be too small to measure.

Activities of plant personnel, such as space conditioning, lunchroom trash and water pollution from sanitary facilities are not included since they would occur whether the product is manufactured or not.

One major result from the SETAC workshop was agreement that data from the inventory assessment, such as air and water emissions, have different environmental impacts and should be reported individually. Results of inventory assessments have sometimes been added together without "weighing" the relative environmental impact of these emissions. However, the comprehensive nature of LCAs makes objective, scientifically-sound "weighing" schemes difficult.

LCAs as a Planning Tool

A key benefit of LCAs is that they provide companies a method to ensure new manufacturing processes, product or packaging options do indeed result in meaningful environmental improvements. An LCA helps to confirm that a gain in one direction (e.g., reduced solid waste generated by a manufacturer) is not compromised by a step backward in another. In this way, LCAs are a valuable internal decision-making tool for process design, product modifications and even the inventing of new products.

The largest number of LCAs performed today are for use by private companies to examine their own products in comparison to a modified version of the same product, or to new or proposed products. Specifically, LCAs are valuable tools to:

- Provide a broad view of the trade-offs associated with product modifications (such as source reduction/lightweighting, use of recycled content and material substitution), raw material sourcing (agricultural vs. fossil fuel derived), technology changes (in process or materials) and different waste management options;
- Serve as a baseline for comparison with future modifications;
- Develop a method to quantify and monitor product's energy consumption and emissions.

In addition, LCAs can be used to develop information on a single product in an effort to identify potential resource and waste reductions associated with individual steps of the manufacturing process (raw material extraction, fabrication, transportation, etc.).

Important But Not An Environmental Panacea

Beyond the life cycle inventory, complete LCAs need to include impact and improvement analysis. However, the inventories alone have led to significant environmental progress by uncovering opportunities to reduce energy and waste.

Comparing the impact of products or processes that use different technologies is extremely difficult. For example, one process may have mostly air emissions, and another, water borne releases. No scientific guidelines have been established to objectively compare these results. Both the Environmental Protection Agency (EPA) and SETAC recommend further effort in these areas.

In addition, LCAs do not "weigh" the relative importance of inputs or emissions (such as making energy consumption more important than raw material consumption). Nor do LCAs include risk assessments of each step of the manufacturing process, since no scientific system has been established to apply risk assessments to LCAs or to evaluate the results. Also important is a thorough understanding of all assumptions made about LCA's inputs, processes and emissions is required to quantify and judge impacts.

Case Study: Evaluating Product Packaging Through LCA

One of the most important uses of LCAs is to provide companies with a method to ensure that new product formulations or packaging options do indeed result in meaningful environmental improvements. In the following simplified example, an LCA was conducted on various packaging strategies for a liquid fabric conditioner product. Only four of the many options studied are shown here. (For a uniform comparison, the data is based upon 1,000 liters of single-strength product.)

The table indicates percent decreases for each energy and emission category as compared to a non-recycled, 64 oz. bottle made of virgin, high-density polyethylene (HDPE).

	Percent Decrease in Energy Usage			Percent Decrease in Emissions		
Strategies for Packaging Improvement:	Process	Transport	Feedstock	Solid	Waterborne	Airborne
1. Incorporate 25% recycled HDPE into the virgin HDPE bottle.	3	0	9	9	(+4)	4
2. Assume 25% consumer recycling of the virgin HDPE bottle.	3	2	11	11	(−4)	5
3. Market a concentrated (3x) product in smaller, virgin HDPE bottles.	55	53	56	55	54	55
4. Market concentrated (3x) product in virgin paper carton to refill HDPE bottle.	53	58	94	91	40	62

These results indicate that the source reductions made possible by product concentration offered greater reductions in life cycle energy requirements and emissions than either incorporation of 25 percent recycled HDPE or a 25 percent recycling rate. Product concentration plus the reuse of existing containers offered additional benefits.

Relative to the non-recycled virgin bottles, each of the four packaging options studied had reduced energy requirements and solid waste emissions. It is important to note that the emissions associated with each packaging option differ in composition, and thus require a more detailed examination for meaningful interpretation. This case study illustrates the merits of LCA in: (1) providing a baseline as a reference for improvement; (2) guiding product/package development efforts; and (3) lending better understanding of the unique environmental attributes of different packaging strategies.

Source: Data compiled by Franklin Associates, Ltd. and provided courtesy of the Procter & Gamble Company

[illegible]

While the LCA concept is useful in developing information on resource usage and environmental emissions, the concept requires further development.

Therefore, using LCAs—as they are currently conducted—as an instrument of public policy is premature. Yet, LCAs are currently being suggested as the basis for "green" labeling of products.

Because LCA methodology includes assumptions and average values, results may not be exact or apply to all situations. As such, results are best characterized as a range of values. In addition, LCA results are "snapshots" in time of processes and technology, and quantify most, but not all environmental consequences of a product. Therefore, specific comparisons between material types must be interpreted carefully and have a limited usefulness. LCAs should not be used to evaluate products as either "good" or "bad," but rather to provide the perspective that environmental issues are not black and white.

For example, LCAs can provide a basis for comparing different products, and can illustrate that every product consumes energy and has an environmental impact. Furthermore, LCAs are only one of the major studies required to obtain a complete and objective analysis of a product or process. Other questions, such as product protection and safety, product/package functionality, value, convenience, personal choice and need are more appropriately addressed by other types of studies

[illegible]

Recent efforts, like those of the SETAC Product LCA Advisory Group—which include's industry, government, academia, and special interest groups—are helping to bring more focus toward refining and improving the LCA process. The SETAC group's stated goal is to, "advance the science, practice, and application of LCAs to reduce the environmental burden and resource consumption associated with products, packaging, processes or activities."

LCA practitioners in North America and Europe are moving forward to refine the LCA inventory methodology, develop impact and improvement analysis, clarify definitions and terms, improve the emissions data base, develop a peer review process, and identify future research needs.

The U.S. Environmental Protection Agency has also formed a task force to address the practice and use of LCAs. The task force includes representatives of federal and state government agencies, industry, academia, environmental and consumer research groups.

The goal of the EPA task force is to "develop a method that can be used by industry and government to inform consumers about product choices, by product and packaging designers and manufacturers to produce products with fewer environmental effects, and by government policy makers to evaluate pollution prevention policy options. This project is part of an overall effort to create market-driven incentives for pollution prevention." However, industry, environmental groups and academicians have expressed concern with the use of LCAs to address broad, public policy questions—as LCAs were not designed for this purpose.

Summary

While LCAs hold great promise, the concept is relatively new and requires further development. LCA inventory methodology has been developed, and significant improvements can be achieved using data from an inventory, but complete LCAs need to include impact and improvement analyses—which have not been developed. As such, until impact and improvement assessments can be incorporated, LCAs must be used very carefully when comparing different products or packages. Industry, environmental groups and academicians have expressed concern with the use of LCAs to address broad public policy questions.

LCAs are ideal for evaluating specific improvements made to reduce resource and environmental effects, and for this reason are being used by industry. Products or packages may best be judged on their own merits and on improvements sought to reduce their total environmental consequences and energy/resource requirements.

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"An Overview of LCA," William E. Franklin, Franklin Associates, Ltd., 1991.

A Technical Framework for Life-Cycle Assessment, Society of Environmental Toxicology and Chemistry, January 1991.

Background Document on Clean Products Research and Implementation, U.S. Environmental Protection Agency, Office of Research and Development, October 1990.

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Environmental Impacts of Polystyrene Foam and Molded Pulp Meat Trays, Midwest Research Institute, Project No. 3554-D, April 1972.

"The Life Cycle Analysis Methodology," Jere D. Sellers, et. al., Franklin Associates, Ltd., 1991.

News Release, R. Parrish and J.Fava, Society of Environmental Toxicology and Chemistry, August 30, 1990 and March 8, 1991.

"Outline of Presentation at Lifecycle Assessment: A Tool for the '90s Conference—SETAC," Bruce Vigon, Battelle Columbus, 1991.

Resource and Environmental Profile Analysis of Foam Polystyrene and Bleached Paperboard Containers, Franklin Associates, Ltd., June 1990.

Resource and Environmental Profile Analysis of Polyethylene and Unbleached Paper Grocery Sacks, Franklin Associates, Ltd., June 1990.

Resource & Environmental Profile Analysis of Plastics & Non-Plastics Containers, R.G. Hunt and R.O. Welch, Midwest Research Institute, Project No. 3714-D, November 1974.

SETAC Product LCA Advisory Group Mission Statement, SETAC Foundation for Environmental Education, Inc., Pensacola, Fla., September, 1991.

Written Testimony of Dr. James A. Fava, Chair, SETAC Product LCA Advisory Group, before the Federal Trade Commission, July 17, 1991.

What is COPPE?

COPPE is the Council on Plastics and Packaging in the Environment, a coalition of packaging manufacturers, plastic resin producers, corporate packaging users, recyclers, consumer products companies, retailers and trade associations. It recognizes that the challenges in dealing with post-consumer plastic packaging waste are both a fact of life and a societal issue that must be addressed. We hope that through sharing information on problems and solutions to them, we will help increase the foundation of knowledge upon which sound decisions will be made.

For More Information:
COPPE
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Washington, D.C. 20036

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Printed on recycled paper

The Vinyl Institute

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NEWS

FOR IMMEDIATE RELEASE

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Chem Systems Inc.
914/631-2828

NEW LIFECYCLE STUDY SHOWS ENVIRONMENTAL BENEFITS OF VINYL

WAYNE, New Jersey, May 15, 1992 — A new lifecycle assessment of vinyl packaging material shows that vinyl products require less energy and petroleum-derived raw materials in production than most comparable materials.

The study, a year-long effort by Chem Systems Inc. of Tarrytown, New York, also concluded that vinyl production creates substantially less carbon dioxide — and potentially, less environmental impact — than most other packaging materials. Carbon dioxide is a major contributor to the greenhouse effect.

Comparisons in the study were made between vinyl (polyvinyl chloride or PVC) packaging and packaging made from glass, paperboard, paper and other plastics commonly used in similar packaging applications.

"This lifecycle assessment strongly confirms that vinyl is an environmentally good product," said Robert Burnett, executive director of the Vinyl Institute. "Because vinyl consumes less energy than other packaging materials and is equivalent in its potential impact on the environment, society is well served by vinyl packaging."

(more)

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The study by Chem Systems inc. also noted that:

- Vinyl is the most stable and least environmentally dispersed end use for chlorine — which "... leaves this element in a form essentially more inert than the salt from which it was made."
- The manufacture of vinyl chloride monomer (VCM) — from which vinyl is made — is "a classic case of waste minimization," since virtually all material used to make VCM is recycled back into the process.
- A new membrane-based cell technology is being introduced into chlor-alkali manufacturing, which will improve energy efficiency and product quality while reducing potential environmental impact.
- Vinyl polymerization is a technology with "a very low discharge of VCM, since extremely strict standards were applied in the mid-1970s." The industry put the strict standards in place after studies showed that higher volume VCM discharges were linked to health problems in workers.
- Devices which rapidly and automatically identify and separate vinyl from other plastics in the mixed post-consumer waste stream permit vinyl to be recycled and reused.

"These conclusions, all based on scientific fact, give public policy decision makers solid information to use as they consider the appropriate role for vinyl in our economy," Burnett said. "Clearly, the weight of evidence says vinyl deserves the support of everyone working to improve the environment."

The Chem Systems study also marks an evolution in product lifecycle assessment methodology, according to Ronald F. Cascone, senior consultant for the work. He said new methodology for the study was developed based on a "critical analysis of the past and current state-of-the-art product lifecycle assessments. We recognized and attempted to overcome the many, and sometimes conflicting, criticisms of the methodology."

Lifecycle assessments attempt to catalog and analyze the total energy use and environmental emissions associated with a product from cradle to grave.

Cascone said some current assessments "have obscure databases and assumptions, are out of date, are naive concerning industry, irrelevant in excess detail and not focused on the most important factors of energy use and emissions."

In assessing vinyl packaging for the Vinyl Institute, Chem Systems relied on actual databases for energy and fuel use — rather than academic models — and on U.S. government emissions data from the Toxics Release Inventory (TRI).

Chem Systems created a computer model for its assessment which accounts for the material and energy used and environmental releases per unit for each kind of packaging analyzed.

"This model especially concentrates on materials conversions, the key energy and emission-intensive steps, such as oil refining, ethylene cracking, chlor-alkali production, glass melting, paper pulping, and monomer and polymer processes," Cascone said.

He explained that the report represents a state-of-the-art lifecycle assessment which can be updated as new data is obtained.

Vinyl used in packaging, the study notes, is only about 9 percent of the total domestic PVC virgin resin demand and compounded vinyl represents only about 7.5 percent of the total commodity plastics used in packaging in the U.S.

Further information on the study can be obtained by contacting the Vinyl Institute, Wayne Interchange Plaza II, 155 Route 46 West, Wayne, N.J. 07470.

The Vinyl Institute, a division of The Society of the Plastics Industry, Inc., is a national trade association representing the leading U.S. manufacturers of vinyl, vinyl feedstocks, additives and film and sheet products. The Vinyl Institute operates the Vinyl Environmental Resource Center (VERCE) which is a clearinghouse for information on vinyl and the environment. VERCE can be reached at 1-800-969-VINYL or 969-8469.

# # #

An LCA on PVC Packaging
A New Look at Methodology and Use of LCAs

Ron Cascone

Senior Consultant

September 1991

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AN LCA ON PVC PACKAGING - A NEW LOOK AT METHODOLOGY AND USE OF LCAs

By Ronald F. Cascone
Senior Consultant
Chem Systems Inc.
Tarrytown, NY

I would like to tell you about an LCA project we have recently completed that Chem Systems believes, along with the Vinyl Institute, represents a milestone of progress in the field.

Although some of Chem Systems' senior staff were among the original practitioners of energy-focused LCAs in the early 1970s, for NATO and other public and private sponsors, the company was not directly involved in the more recent spate of environmentally - oriented LCAs. However, we were pursuing the related issues through many other activities of our core and environmental practices. When the Vinyl Institute asked us to perform an LCA on certain vinyl packaging products and some alternatives, we were able to make a fundamental appraisal of the whole subject, since we did not have any vested interest in the status quo.

There have been for a long time some glaring flaws in LCAs, such as the tendency of presenters or users to attempt to add together the weights of emissions of vastly dissimilar materials, with or without "weighing factors", to derive glib, but meaningless "bottom lines" for comparisons. Also, seldom was the issue of data uncertainty broached. We proposed an approach that would address these and many other, sometimes divergent criticisms that have been leveled at LCAs recently.

Clearly, the public is disenchanted with LCAs because of the conflicting conclusions that have been published, and because of reversals of decisions by businesses based on them. It gives people the impression that someone is "cooking the books", so that it is likely there will eventually be much resistance to prescriptions based on these studies of which materials, products or systems are best for the environment. The public generally believes that science has precise answers to concerns and problems, but they also tend to believe that industry and its scientists are barely to be trusted with their health and safety. Doonesbury (Garry Trudeau) expressed the public confusion and skepticism very well in a recent cartoon on the subject.

LCAs need to be made more accessible to critical review and capable of being regularly updated to reflect the rapidly changing conditions of industry and society. They should be based as much as possible on publically available data, not private communications and estimates, and should analyze the uncertainties in their data. They should provide and discuss frames of reference for understanding the relative importance of factors inventoried. It is not enough to say, "this process emits a million pounds of ammonia per year!", without giving an understanding of what ammonia is, what it does to the environment, and what else emits it. It is widely agreed that dissimilar emissions should not be added together to achieve totals for comparisons, yet the practice continues. Pollutants are not fungible products like fuels, commodity materials, or electricity. LCAs should be performed, or at least guided, by individuals who are thoroughly expert and current in the industrial, utility, and other underlying processes used to obtain products. They should avoid facile assumptions in favor of their sponsors, or at least provide sensitivity analyses of the key assumptions. Their execution and analytical conclusions should reflect a healthy skepticism and acknowledgement of their limitations.

All of these "shalts" and "shalt nots" pointed Chem Systems to the development of an automatically-solving Lotus 1,2,3 (Version 3.1) spreadsheet model with open access to assumptions and key parameters to enable changes over time or for sensitivity studies. Figure 1 illustrates the overall architecture of the model. Figure 2 indicates the structural relationships and information flows among the model's process modules and information sources.

Our analysis also suggested that we reevaluate the traditional slate of inventoried pollutants to make them more responsive to the current state of knowledge and concerns. The 1990 report of the EPA's Science Advisory Board (SAB), a committee of remarkably broad scientific and community representation, set global air pollutants and toxics emissions as the highest priorities that can be qualitatively inventoried. This led us to select an ordered slate of "greenhouse" and ozone-depleting gases (including CO_2 and methane), the bulk of materials in the federal Toxics Release Inventory (TRI), and the Criteria Air Pollutants (SO_2, NO_x, CO, VOCs, and airborne particulates) as the priority species for our inventory. Figure 3 compares the 1988 estimated relative contributions of industrial processes and other sources of Criteria Pollutants in the U.S.

The TRI requires all significant manufacturing facilities to report annually on releases and transfers of 322 individual chemicals and groups. Figure 4 illustrates the scope of TRI releases considered in the study, as to chemical species in the TRI list, economic sectors covered, and relative magnitude of releases and transfers covered. Figure 5 indicates the complexity of the distribution of TRI chemicals among air, water, and land releases and transfers to treatment or disposal.

We made our models, and exercised them on cases of PVC detergent and oil bottles, thermoformed sheet blister pack and cartons, and plasticized film meat wrap, compared to alternatives in glass, HDPE, PET, PETG, SBS paperboard, and PE-coated kraft "butcher paper", respectively.

The model showed that PVC has modest advantages among the plastics products in total energy equivalents contained and released in manufacturing. Only glass bottles, even with the current substantial amount of recycling showed, a much greater energy requirements than PVC, while SBS paperboard showed a much lower energy requirement than PVC carton material. Related to these are similar distinctions in CO_2 and Criteria Pollutant emissions. Chem Systems cautions against making too much of these differences, because of the substantial uncertainties of total lifecycle models, in spite of the relatively accurate knowledge of energy requirements and process stoichiometry (material balances and yields).

Especially critical as "wild cards" are the energy and emissions for transportation, recycling, and disposal, which can be significant, but are poorly known. Figure 6 illustrates the wide diversity of transportation modes among various chemical commodity classifications. Compared to all the energy and by manufacturing industries in the U.S., including that imported for consumed electric power, freight transportation requires about another 22 percent. However, fuel and emissions can vary by several orders of magnitude among transportation modes on the basis of weights of various products transported.

As for toxics releases and transfers, some differences are apparent among products, but there are many qualifications. The most important is that the differences among facilities tend to be greater than among products. Figure 7 illustrates this point for key toxic emissions from a number of U.S. ethylene plants, which are diverse in their capacities and feedstock mixes. The ranges of emissions of each pollutant cover several orders of magnitude, and are greater than the difference among the PVC, HDPE, and glass products compared. Ethylene plants are typical of the problem that not all the facilities of a type can be included in a statistical analysis because many are within complexes that report their emissions lumped together. A corollary is that the glib models that others have constructed of process emissions from various types of processes are useless at best, and misleading at worst. Further, the TRI reporting, the best possible source of emissions data, does not extend to mining, transportation or to commercial, military, public works, nuclear, or power utility facilities; it only covers manufacturing operations. Figure 8 illustrates the conceptual degradation of confidence towards the raw material supply and end use parts of the life cycle. Fortunately, the key material conversion processes are covered in the TRI.

Chem Systems cautions companies and agencies that it will rarely be feasible to "micromanage" the economy for the benefit of the environment by selecting one product, material, or system over another using LCA environmental comparisons. The present state of knowledge simply does not justify such actions. We urge that the TRI reporting be expanded to other sectors of the economy, which can be greater emitters of some of the species than are manufacturing operations. We also recommend that much more federal effort be spent on characterizing the energy budget of freight transportation, a significant energy and emission item with a high sensitivity to assumptions in LCA modeling.

We recommend that other practitioners and the EPA consider the methodology we have created and the cautions we have stated on uses of LCAs in their efforts to evolve a new universal standard.

Flaws of LCAs

Sources and uses of data

Poor quality, obscure models

System definition - scope limitations

Selection of effluent inventory species

Presentation of results

Goals of Chem Systems/VI LCA

Scope - Complete systems analysis; full breadth of environmental concerns

Credibility - Involve peer reviewers, avoid facile assumptions

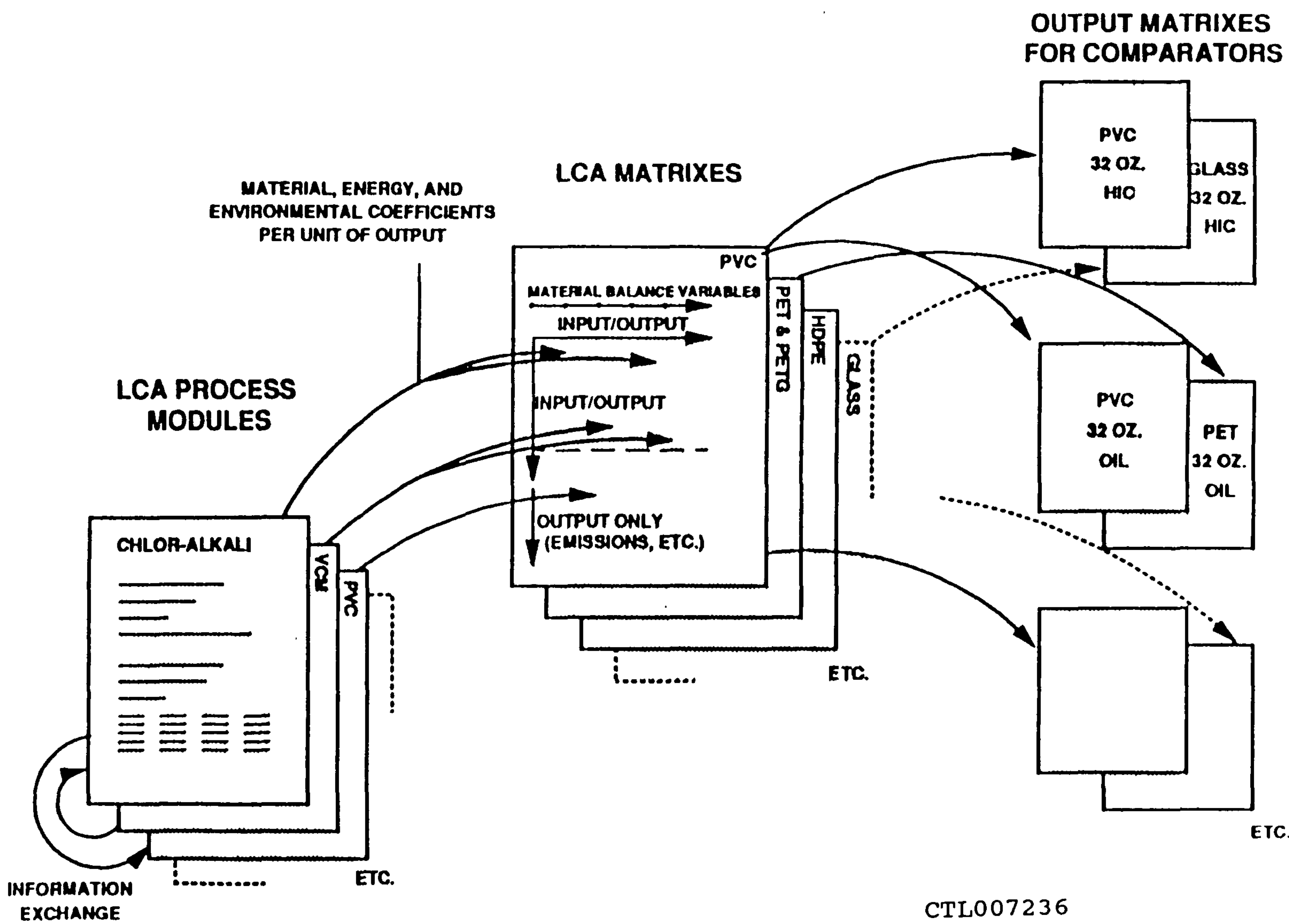
Flexibility - Lotus computer model

Accessibility - Discuss assumptions, disaggregate data

Objectivity - Avoid weighting factors or "bottom lines"

FIGURE 1

CSI LCA MODEL ARCHITECTURE



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CHEM SYSTEMS

FIGURE 2

MODEL COMPONENT RELATIONSHIPS

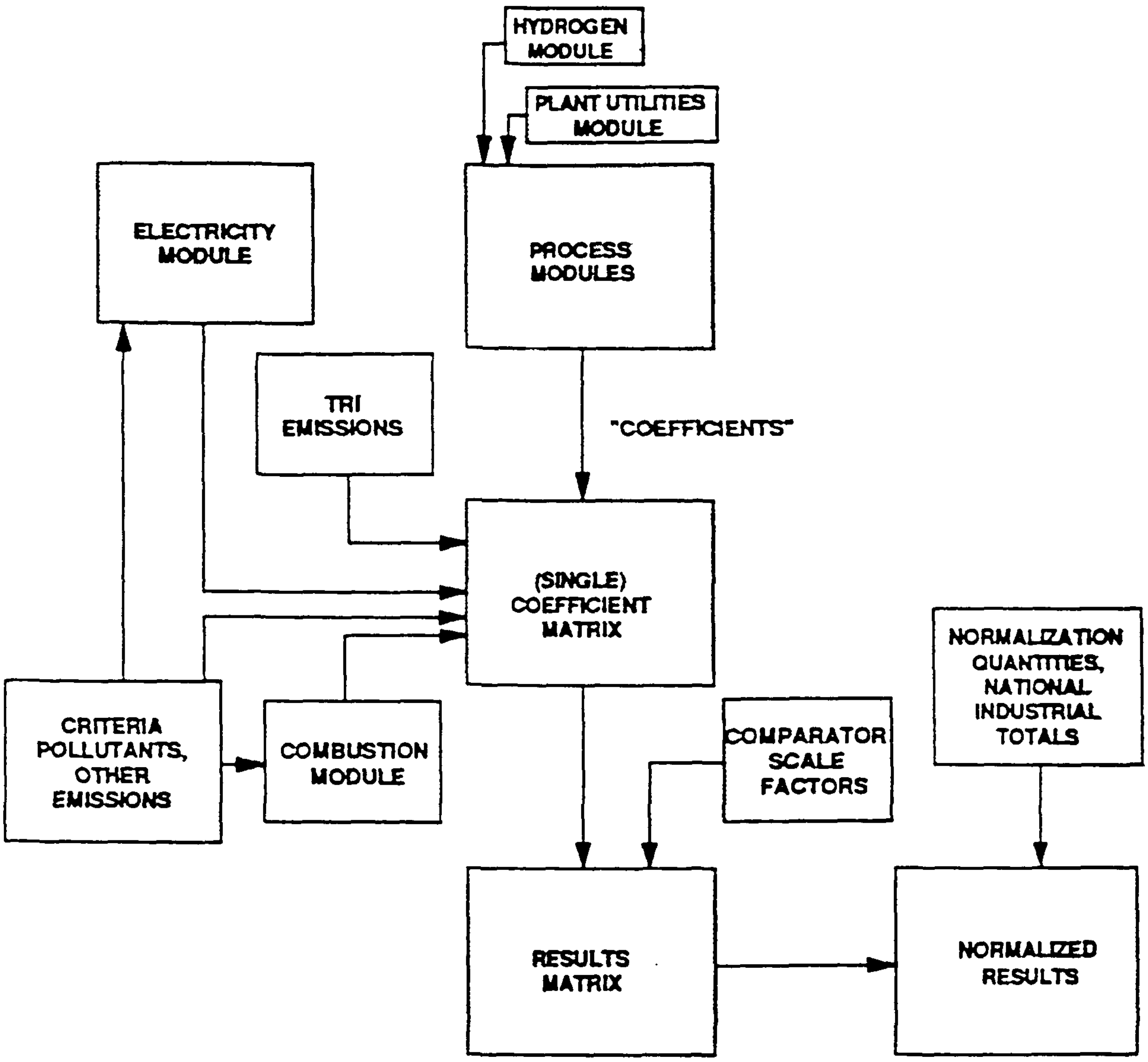


FIGURE 3

EPA ESTIMATES OF 1988 EMISSIONS OF CRITERIA POLLUTANTS BY SECTOR

	Million Short Tons/Year				
	SO_x	NO_x	PM	CO	VOC
Total transportation	1.0	8.9	1.5	45.3	6.7
Stationary fuel combustion					
Electric utilities	15.0	7.8	0.5	0.3	0.0
Industrial	2.3	3.4	0.2	0.7	0.1
Commercial/institutional/residential	0.8	0.6	1.1	7.4	0.8
Industrial processes	3.7	0.7	2.9	5.2	9.4
Solid waste incineration	0.0	0.1	0.3	1.9	0.7
Forest fires	0.0	0.2	0.9	5.9	0.8
Other miscellaneous	0.0	0.0	0.1	0.7	1.9
Total of all sources	22.8	21.8	7.6	67.3	20.5

Emission data from the TRI

Public data base - designed for accessibility

Manufacturing industries are compelled to report (fines up to $25K/day)

Industry reports annually

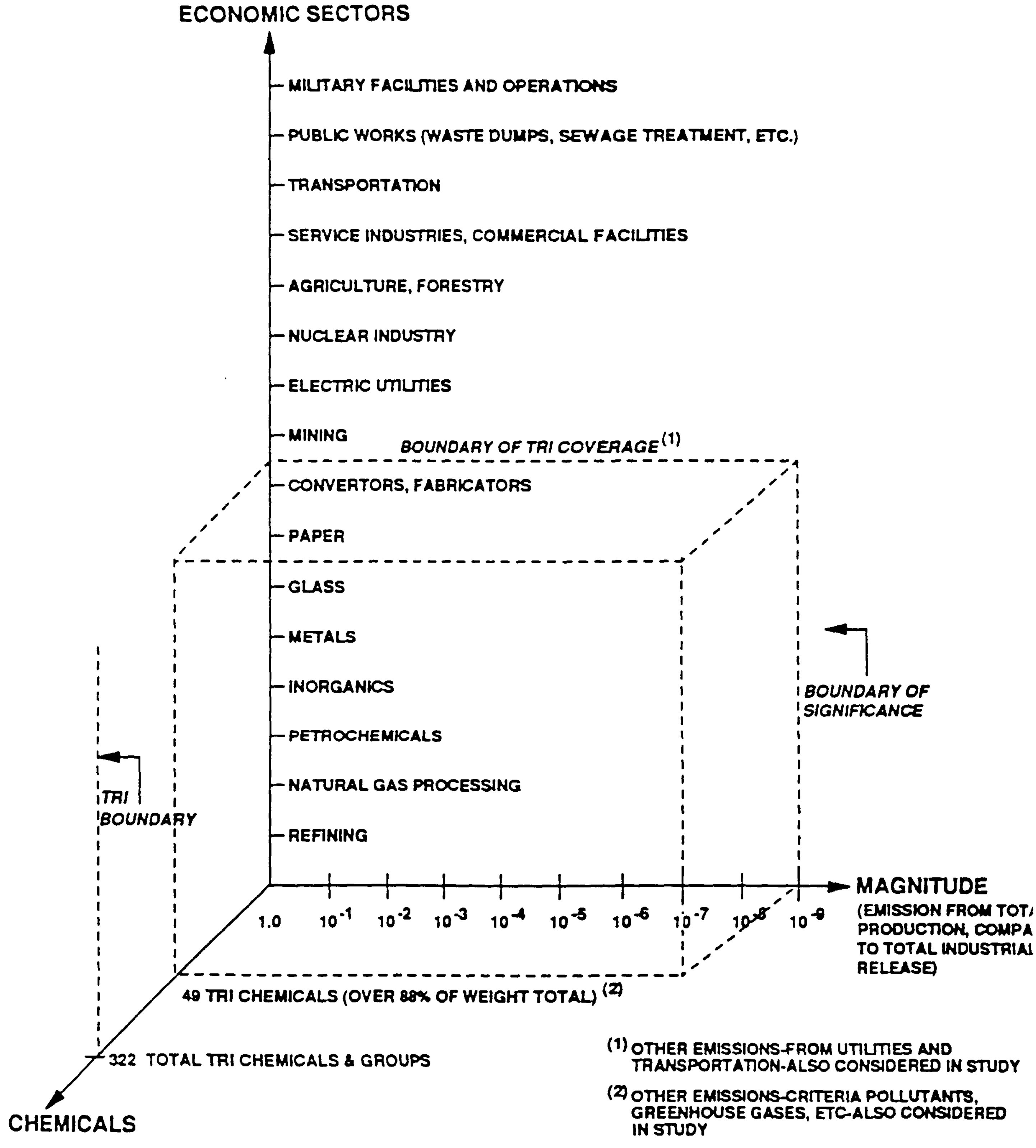
Basis constantly reviewed, updated, challenged, debated

Serves as the benchmark for U.S. industrial performance

Provides a consistent, credible, and relevant basis, but has some deficiencies

FIGURE 4

SCOPE OF TRI RELEASES CONSIDERED IN STUDY



(1) OTHER EMISSIONS-FROM UTILITIES AND TRANSPORTATION-ALSO CONSIDERED IN STUDY

(2) OTHER EMISSIONS-CRITERIA POLLUTANTS, GREENHOUSE GASES, ETC-ALSO CONSIDERED IN STUDY

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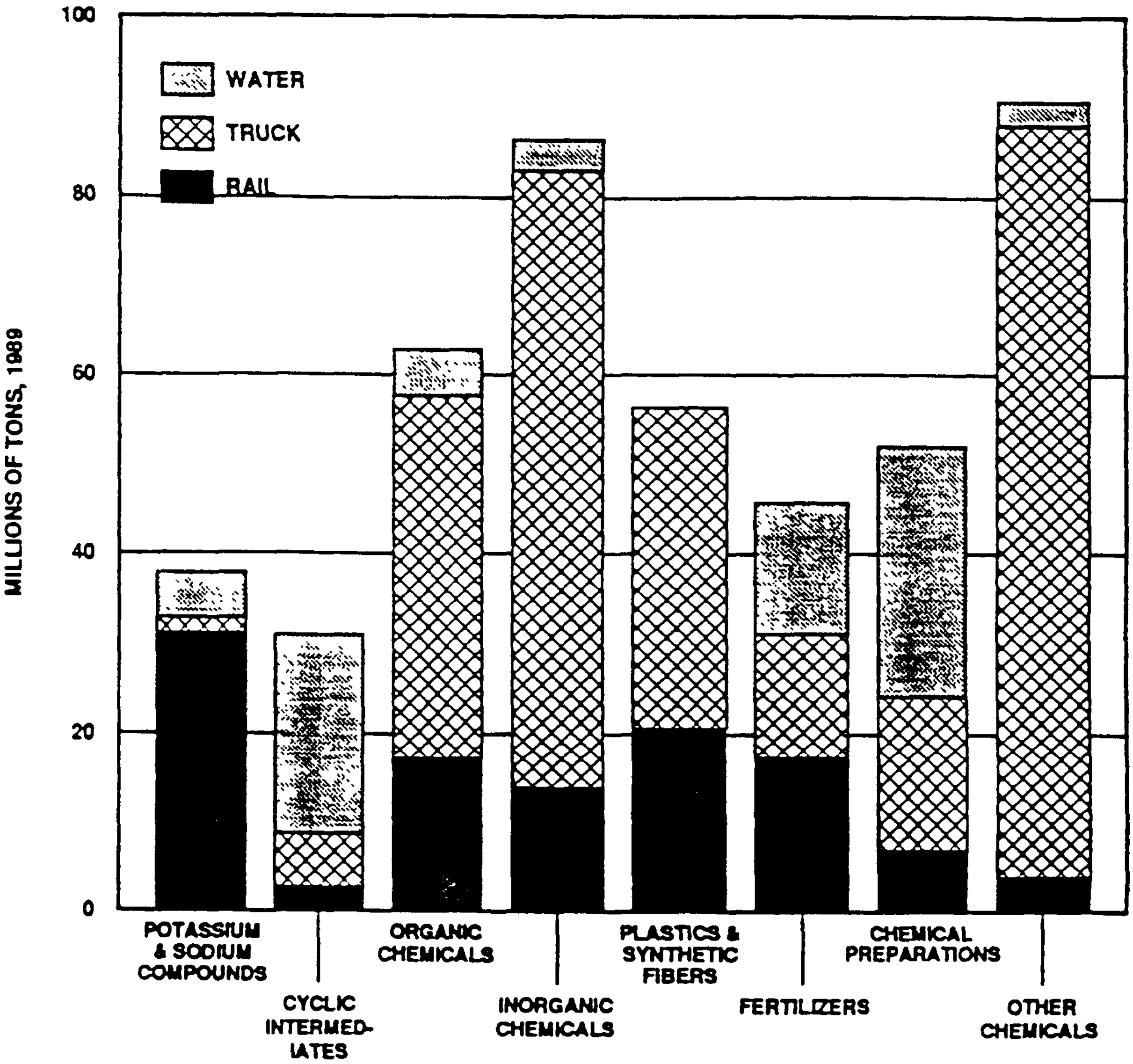
FIGURE 5

ENVIRONMENTAL DISTRIBUTION OF TRI RELEASES AND TRANSFERS

TRI Environmental Distribution	Percent
Release to air (fugitive and point source)	38.90
Release to surface waters	5.79
Release to land disposal	9.00
Public sewage treatment	9.14
Off-site treatment or disposal	17.70
Transfer to underground (deepwell) injection	19.47
Total	**100.00**

FIGURE 6

TRANSPORTATION VOLUMES AND MODES OF MAJOR CHEMICAL GROUPS



NOTE: FIGURES ARE FOR THE FIRST MOVEMENT FROM PRODUCTION TO CUSTOMER, WAREHOUSE, OR REDISTRIBUTION LOCATION; FOR SOME PRODUCTS THERE IS SIGNIFICANT SECONDARY SHIPMENT BY DISTRIBUTORS

SOURCE: C&EN, REEBIE ASSOCIATES, GREENWICH, CT.

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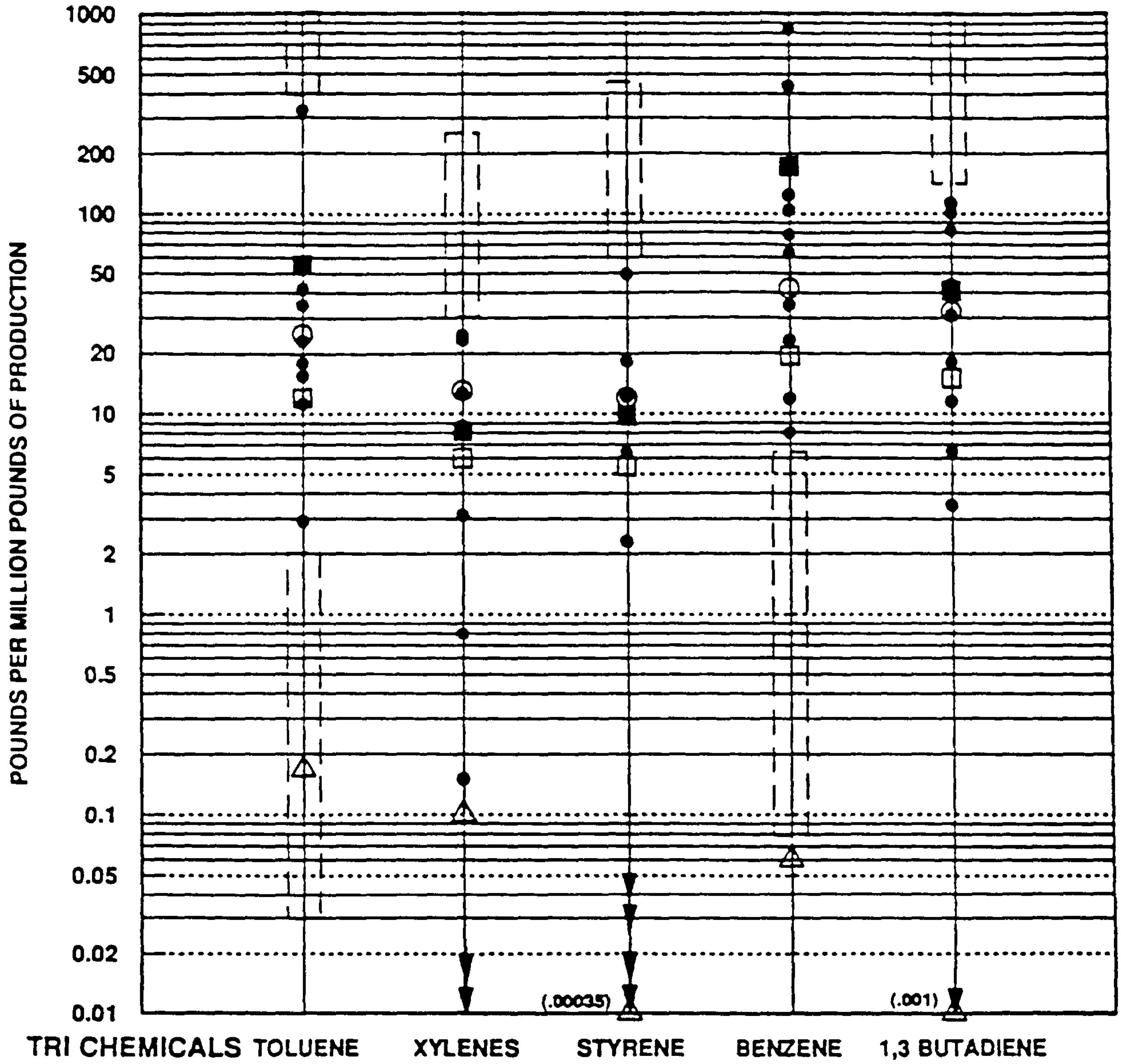
FIGURE 7

ANALYSIS OF SELECTED TRI EMISSIONS AMONG ETHYLENE PLANTS
(ON A SAMPLE OF 10 OF 35)



[ ] ⌊ ⌋ RANGE EXTENSIONS ASSUMING OTHER 25 ETHYLENE PLANTS HAVE EMISSIONS AMONG THEM 2 ORDERS OF MAGNITUDE LOWER AND ONE ORDER HIGHER THAN INDICATED RANGE FOR SAMPLE OF 10

ARROWS INDICATE CASES OF ZERO (OR BELOW MINIMUM) EMISSIONS REPORTED

LEGEND:
- ■ AVERAGE OF 10-ETHYLENE PLANT DATA SET
- □ PVC 32-OZ HIC BOTTLE TOTAL (EX. TRANSPORTATION)
- ○ HDPE 32-OZ HIC BOTTLE TOTAL (EX. TRANSPORTATION)
- △ GLASS 32-OZ HIC BOTTLE TOTAL (EX. TRANSPORTATION)

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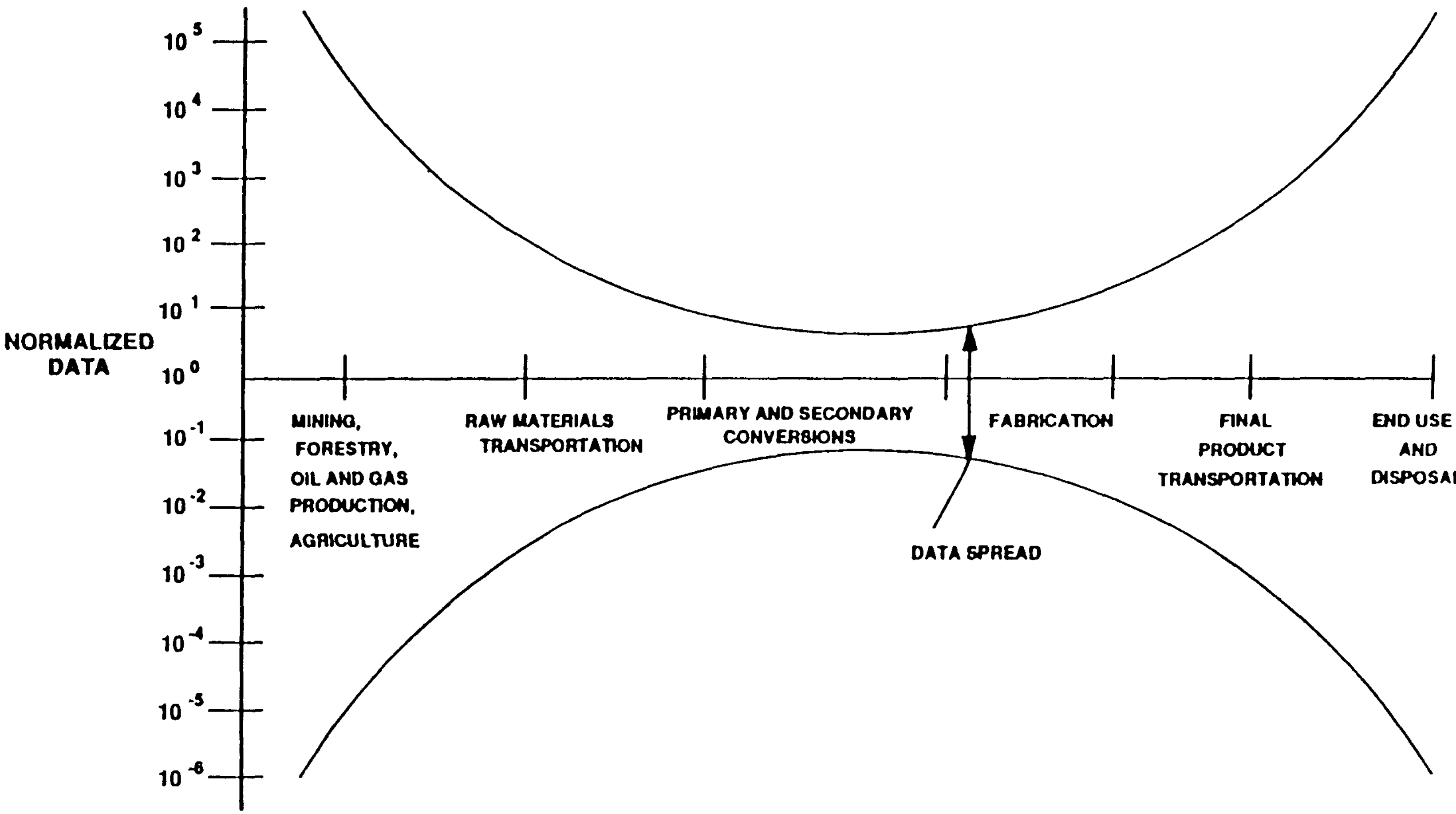
FIGURE 8

CONCEPTUAL CONFIDENCE LIMITS OF LCAs



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Conclusions

PVC generally has some energy advantages over most alternatives

Conclusions on environmental issues are difficult, uncertainties overwhelm differences

Don't "micro-manage" economy to achieve environmental improvement

Use LCAs to help improve each product or system individually

LCAs are better than anecdotal approaches

Need much more work on LCA methodology and data base

Peer review feedback

General approval of methodology - TRI use, computer program

Past LCAs accurate and useful on energy analysis, but not on environment

Differences between U.S. and European analyses - feedstocks, processes, transportation, data available

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