United States
Environmental Protection
Agency

Pollution Prevention
and Toxics
(7406)

EPA742-R-97-008
December 1997

EPA

Pathway to Product Stewardship: Life-Cycle Design as a Business Decision-Support Tool

Printed on paper that contains at least 20 percent postconsumer fiber.

ACKNOWLEDGMENTS

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Cooperative Agreement # X 821580-01-0 to Tellus Institute. It has been subjected to the Agency's publications review process and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The authors gratefully acknowledge Eun-Sook Goidel, EPA Project Manager, in the Pollution Prevention Division, Office of Pollution Prevention and Toxics, for her continuous and substantive contributions during all phases of this study. Her critique of earlier drafts of the case studies challenged us to revisit their content in ways that resulted in more incisive and more useful products. In every sense, she was as much a research collaborator as a project manager. We also extend our gratitude to Mary Ann Curran at EPA's Systems Analysis Branch, Office of Research and Development, for her insightful comments on the final draft document.

Our case research would not have been possible without the generous donation of time and insights of our industry colleagues, including site visits and innumerable follow-up data requests and conference calls. These colleagues include: Wayne Bonsell, Bill Freeman, Jack Kaufman, Steve Piguet, and Jim Tshudy at Armstrong World Industries, Inc.; Mary Beth Koza and Jerry Schinnaman at Bristol-Myers Squibb Corporation; and Anne Brinkley, Barbara Hill, J. Ray Kirby, Tim Mann, and Inder Wadehra at IBM.

Any remaining errors of fact or interpretation, of course, are the sole responsibility of the authors.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TEXT BOXES

EXECUTIVE SUMMARY

Corporate competitiveness traditionally has been achieved through new product development, quality performance, and cost control. Competitiveness in the 1990's and beyond will require extending these traditional elements to include the life-cycle environmental impacts of materials and final products. Three forces are driving this evolution. First, government regulations gradually are moving in the direction of life-cycle accountability whereby firms increasingly will face cradle-to-grave responsibility for their products and component parts. Second, emerging international standards with life-cycle requirements will affect access to, and competitiveness in, the global marketplace. Third, environmental "preferability" has emerged as a key criterion in both consumer markets and government procurement guidelines. Collectively, these developments have fostered a burgeoning corporate interest in the concepts of life-cycle design (LCD) – the application of life-cycle assessment (LCA) concepts to determine what a product contains, how it was produced, how it will perform, and what will be left after its useful life is expired.

Numerous firms have begun incorporating environmental effects as a criterion in product/process design. Because LCD is used as an internal decision-making tool, its strengths, successes, and limitations remain largely undocumented. Companies practicing, or inclined to adopt, LCD methods do not benefit from methodological advancements achieved by others and, with few exceptions, opportunities for cross-fertilization across firms has been limited.

With funding from the U.S. Environmental Protection Agency's Pollution Prevention Division, Tellus Institute has collaborated with 3 companies -- (1) IBM, (2) Bristol-Myers Squibb (BMS), and (3) Armstrong World Industries – to understand why and how LCD is finding its way into business decision processes. Documenting, advancing and disseminating LCD practices is the central objective of this project.

Case Study Findings

Armstrong, BMS, and IBM demonstrate a range of LCD practices, indicating the reality that there is no one-size-fits-all approach in transforming LCA approaches into a working decision-support tool. While all three LCD programs continue to evolve, our study suggests a number of themes that serve as valuable lessons both for other firms and for government initiatives aimed at advancing LCD practices.

Motives. LCD initiatives are likely to be driven by linked environmental and economic pressures. Moving beyond compliance to stay ahead of regulatory trends, improving customer service and product quality, and creating green market opportunities, typically provide the impetus to building and sustaining an LCD program.

Pragmatism. Non-prescriptive, customized, and flexible describe the approaches to LCD adopted by the three companies. For these firms, rigid protocols simply do not mesh with business reality. For example, while BMS has developed a generic framework for PLC reviews, the framework is tailored to the varying needs of BMS' different business units to account for the differing regulatory frameworks under which each unit operates. Electronics firms, such as IBM, facing an average 18 month time horizon in translating product concepts to market cannot afford LCD methods which may delay a product cycle. Product cycle time and trade-offs with other design criteria (e.g., performance, reliability, safety, cost) necessitate an adaptive approach to LCD.

Buy-in An effective environmental management structure, coupled with a solid corporate commitment to continuous environmental improvement, is key to a successful LCD program. Armstrong, IBM, and BMS have each established corporate environmental policies emanating from high levels within each company. Translating these polices into actions requires educating and achieving buy-in from employees across many levels of the company.

Streamlining. Complex, resource-intensive LCD systems may contain the seeds of their own undoing. They are tougher to market internally and more vulnerable to orphaning during business downturns and restructuring. Reducing the stages and impacts is one way of making LCD affordable and relevant to internal decision-making. All three companies practice such streamlining in some form, especially in the upstream extraction, transport, and intermediate manufacture stages of the product cycle.

Suppliers. Supplier relations as a component of LCD programs are uneven and slow to evolve. Our collaborating firms generally show an arms-length relationship with suppliers when it comes to implementing their LCD programs. Liability and proprietary concerns, and a reluctance to impose costly data development requests, are some of the impediments to more aggressively bringing suppliers into the LCD fold. Nonetheless, without supplier involvement -- including information exchange between customer and supplier essential to support final design decisions -- the absence of upstream inventory data will continue to impair a comprehensive life-cycle perspective on product design.

Teamwork. The most effective LCD programs are those that recognize the cross-functional nature of LCD, and integrate multiple business functions into the LCD process including product designers, materials engineering, process engineers, operations, marketing, and accounting/finance.

These themes point to a future in which LCD gradually continues to make inroads into corporate product development, but in diverse and often diffuse ways throughout the product life cycle. In the mid-term, realizing the benefits of LCD will require its integration in standard business functions such that each such function sees its benefits. This kind of seamless integration will help LCD avoid the risk of being another "environmental" program which costs, rather than saves, and constrains, rather than strengthens, the market position of the firm and its products.

1. INTRODUCTION

Product design lies at the core of business competitiveness. How a product looks, functions, performs, lasts, and costs all directly depend on design decisions. These decisions, in turn, represent complex trade-offs which, through a gradual and iterative process, transform a product idea into a final design ready for commercial scale manufacturing. Whether the product is a computer, an automobile, refrigerator, or shaving cream, the product designer stands on the front-line of translating an idea into a commercial success that meets customers' expectations at an affordable cost.

The decisions facing product designers require information of multiple kinds. What materials are required for manufacturing the product? How must the product function to meet customer needs? How can such materials and function best be packaged in terms of weight, size, and shape for each market and submarket? And, how can all these design considerations be meshed to yield a product which meets durability and cost constraints which will ensure marketplace competitiveness? All these design criteria -- functionality, performance, durability, cost -- combine to challenge the product design at each step of the design process, from conceptual/preliminary design, to detailed design, engineering review, and final specification.

While these traditional criteria has guided product designers for decades, a confluence of several forces have raised yet another criterion that increasingly commands the designer's attention. This criterion is the environmental performance of the product, or product stewardship. The driving forces behind this trend are several and varied. First, as government regulations and voluntary standards move toward life-cycle accountability, firms will face cradle-to-grave responsibility for their products and component parts. In the post-use (e.g., reuse and recycling) and disposal stage, extended product responsibility means that manufacturers increasingly will own a product well beyond the point of sale. Product stewardship in the form of take-back programs -- initiated either by regulation to reduce waste streams or by business acting in its self-interest to reclaim valuable material assets -- portend a future in which durable goods will find their way back to manufacturers in their entirety or in their component parts. With this responsibility, product designers will face the additional challenge of designing materials and structures which are disassemblable and recyclable.

Second, the global economy, fueled by the free trade movement, has exposed manufacturers to the rigors of international competition. From products as diverse as automobiles, electronics, electric power equipment, and chemicals, global competition means that firms must continually seek ways to more effectively compete on both cost and product differentiation. Since a large fraction of a product's life-cycle costs are fixed at the point of design, product design has never been more integral to establishing and sustaining market share and profitability. Additionally, emerging international standards such as ISO 14000, with includes life-cycle guidelines, will affect access to, and competitiveness in, the global marketplace.

Third, environmental "preferability" has emerged as a key criterion in both consumer markets and government procurement guidelines. As these expand, product designers will feel increasing pressure to deliver designs which minimize use of hazardous materials used in process and embodied in the product itself. In the product use stage, for example, products which minimize energy and water use and pollutant emissions will reap market advantages through eco-labeling schemes and through appeal to increasingly sophisticated customers sensitive to longer term, not just point-of-purchase, costs of products.

1.1 A Tool for the Design Transition

For all these reasons -- both external to the firm and driven by global competition or government regulation, or internal to the firm and tied to a new vision of materials value and management -- environmental objectives place mounting demands on designers to integrate environmental criteria into their activities. Meeting this challenge will require adjustments to traditional design practices and tools which in the past marginalized or entirely omitted environmental criteria. To correct this situation, adjustments are necessary along two dimensions: (1) integration of environmental considerations ***within*** the stage of the product life-cycle on which designers are traditionally focused, namely the production stage; and (2) expanding the purview of the designer's thinking to encompass other stages traditionally outside the purview of designers but where design decisions generate environmental impacts, namely upstream in the supplier chain and downstream in the use, post-use, and disposal stages.

One such tool capable of playing a pivotal role in this transition is life-cycle design (LCD). We define LCD as simply *the application of life-cycle concepts to the design phase of product development*. Thus, following the two dimensions noted above, LCD equips designers to build environmental considerations into both their current, production-focused decision-making while, at the same time, expand the designer's horizon to encompass stages upstream and downstream of the production stage. In this sense, LCD may be viewed as a translation and adaptation of the broader concept of life-cycle assessment (LCA) to the specific activities of the product designer. The two are closely coupled of course, but still may be differentiated.

Major methodological advances in LCA during the 1990s, spearheaded by the Society for Environmental Toxicology and Chemistry (SETAC) and US Environmental Protection Agency (US EPA), have yielded the widely accepted four part approach:[1]

- ***Goal definition and scoping***: identifying the LCA's purpose, boundaries, assumptions and expected products;
- ***Life-cycle inventory***: quantifying the energy and raw material inputs and environmental releases associated with each stage of production;
- ***Impact analysis:*** assessing the impacts on human health and the environment associated with energy and raw material inputs and environmental releases quantified by the inventory;

- ***Improvement analysis:*** evaluating opportunities to reduce energy, material inputs, or environmental impacts at each stage of the product life-cycle.

The "life-cycle" or "cradle-to-grave" impacts encompassed by LCA include the extraction of raw materials; the processing, manufacturing, and fabrication of the product; the transportation or distribution of the product to the consumer; the use of the product by the consumer; and the disposal or recovery of the product after its useful life. Thus, LCA examines the product and its manufacturing processes in a holistic fashion, examining environmental trade-offs and opportunities within and between the various production stages.

Whereas LCA is a broader concept with value to a host of different business functions which interact with product designers (e.g., materials engineers, production engineers, marketing, environmental), LCD targets the specific role designers play in shaping the environmental attributes of a product over its entire life-cycle. Thus, the scope of LCD tends to be more narrowly defined than LCA, limiting or eliminating upstream or downstream life-cycle stages (e.g., raw material mining, product disposal) or impact categories (e.g., focusing on human health impacts only).

Numerous LCA applications to specific products have produced results which have both informed further LCA methodology advances but, at the same time, produced substantial skepticism in the business community. This skepticism is spawned by a number of conditions that characterize LCA studies: product studies whose results seem to depend as much on who performs the analysis as on the inherent environmental attributes of a product; use of generic information (to protect proprietary data) in LCA inventory studies when such information varies widely from real-world, firm-, facility-, and/or technology-specific inventory information; concerns that the decision-relevant information generated by in-depth LCA inventory studies are less than the resource requirements necessary to conduct such studies; potential impediments to product cycle time, especially in sectors such as electronics where time-to-market pressures disallow any type of delay which life-cycle studies may create; and, finally, the lack of broad-based consensus on LCA impact assessment methodologies.

All these perceived shortcomings are a matter of continuing debate in the business, scientific, environmental, and government communities with respect to their seriousness and resolution. What is clear, however, is that many in the business community have selectively embraced LCA concepts, and that application to design decisions via LCD is one concrete form in which LCA concepts are permeating the ranks of manufacturers in industrial countries.

1.2 Organization of the Report

Because LCD is used as an internal decision-making tool, its strengths, successes, and limitations remain large undocumented. Thus, understanding why and how LCD is finding its way into business decision processes is the central objective of this study. What are the preconditions for effecting a sustained LCD program with the corporation? What stages of the life-cycle are included in corporate LCD practices? How do designers in practice make trade-offs between competing design criteria? What types of protocols and data are they using to make LCD a working tool? And how do designers relate to materials engineers, production engineers and other participants in the production process? Such an assessment will serve multiple purposes: to document LCD practices, enabling interested firms to benchmark their LCD initiatives; to identify gaps in methodology and data to guide both private and private-public initiatives to correct such deficiencies; and to advance our understanding of the dynamics of organizational innovation in corporate environmental management and product stewardship.

LCD is an evolving tool that continues to change. Through a series of case studies conducted in 1995 and 1996, this report presents a current-day snapshot of LCD. The remaining chapters of this report are organized as follows. Chapter 2 briefly reviews current LCD approaches in North American and Europe based on recent survey studies and secondary literature. Chapters 3, 4, and 5 present in-depth case studies of LCD in our three collaborating companies: IBM, Bristol-Myers Squibb, and Armstrong World Industries. Each of these chapters describes the corporate environmental management structure, history of LCD programs, specific methodologies, future directions, and our interpretation of the accomplishments, strengths and lessons from each of these companies. We conclude in Chapter 6 with a synthesis of our findings and a prognosis as to where LCD is headed in the next few years.

1.3 Endnotes

1. Society of Environmental Toxicology and Chemistry, *Guidelines for Life-Cycle Assessment: A "Code of Practice"*, 1993; U.S. Environmental Protection Agency, Office of Research and Development, *Life-Cycle Assessment: Inventory Guidelines and Principles*, EPA/600/R-92/245, Feb. 1993.

2. OVERVIEW OF LCD PRACTICES AND APPROACHES

To provide a broader context on the state of LCD practices in industry, and to provide a benchmark for our three collaborating case study firms, this chapter presents an overview of the range of LCA/LCD approaches and applications. This overview is informed by a recent survey conducted by Tufts Institute, a report co-sponsored by the European Commission (EC) and OECD, and supplemented by Tellus interviews with four firms.

2.1 Tufts Survey[1]

In 1994, a group of four graduate students in the Tufts University Department of Civil and Environmental Engineering Program undertook a Master's Degree project examining the current state of the science of LCA. Funded by the U.S. Department of Energy (DOE), this study evaluates trends and issues driving LCA at the international level, describes and compares current LCA methods, and surveys corporate perspectives and uses of LCA.

As part of their study, they performed a telephone survey of 34 "Fortune 500" companies that were known to be (or who intended to be) actively involved in using LCA. Of the 34 companies, fourteen were classified as belonging to the chemicals/plastics/paper sector, eight to the electronics/computers sector, five to consumer products, two to food and beverage, and two to "other." While the study recognizes its own limitations (e.g., respondent bias, small sample size), it attempts to generate initial information on the current uses of LCA, identify the common themes and differences, and possibly identify potential areas for improvement as described below.

Which divisions integrate LCAs

In the electronic/computer sector, both the Health, Safety, and Environment (HS&E) department and the Product Design and Development department are highly involved in integrating LCAs. Because of the innovative and fast-paced conditions of the field, LCAs need to be integrated into the design process (for example, as part of an LCD program). The chemical/plastic/paper sector, on the other hand, typically integrate LCA strictly from within the HS&E department. Few companies use strategy teams or research and development departments to develop LCA or LCD programs.

Company motivations

The survey found that primary motivations for integrating LCA are product and process improvements and cost savings, achieved primarily by improving the efficiency of raw material use and by reducing emissions. Also motivating companies is a desire to be environmentally proactive. The report notes that "although altruism appeared to be the feeling that these companies wanted to get across, it also appeared this motivation was linked to other reasons such as costs, regulatory considerations, and public image." Finally, meeting customer requirements and ISO standards appear increasingly important, primarily from companies' efforts to remain competitive in international markets.

Methodologies

While many different methodologies exist throughout industry, the most common is the Society for Environmental Toxicology and Chemistry (SETAC) model, consisting of four interrelated components (goal definition and scoping, life-cycle inventory, impact analysis, and improvement analysis). However, companies frequently streamline the SETAC model in an effort to save time and costs, and to tailor the model to suit a particular company's individual needs. The streamlining generally occurs in three ways: the scope of the LCA is minimized (e.g., by not including ancillary operations); data are omitted where appropriate (e.g., by excluding the collection of data on recycling of a product whose constituents, when expended, are not hazardous); and the boundaries of the LCA are contracted, often eliminating the raw materials acquisition stage. Companies do not regularly incorporate the impact assessment stage into the LCAs performed, primarily because this stage is not standardized for consistency. Impact assessments, when performed, are generally qualitative, and typically include human health risks. Many companies are taking a "wait-and-see" approach, while others are simply avoiding the stage entirely. Thus, while most companies use the term LCA to describe their practices, none appear to be conforming to the SETAC-defined practice.

Uses and benefits

The primary use of LCA is to make a product or process change, particularly by uncovering previously overlooked areas for improvement. In addition, LCAs are used as a marketing tool, and as a means to justify the costs for an environmental improvement. According to industry, LCA benefits their business most by providing a prioritization and decision-making tool, and by broadening the company's perspective. LCAs also provide a tool for reaching Total Quality Management (TQM) goals of reducing waste, thereby reducing costs.

Impediments and areas of improvement needed

Survey responses indicate that poor data quality, costly and time-consuming procedures, and overly subjective impact analyses are the primary impediments, or limitations, of LCA. Many respondents expressed a distrust in the accuracy and completeness of data available either internally or through outside sources. In addition, the storage, management, and retrieval of such voluminous amounts of data are viewed as costly and impractical. Again, the impact analysis stage is a cause of concern: one respondent notes, "One can spin a roulette wheel and get just as good a number." The time required to complete an LCA also causes concern, particularly in the fast-paced electronics/computers sector, where LCA results may be obsolete by the time the LCA is complete. Most companies agree that LCA would be improved by: better data gathering and access to databases; streamlining the methodology; and making the impact assessment more quantitative and standardized.

2.2 The European Commission Study[2]

The European Commission (DG III — Industry) in association with the Environment Directorate of OECD sponsored a report published in 1996 called *European Commission: Adoption by Industry of Life Cycle Approaches (LCA): Its Implications for Industry Competitiveness and Trade*. The study, designed to assist the Commission in developing its policies on industrial adoption of LCA, investigates how European industry is using LCA and whether European companies are influenced by policy instruments based on LCA. The study uses this research to discuss the utility of European Commission policies and programs on industrial LCA and the design of future relevant programs.

The report was based on case studies of six industrial sectors and on discussions with industrialists, policy-makers, and LCA practitioners. The six industry sectors were: aluminum, chemicals (plastics and surfactants), building materials, personal products, electronic goods, and automobiles. Approximately 80 interviews were conducted with firms from the EU, Asia, and the United States.

Drivers of LCA activity

Firms adopt LCA practices for external and internal purposes. Externally, LCA uses include responding to environmental pressure from regulators and the marketplace. Firms typically respond to regulatory pressure by using LCA to influence the direction of future policies, often via sector-wide collaboration. Firms generally respond to market pressure for environmentally sound goods by using LCA to make or refute competitive claims. If the competition is inter-sectoral, firms frequently collaborate on LCA; but if the competition is intra-sectoral, the LCA is company-specific. Whether in response to regulatory or marketplace pressure, externally-oriented LCAs are generally initiated by top management to mitigate particular threats.

Some firms use LCA internally to respond to longer-term, less direct market competition. Internal LCAs often emerge from particular divisions where engineers are using it as a problem-solving framework for new product design. The information and analysis can facilitate product development and investment decisions. Internal studies are generally conducted in-house and range from formal to smaller, less-standardized assessments. LCA can help firms address their environmental impact both at global and local levels, and it can help satisfy public demand for similar information (e.g., through eco-labelling schemes).

Study results indicate that the position of a firm in the product chain is the most important factor in determining its approach to, and use of, LCA. Commodity producers most frequently take an external, "top-down" approach (to produce collaborative inventory data), while complex final goods producers most frequently take an internal, "bottom-up" approach (for product development). Commodity producers focus on the upstream portion of the product chain, while the complex final goods producers take a much larger segment of the chain into account.

Methodology

LCA varies widely in scope and purpose; LCA methodologies therefore differ as well. Standardization has emerged within the scientific, official, and industrial communities through SETAC and the International Organization for Standardization (ISO), but this has by no means eliminated the diversity of methodologies being used. France and Canada have developed national standards, and Germany is finalizing its own set. None of these country-specific standards have yet had any real impact in Europe. Sectoral standardization has been the most useful as it addresses industry-specific concerns. Although firms generally support standard-setting, they recognize that the standards often have to be tailored to meet the needs of individual companies.

The study firms used LCA in very different ways due to their different competitive environments and different locations along the supply chain. All of the firms were knowledgeable about LCA, most had performed LCAs (either internally or via the use of contractors), and many had developed in-house expertise. Collaborative LCA activities included sectoral inventory studies, sectoral methodological projects, vertical cross-sectoral process studies, and end of life studies. Independent LCA activities included streamlined studies (to produce quick results) and larger studies (to produce answers over a longer period).

Barriers / Hurdles

The study identified five main barriers to adopting LCA. The first was cost -- LCA requires many hours of data collection and analysis. Small firms frequently consider LCA prohibitively expensive, and even big firms need to be convinced of its utility before spending the time and money. Industry sectors that collaborated on data collection and methodology found the cost less prohibitive.

Second, the lack of a standardized methodology creates problems for interpreting and comparing study results. Third, access to data is usually limited. Not only does internal data take time to collect, but external data necessary from firms upstream and downstream along the supply chain may not be available due to its commercial sensitivity. Firms are typically reluctant to reveal confidential information.

Fourth, the range of environmental impacts that can be evaluated through LCA determines how useful LCA is as a business tool. The energy implications of products and processes have long been evaluated using LCA, but both producers and consumers alike are seeking additional information (e.g., on human health and ecotoxicity) that can be very challenging to generate.

Finally, it is virtually impossible for non-experts to interpret and evaluate the competing claims resulting from LCAs because of their complexity, technical uncertainty inherent in much of the analysis, and the diversity of methodologies.

2.3 Tellus Interviews

In July and August of 1995, Tellus Institute conducted a series of informal interviews with four selected companies in differing industry sectors (including Monsanto Co., Chesapeake Paper Products Co., Safety Kleen, and a fourth company which preferred to remain anonymous) based on their history of LCA/LCD involvement. The purpose of the discussions was to gain a qualitative overview of the current state-of-the-art of corporate LCD, as well as some of the trends and patterns that may exist. While the small sample size limits our ability to generalize results, the conversations provide a potential basis for comparison, and contain insights on current LCD practices. The following topics were discussed with each company.

Definition of LCD

While all companies describe their programs as incorporating life-cycle thinking or life-cycle design, they each define LCD in slightly different ways. In general, the definitions relate to the EPA and SETAC models, and include life-cycle inventory, impact assessment, and improvement assessment. However, not every company uses each stage in their analysis. The reasons for straying from the EPA and SETAC methods vary. One company is consciously not using any specific life-cycle methodology, in part because they feel that the inventory method is poorly developed. Another company omits the impact analysis stage for projects with "low hanging fruit" to avoid unnecessary costs and time delays, going straight from inventory to improvement. A third company encourages a program that expands the designers' traditional focus to include end-of-life issues, as well as increasing the focus on the customer-use phase for their products. Subtle differences between two products or process alternatives, both generating pollution of different kinds, are not assessed from a life-cycle perspective, but rather from a legal and regulatory liability and pollution prevention hierarchy standpoint (preferring source reduction).

Program initiation

Our questions focused on when and at what level each company's LCD program was initiated. Three of the four programs were initiated in the mid-80's to early 90's. One company initiated its program at least 20 years ago at their facility level, but only started calling it "LCA" since the early 1990's. Two programs initiated LCD activity within business units, one of these at the Senior Engineer/Manager level, and one at the Product Development function level.

How LCD is integrated in the company

LCD spread to other levels within each company in part due to the efforts of one or a few key individuals championing the possibilities and benefits of LCD as a business management tool. Efforts included writings, technical papers, seminars, and the formation of committees. One company introduced outside speakers and experts to contribute to the education process. The ideology spread as a result of generating curiosity about the importance of LCDs in relation to market position, business opportunities, and the future of business. Another company formed a "green team," the genesis of further ideas for internal improvement. At several companies, LCD activity has spread from the business level to the corporate level, incorporating several business units. A Vice President of Manufacturing noted that while he was the primary lead on LCD work, for specific projects he pulls together a team of individuals from across a variety of business levels, depending on the specific project.

Resources devoted to LCD development

None of the companies we talked to have specific budgets for conducting LCD. Typically, several staff members (approximately 5 people) will devote a relatively small percentage of their time to LCD projects. At several companies, LCD activities are performed on an as-needed basis; the amount of time devoted fluctuates depending on the project. One company has a pilot program dedicating 5 people at 10-15% of their time for approximately 3 years.

Product/process lines encompassed by program

None of the companies we talked to perform LCDs for a specific product. One uses LCD for virtually every process line, with an internally-created spreadsheet model that looks at the effects on pollution from incrementally changing any part of the manufacturing process. Another uses life cycle concepts as a means to begin to understand and improve internally many of their manufacturing systems. At a third, LCD is not limited to products or processes; LCAs can be performed across the corporation as a whole.

Primary reasons for applying LCD methods

Companies apply LCD methods both for internal guidance and for strategic marketing advantage. Two companies specifically mentioned that their interest stems from an attempt to include a "holistic perspective" in their self-analysis; LCD enables them to expand analysis boundaries. With this perspective, the companies can use the results to guide internal decision-making. In addition, companies recognize the existing or potential market advantages of including LCA/LCD thinking in their decision-making processes. For example, one company stated that the information resulting from performing LCDs was potentially useful to sales and marketing, particularly when working with government customers. Another mentioned that the company's future may lie in redefining their business type, changing people's perception of them from a *waste* management business to a *resource* management business. They noted that adopting LCD techniques provides their customers with an indication of the general direction the business is taking.

Boundaries

How companies define the boundaries of LCD can vary dramatically, and no one method has been universally agreed upon. We asked companies to describe the boundaries they established for evaluating the life cycle impacts of products or processes. Three use a "gate to grave" approach, in which the upstream side of the life cycle begins with the manufacturing process within the company "gates," and the downstream side continues through customer use and disposal or recovery. Companies cite both technical (e.g., lack of reliable upstream data) and monetary (e.g., the high cost of obtaining or calculating data for upstream activity) constraints as reasons why the evaluation does not extend back to raw material extraction. One company, however, uses a "cradle-to-grave" approach, typically including the impacts of raw material extraction, and incorporating recycling/disposal and post-consumer transportation impacts as well.

Quantitative vs. qualitative assessment

At all the companies we talked to, both quantitative and qualitative information is used for assessing life-cycle impacts. Assessment methodologies typically are internally developed, and use a combination of qualitative and quantitative data as indicators for the decision-making process. For example, one company establishes a unit of measurement (such as pounds of pollutant emitted), and judges the value of an alternative product or process design based on the potential for reducing adverse effects on human health, ecological health, and resource depletion. However, there is very little collection and interpretation of data. Whether the analysis includes qualitative or quantitative data will depend, in some cases, on the specific project being analyzed. One company noted that larger, more inclusive studies are typically performed by an outside consultant, and involve a far greater use of quantitative data. Another company focuses on the elements of a product's life-cycle that are the primary contributors to pollution and health risk, and then isolates these areas for quantitative analysis. The primary drivers for decision-making are minimizing risks (particularly choosing those options that have the most control in minimizing risks) and extent of resource use (e.g., choosing the option that reduces resource use and saves money).

How LCD results are used

How LCD results are used relates closely to what the primary reasons are for adopting LCD techniques. Companies mention a variety of internal uses for their results, including influencing internal decision-making. At one company, LCD results have led to changes in certain processes. Another company uses the results to influence product design, expanding designers' perspective to include end-of-life issues. A third also uses LCD to aid internal decision-making, although they note that developments are evolutionary, not revolutionary. The economics of a project are significant; if an alternative makes economic sense, and enables the company to reduce their environmental impact, the alternative will be implemented. At the same time, as one company pointed out, "Doing the right thing" has a fair amount of clout.

Hurdles faced

There is no single, universal hurdle that companies cite as a barrier to further implementation of LCD methods, but several patterns emerged from our interviews that resemble the types of hurdles identified in other industry studies. Two companies mentioned problems with the inventory stage: database consistency, quality, and uniformity remain problem areas. Companies also cited the lack of consensus on approaches to impact assessment as a hurdle.

Financial hurdles are another theme. One company mentioned that benefits from performing LCD are not easily measured, and therefore are not easily recognized by upper management. Another company also indicated the difficulty of defending the cost of LCD, particularly when the practitioners needed to show a return on investment to senior management. In addition, LCD may indicate that an alternative product or process should be initiated, but traditional financial indicators do not provide a long enough time horizon to enable the alternative to be economically viable.

2.4 Conclusions

Results of the Tufts survey, EC study, as well as Tellus discussions with firms, indicate that there remains a variety of interpretations for defining LCA/LCD. Most companies use the term LCA, rather than LCD, regardless of conformance with the EPA/SETAC LCA model. Some companies believe that an LCA can only be conducted once the inventory, impact, and improvement components have been quantified entirely. Other companies have less strict definitions, and define LCA as an inventory quantification only, along with a qualitative improvement process. Companies often refer to such alternative approaches as "using LCA concepts" or "life-cycle thinking," or conducting "streamlined LCAs."

Data constraints, including lack of data or cost for obtaining data, are the most frequently cited reasons for streamlining LCAs. Streamlining methods include narrowing the LCA's scope and boundaries, such as eliminating ancillary operations that the company is responsible for, but which it considers as minor to its processes or products, or eliminating life-cycle stages that occur outside the company's "gates."

Achieving product and/or process improvements and cutting production costs are the two main motivators for undertaking an LCA or applying LCA concepts. European companies also cite external purposes for undertaking LCAs. These include using LCA as a basis for influencing environmental policies as well as responding to market pressures for "green" products. In the U.S., marketing advantages were cited to a lesser degree, perhaps due to the complexity of communicating LCA results to consumers. Finally, many companies find LCAs useful for prioritizing process improvements and for supporting requests for funds for implementing those improvements.

2.5 Endnotes

1. Breville, M., *et al.*, *Life-Cycle Assessment, Trends, Methodologies and Current Implementation, prepared for U.S. Dept. of Energy, Aug. 5, 1994.*

2. Ernst & Young, SPRU, and Atlantic Consulting, European Commission: Adoption by Industry of Life Cycle Approaches (LCA): Its Implications for Industry Competitiveness and Trade, prepared for European Commission, Oct. 1996.

3. CASE STUDY -- IBM CORPORATION

3.1 Company Profile

IBM Corporation develops, manufactures and sells information technology products and services worldwide. Products include computers and microelectronic technology, software, networking, and related services. The company is divided in four geographic units (Asia Pacific, North America, Europe/Middle East/Africa, and Latin America) and approximately 18 business units, including both divisions and companies. In 1994, IBM manufacturing, hardware development and research facilities were located at 35 sites, including 17 in the U.S., 3 in Latin America, 12 in Europe, 4 in Japan and one in Australia. Company revenues in 1995 totaled $70 billion and employees numbered 220,000, making the company the largest electronics firm in the world.

3.2 Environmental Management and Policy

At IBM, corporate environmental, health and safety (EHS) policies are issued by the Chief Executive Officer (CEO). Early policies on safety (1967), environmental protection (1971) and conservation (1974) provide the underpinnings of the company's EHS programs. The driving force behind these early policies was IBM's commitment to employees, shareholders, and the communities in which the company operates, as well as foresight enabling the company to keep ahead of environmental legislation.

Over the years, these have been updated and, in 1990, the Corporate Policy on Environmental Affairs was issued, incorporating and expanding upon key elements in the three earlier policies. In 1995, this integrated policy was updated and issued as IBM's Corporate Policy on Environmental Affairs, providing additional focus to earlier policies. This statement (see Text Box 3-1 for the full text) encompasses commitments to:[1]

- workplace health and safety
- accountability to host communities
- conservation of natural resources
- product stewardship
- environmentally conscious production methods
- energy efficiency and renewables
- environmental technology information sharing
- using company products and services to solve environmental problems
- meeting or exceeding compliance in all operations, and adhering to stringent, internally-defined standards where none exist
- rigorous audits and assessments

Text Box 3-1. IBM's Corporate Policy on Environmental Affairs

- IBM is committed to environmental affairs leadership in all of its business activities. IBM has longstanding corporate policies of providing a safe and healthful workplace, protecting the environment, and conserving energy and natural resources, which were initiated in 1967, 1971, and 1974, respectively. They have served the environment and our business well over the years and provide the foundation for the following corporate policy objectives:

- Provide a safe and healthful workplace, including avoiding or correcting hazards and ensuring that personnel are properly trained and have appropriate safety and emergency equipment.

- Be an environmentally responsible neighbor in the communities where we operate, and act promptly and responsibly to correct incidents or conditions that endanger health, safety, or the environment; report them to authorities promptly, and inform everyone who may be affected by them.

- Maintain respect for natural resources by practicing conservation and striving to recycle materials, purchase recycled materials, and use recyclable packaging and other materials.

- Develop, manufacture, and market products that are safe for their intended use, efficient in their use of energy, protective of the environment, and that can be recycled or disposed of safely.

- Use development and manufacturing processes that do not adversely affect the environment, including developing and improving operations and technologies to minimize waste, prevent air, water, and other pollution, minimize health and safety risks, and dispose of waste safely and responsibly.

- Ensure the responsible use of energy throughout our business, including conserving energy, improving energy efficiency, looking for safer energy sources, and giving preference to renewable over non-renewable energy sources when feasible.

- Participate in efforts to improve environmental protection and understanding around the world and share appropriate pollution prevention technology, knowledge, and methods.

- Utilize IBM products, services and expertise around the world to assist in the development of solutions to environmental problems.

- Meet or exceed all applicable government requirements. Where none exist, set and adhere to stringent standards of our own and continually improve these standards in light of technological advances and new environmental data.

- Conduct rigorous audits and self-assessments of IBM's compliance with this policy, measure progress of IBM's environmental affairs performance, and report periodically to the Board of Directors.

- Every employee and every contractor on IBM premises is expected to follow the company's policies and to report any environmental, health, or safety concern. Managers are expected to take prompt action.

Environmental responsibility extends to IBM suppliers and hazardous waste vendors. Although there are no formal written guidelines, every effort is made to ensure that only those suppliers employing environmentally responsible operations are considered as providers of goods, processes, or services. In general, the level of evaluation and the criteria used is dependent upon the service or product being supplied. These efforts may intentionally or unintentionally affect a supplier's environmental performance. For example, for suppliers manufacturing chemical-intensive products, IBM may use environmental performance as a criteria for supplier selection, shielding itself from potential liability. Perhaps the greatest exposure to potential liability stems from hazardous waste management. Therefore, vendors supplying hazardous waste management services are subjected to an in-depth review and assessment of qualifications, including a financial review by IBM's corporate environmental affairs staff.

In special circumstances, (e.g., when a process is patented by IBM), the company consigns equipment or chemicals to a supplier, also ensuring environmentally responsible conduct from the supplier. A chip manufacturer using photoresist (a required chemical in chip manufacturing) developed by IBM will undergo a review of environmental policies and practices, and a site review, for example. When IBM committed to manufacturing CFC-free products, suppliers were required to provide parts and subassemblies that were manufactured without using CFCs. While not explicitly covered by its Corporate Policy, on a project-specific level, IBM is at times able to use its considerable buying power to influence suppliers' environmental performance by choosing to work with environmentally responsible suppliers.

Worldwide environmental strategy and performance measurement is overseen by the corporate environmental affairs staff. This staff provides strategic direction, advice, and counsel, and covers five areas: Environmentally Conscious Products (ECP), Product Safety, Chemical Management, Employee Health and Safety, and Environmental Programs (encompassing environmental engineering activities). Staff located in facilities worldwide implement IBM's environmental programs.

Extensive communication with staff is necessary for achieving support for environmental policies and instructions at all levels of the company. IBM uses both a top-down and bottom-up approach, involving staff from affected divisions of the company when setting or revising policies. For example, all IBM hardware divisions were involved with drafting a new corporate instruction on ECP. The draft instruction was then forwarded to the division presidents for formal review and concurrence. Envirofimental policies and instructions are then circulated to senior management, accompanied by a memo from a Vice President reminding staff of their responsibilities and obligations for overseeing policy compliance. Employees can access all instructions via IBM's on-line computer system.

IBM's environmental policies and goals, and progress towards meeting those goals, are described in the company's annual environmental report, *Environment -- A Progress Report*. This report is circulated to various stakeholders including key shareholders and customers, regulatory officials, non-governmental environmental organizations, and to many, but not all, employees. A notice of the report's availability is posted for all employees and its full text is also available on the company's Internet site. IBM's marketing departments may also include the report in bid packages.

The 1994 report, issued October 1995, is IBM's sixth environmental report and uses the Public Environmental Reporting Initiative (PERI) Guidelines for report contents.* PERI Guidelines offer report content recommendations in 10 areas including:

- Company profile, e.g., size, number of locations, major activities, and the nature of the company's environmental impacts
- Information on the company's environmental policy(ies)
- Environmental management structure, objectives, targets, and goals
- Guidance on reporting and benchmarking environmental releases
- Resource conservation efforts, e.g., materials, energy, and water conservation
- Environmental risk management programs, e.g., environmental audits, emergency response programs
- Environmental compliance reporting such as fines and penalties
- Product stewardship commitments including programs, research, and design decisions affecting the environmental attributes of product production and end-of-life issues
- Employee recognition and reward programs encouraging environmental excellence
- Stakeholder (e.g., universities, industry associations, non-governmental organizations) involvement in environmental initiatives

* Founded in 1992, PERI is a voluntary private sector effort whose goal is to expand and improve corporate environmental reporting to the public. PERI affiliates include IBM, Dow Chemical, Amoco, and other corporations. Through its Guidelines, PERI aims to identify the types of information needed to provide a balanced perspective on a company's environmental policies, performance, and practices.

3.3 Product Stewardship

In 1989 and 1990, the company reassessed its environmental strategies with a view towards developing new strategies for the 1990s. Convening an international task force, various working groups were established to examine technology and legislative issues. The group recommended establishing a program focusing on product environmental improvements as a means of staying ahead of technology and legislative trends. In November 1990, the Corporation released a policy letter, followed by a directive in January 1991, encouraging product managers to develop products which are safe for their intended use and protective of the environment. Toward this end, IBM established its Integrated Environmental Design program in 1991.

IBM's approach to product stewardship, incorporated in its Integrated Environmental Design Program, is founded on four goals for product design.[2] These goals, based upon recommendations of the international task force, include:

- To design products that have reusable components and that use materials with recycled content
- To reduce the energy consumption of products
- To design products for easy disassembly
- To make product contents capable of being recycled or reused at the end of product life

These goals emphasize the use and post-use phases of the product life cycle, consistent with the company's position as provider of final products to the business and consumer markets.

Stewardship is practiced in several forms over the course of product development. Within product development business units, product managers are responsible for overseeing new product development from design through manufacturing. As new or existing products are designed or redesigned, the responsible business unit performs a Product Environmental Profile (PEP). The PEP is a checklist of environmental attributes comprising such items as energy consumption, the disposal requirements of individual parts, battery requirements, coating, hazardous materials used in manufacture, and qualifications for any type of country-specific environmental certification (e.g. Germany's Blue Angel or Nordic White Swan).* Ultimate responsibility for ensuring completion of PEPs rests with the project manager who may receive guidance from a PEP coordinator, typically an EHS staff person, in each product development business unit. Coordinators consult

---

* Germany's Blue Angel and Eco Labeling requirements, for example, require no polybrominated biphenyls (PBBs) or polybrominated biphenyl ethers (PBBEs), no short chain chloride or paraffins, limitation on chlorine content, and virtual elimination of the use of unfilled/unmodified polyvinyl chloride (PVC) and polyvinylidene chloride (PVDC). Austria's bidding system requires disclosure of information if product or packaging materials offered contain PVC and other halogenated plastics or halogenated hydrocarbons, and the reasons for use of such materials. Sweden, as of 1995, had drafted a regulation prohibiting the use of all halogenated flame retardants. All these are examples of constraints which Environmentally Conscious Products (ECP) continually brings to the attention of product designers, materials engineers, and production engineers.

with relevant technical experts in preparing a PEP including, for example, staff in industrial hygiene, chemical control/management, environmental engineering, manufacturing technical services, medical/health, product safety, and legal.

Specifically, a PEP comprises six sections with the following minimum data requirements:[3]

1. Product Description -- a description of the product, including its intended use and applications

2. Product Operational Data -- includes energy consumption, and compliance with IBM Standards for noise, radiation, and chemical emissions

3. Product Composition Data -- includes a listing of hazardous parts and assemblies contained in the product, a listing of reusable parts identified for recovery, and an assessment of the product's compliance with IBM standards for banned or restricted chemicals*

4. Product Consumables Data -- includes chemicals used in the operation of the product, chemicals shipped with the product or recommended for use with the product, special requirements for storing, packaging, and transporting the product, and wastes produced during product operation and maintenance

5. Environmentally Conscious Attribute Data -- ECP attributes (described below) designed into the product and environmental certifications or eco-labels planned for the product

6. Summary -- includes a list of "deviations" from IBM Environmental/Safety Standards and supporting background information on any Environmental/Health impacts requiring a risk acceptance. This provides a safety net ensuring that such deviations only occur when product or process options do not exist. Acceptance of such deviations, a rare occurrence, requires approval of upper management.

For components and simple parts, a streamlined PEP is available, requiring the following information:

- product description, including its application, weight, and energy consumption
- a list of ECP attributes designed into the product
- identification of a product's hazardous characteristics arising during handling, use, or disposal
- a list of any deviations from IBM Environmental/Safety Standards

* IBM's list of banned or restricted chemicals is based upon world-wide legislation and regulations and is applicable to IBM's facilities world-wide. This list may extend up the supplier chain as exemplified by IBM's requirement that parts and subassemblies are to be manufactured without using CFCs.

- supporting background information on any Environmental/Health impacts requiring a risk acceptance

Besides manufacturing IBM Products, the company also manufactures products without the IBM logo for other vendors and purchases products from other vendors to which an IBM logo is attached. Guidelines instituted in 1995 specify that IBM Product Managers for non-IBM logo products shipped in "significant numbers"..."should consider" preparing a PEP or, where a supplier is providing the product, have the relevant vendor do so, although preparing a PEP for such products is not mandatory.[4] While, to date, no PEPs have been completed for non-logo products, the guideline is too recent to assess future trends.

In its best form, a PEP is prepared early in the design phase and updated and revised as the design moves toward its final stages. This type of iterative process allows for continuous improvement of the environmental performance of the product from a manufacture, use, and post-use perspective. In a six month product development cycle, environmental staff may interact twice with product managers; in an 18 month cycle, an average of three iterations typically occur.

The volume of PEPs is formidable: several hundred may be prepared each year, including both original documents and those prepared as revisions to a product move from early conceptualization through various design and redesign stages. Not surprisingly, a major challenge to managing the Product Environmental Profiles is information management. Because product cycles are short and products often are not named until near or at completion of final design, custody of the design documents often changes hands. Moreover, product profiles historically are product-based rather than component-based, sometimes obscuring information on the attributes of a particular component. This, in turn, may lead to future information gaps to support decisions around optimal recycling or disposal methods for product components. To rectify this situation, IBM is working toward a component-specific system to improve its product environmental profile archive systems by establishing databases to track this information. The database will include PEP information completed for components. Thus, if a component is used in multiple products, the information required for completing a component PEP will be collected once, and will then be readily accessible for evaluating the environmental profile of a product utilizing the same component. This will allow more reliable and easier access to environmental information in future years.

At IBM, *product* development is conducted separately from *process* development and guided by two separate corporate instructions. The processes used by IBM in manufacturing their products -- e.g., IBM semi-conductors and printed circuit cards -- are examined under a companion procedure, Environmental Impact Assessment, under the umbrella of the company's product stewardship program. Under the framework of IBM's Integrated Environmental Design Program, Environmental Impact Assessments (EIAs) are prepared for every IBM process. Similar to PEPs, the goals of EIAs are to ensure early identification of potential adverse environmental effects, provide a mass balance for materials used, ensure that safer materials and processes have been considered, and disposal plans provided.

Environmentally Conscious Products -- Operationalizing Product Stewardship

While PEP provides a *tool* for advancing product stewardship and LCD, integral to achieving IBM's stewardship goals is the Engineering Center for Environmentally Conscious Products (ECECP). Created in 1991 and located at the company's Research Triangle Park (North Carolina) site, ECECP houses the principal technical support staff who provide *guidance* to manufacturing, hardware development, and research sites such that stewardship goals are embedded in design and manufacturing decisions. ECECP is charged with translating the broad stewardship goals of developing environmentally conscious products (ECPs) into concrete materials and process guidance to all business operations. While product environmental performance is the central function of ECECP, product designers must attend to other, first order performance goals which cannot be sacrificed in the interests of environmental performance. These include: performance in terms of delivering the service for which a machine is designed, long term reliability, user safety, and cost.

Each IBM product division has an ECP "strategy owner," a high level manager responsible for overseeing the division's overall ECP strategy and explaining the strategy to the division's product managers. The strategy owner is also charged with setting ECP goals and performance metrics. At the discretion of the product manager or strategy owner, ECP teams may be assembled to review products. (These reviews supplement, but are not in lieu of, the requirement of completing PEPs.) These ad hoc teams may be comprised of staff from product safety, environmental engineering, industrial hygiene, and materials engineering, with team composition varying depending upon the expertise required for examining a specific product. While IBM requires product managers to complete PEPs, no similar requirements are placed upon ECP teams. This allows freedom for teams to operate in a fashion most suitable to the team and at a level of effort required for meeting product design needs and company goals. No formal metrics are used for measuring the effectiveness of ECP teams, although the company believes these teams effectively carry out ECP goals. At the corporate level, IBM is considering an ECP progress measurement system that would encompass ECP goal setting and metrics to measure progress towards those goals. Such a system would indirectly measure the success of the ECP team process.

ECP goals are also executed in the company's Research Division. For example, the Division's ECP strategy owner has initiated reviews of alternatives to lead solder used in connecting chips to circuit boards, using supercritical fluids as cleaning solvent alternatives, and eliminating methylene chloride from manufacturing.

The staff from ECECP support ECP teams affiliated with each IBM product division. Each ECECP staff member is assigned to multiple product divisions which may also correspond to multiple production sites. ECECP staff interact with ECP teams on an as-needed basis. Designers may confer with ECECP staff on materials selection. For example, ECECP staff work with the company's technical experts to evaluate new battery technologies across environmental criteria, disseminating their findings to the IBM design community. To further assist materials selection, guidelines to assist design engineers in developing ECPs are currently under development by ECECP. These guidelines will include ECP "attributes" for evaluating products across fifteen attribute categories displayed in Table 3-1. These guidelines are informed by recommendations from the international task force convened in 1990 to develop new environmental strategies and refined by ECECP.

Communicating ECP goals, progress, and trends is achieved through a quarterly newsletter, ***ECP News***. Issued by ECECP, the newsletter is circulated to ECP strategy owners and IBM's design community and includes articles on ECP marketing, activities and accomplishments achieved by the company's divisions, ECECP, relevant industry activities, and ECP technology (environmental attributes of battery systems, for example). Supplementing ***ECP News*** is IBM's computer network linking ECP strategy owners and teams to keep staff apprised of recent news. The network includes an on-line interactive forum for posing questions as well as on-line reference materials. Information is also disseminated at a yearly symposium attended by ECP strategy owners, ECP teams, marketing, and government affairs staff.

From the product use standpoint, a computer's major environmental impact arises from electricity use. Therefore, IBM dedicates resources to developing engineering designs that minimize electricity requirements. The AS/400 division, for example, has designed its product for energy efficiency, integrating automatic power-on and power-off programming enabling the system to tailor its energy use to individual usage patterns. Striving to meet the U.S. EPA's voluntary Energy Star program goals, is a priority for IBM's personal computer division.*

While IBM does not typically use product environmental attributes in marketing its products, a brochure marketing the environmental attributes of IBM's AS/400 mid-range computer is one of IBM's early attempts at using environmental performance in product marketing.[5] In addition to highlighting reductions in energy use trends for this product, the brochure highlights pollution prevention opportunities implemented for the product's manufacture, including elimination of CFCs, methyl chloroform, and methylene chloride. Similar brochures have been developed for storage system products and high-end systems (mainframes.)

* Energy Star is a voluntary program of U.S. EPA. Qualifying products such as personal computers, monitors, or printers, for example, must power down to 30 watts or less after a specified time period of inactivity. Other requirements are also placed on products.

Table 3-1. ECP Attributes

Attribute	Attribute Guidance
Design for easy disassembly	Facilitate product disassembly through product design, enabling recycling and reutilization of parts
Design for modularity/expandability	Design products so that components can be replaced and upgraded, thereby extending product life
Electromagnetic compatibility	Design monitors to meet IBM standards for electric and magnetic fields
Batteries	Identify suitable cadmium- and lead-free batteries
Acoustics	Minimize noise from machines to meet IBM standards
Power consumption	Minimize power consumption to promote energy conservation
Limiting plastic materials for major mechanical parts	Limit the variety of plastics to aid material identification and increase volumes for recycling and reuse
Coding of plastic parts for materials identification	Coding, as required by IBM standards, facilitates reuse and recycling
Use of recycled materials	Recycled materials recovered from unpainted and unmetallized parts is recommended
Recyclability/reutilization of parts	Use parts recovered from end of life (EOL) machines, when possible, and design parts to be reutilized
Part finishing	Integral, molded-in finish, is recommended, eliminating need for paints and solvents; if paint is used, recommend powder coatings as having lower environmental burden than water or solvent based paints
Electromagnetic compatibility (EMC) protection	Metallic foil is environmentally preferable to metal based paints or electroless plating or vacuum deposition of aluminum to provide EMC protection of parts
Part fastening and joining	Snap fit joining of parts is preferable for fastening and joining to facilitate material recovery and recycling
Part labeling/marking	Molded-in labels/markings for plastic parts is recommended to assist recovery and recycling without contaminating the material with labels
Eliminating regulated materials	Use of PBBs, PBBEs, lead, cadmium, mercury metal and/or compounds, and ozone depleting compounds is to be avoided

The company is working to improve communications between product and marketing staff, recently holding a workshop attended by ECP team members, ECP strategy owners and marketing staff. The focus of the workshop was translating product environmental improvements into customer benefits, and leveraging these improvements in the marketplace. Product development teams are also encouraged to furnish environmental performance information to product marketing teams.

Role of Life-Cycle Design in ECP

Minimum environmental burden is IBM's overarching goal for developing environmentally conscious products. In 1992, IBM began exploring *if* and *how* LCA can be used for determining relative environmental burdens.* Specifically, IBM's initial objective was to assess the role of LCA:

1. in selecting materials and processes with minimum environmental burdens at the part and subasssembly levels and
2. as a tool for IBM's engineering community, informing product decisions.[6]

Because of the complexity of a computer, IBM's approach is to explore LCA's use for evaluating parts and subassemblies constituting the bulk of a computer's weight (which is 80% structural parts by weight and includes metals and plastics), and to study only those parts and subassemblies for which alternative material or process options are available. This approach can require working with hundreds of IBM's suppliers to obtain data and information on parts and subassemblies which in part constitute the final product which consumers purchase. ECECP staff organize meetings with key suppliers, educating them about IBM's approach to designing environmentally conscious products. For example, when working with a polymer supplier to provide a recyclable polymer, supplier and ECECP staff will meet to address recyclability goals. If a study is to be conducted on a product provided by the supplier, a team from the supplier firm meets with ECECP staff for a one day educational seminar to address life-cycle principles and practices and issues germane to the supplier.

IBM then hires consultants to work with their principal suppliers. Consultants sign confidentiality agreements with the suppliers to obtain necessary data, an arrangement which creates an arm's length relationship between IBM and its supplier community. Currently, LCA is being used to investigate differences between materials (solvent-based paints versus powder coatings, for example) but not differences between suppliers of the same materials or components. In this fashion, the company uses LCA as an overall guidance framework for choosing materials and technologies, leaving detailed process and operating decisions to its supplier community. To date, IBM has worked with approximately ten suppliers in this fashion. Response from suppliers has been positive which is largely attributable to IBM's communication with suppliers explaining ECP's goals and objectives.

---

* While IBM's application of LCA does not conform with the SETAC/EPA definition of LCA provided in Chapter 1, we use the term "LCA" in this section to conform with IBM's terminology.

Two publicly released studies demonstrate IBM's application of LCA methods. Methods for fabricating sheet metal computer covers were the focus of IBM's first study.[7] Conducted collaboratively with Scientific Certification Systems (SCS) between 1993 and 1994, this study examined three protecting surface treatment options for IBM's PS/2® Model 95 steel cover -- electrogalvanizing, aluminizing, and galvannealing -- and two decorative finish options -- powder coatings and water-based paint. Two steel manufacturing technologies, basic oxygen furnace (BOF) and electric arc furnace (EAF), were also examined, although IBM does not specify these technologies in its steel purchasing. Activities excluded from the study's boundaries include fabricating the cover from sheet steel, assembling the cover with the computer, operating the computer, and ultimate disposal. The environmental profile of these activities presumably would not be affected by choice of surface treatment or decorative finish options.

Primary (i.e., from vendors) and secondary (i.e., from literature) life-cycle inventory data were collected for surface treatment options, decorative finish options, and steel manufacturing technologies. An "enhanced inventory evaluation" method that classifies and characterizes data into 20 categories was used in lieu of a more formal impact assessment method since, in IBM's view, a consensus regarding impact assessment methods is currently lacking. These 20 categories, referred to as critical environmental burdens (CEB), represent data aggregated by similar chemical properties (e.g., sulfur oxides) , environmental impact categories (e.g., ozone depletion), or resource use (e.g., water, minerals). CEBs are further classified by input categories (resources and energy) and output categories (air emissions, water emissions, and solid waste).

Aggregating data into CEBs facilitates comparisons of surface protection treatments and decorative finish options and provides a format that is protective of confidential information from the vendor's standpoint. For example, Table 3-2 presents life-cycle inventory data aggregated by CEB categories for powder coatings versus water-based paints for a single computer housing. The "Environmental Savings" column in this table depicts resource and environmental gains achieved by powder coatings. Environmental savings from water, for example, is approximately 6.6 in favor of powder coatings; that is, for each single computer housing, 6.6 kg of water use is avoided when powder coatings versus water-based paints are used. In this inventory, all categories except toxic water pollutants (-4 mg/computer housing) either favor the powder technology or result in no net environmental gain. In percentage terms, the most dramatic gains are in energy feedstocks, hydrocarbon emissions, and oxygen depleters.

Table 3-2. Paint Finishing Subsystem

Critical Environmental Burdens	Powder Based	Water Finish	Environmental Savings	Environmental Costs
Resources				
Water (kg)	6	13	6.6	
Wood (g)	NR	NR		
Metal Ores (g)	NA	7		
Minerals (g)	41	81	40	
Energy				
Nonrenewable (MJ)	6	12.6	6	
Feedstock (MJ)	2	8.7	7	
Total Energy (MJ)	8	21.3	13	
Air Emissions				
Carbon Dioxide (g)	0.33	0.52	0.19	
Carbon Monoxide (g)	0.25	0.24		
Sulfur Oxides (g)	4	6	2	
Nitrogen Oxides (g)	2	4	2	
Hydrocarbons (g)	3	33	29	
Particulates (g)	0.71	0.72		
Unclassified (g)	<0.001	<0.001		
Hazardous (mg)	NA	NA		
Water Emissions				
Total Solids (g)	2.8	3.0	0.2	
Oxygen Depleters (g)	0.0011	0.0059	0.005	
Toxic Pollutants (mg)	17	13		4
Solid Wastes				
Unclassified (g)	41	44	3.3	
Hazardous (g)	NA	NA		

Note: NA signifies data not available at time of report.
Table adapted from Reference 7.

The authors conclude that electrogalvanizing is environmentally preferable to other surface treatment options, powder coatings are preferable to water-based paints, and EAF-produced steel is preferable to BOF steel. IBM has used this study's results in recommending the use of powder coatings and electrogalvanizing to its designers, issuing a technical report to its design community and presenting study results at an annual symposium. Due to data quality concerns in this study, including data that could not be verified or substantiated, IBM has not mandated these processes. However, most major products using decorative finishing have subsequently switched to powder coatings. Study results have not had as significant an effect on surface treatment option selection as electrogalvanizing is already widely used since this surface treatment is often required for functional reasons and many components provided by far upstream suppliers (e.g., suppliers to IBM's suppliers) arrive as electrogalvanized.

IBM continues exploring the use of LCA for material and process choices. A second study collaboratively conducted with Ecobalance evaluated the trade-offs between disposal options for PVC monitor housings.[8] Three disposal options were examined -- incineration, landfilling, and closed loop recycling -- using mostly secondary data. Study boundaries include transporting monitors to a disassembly site and subsequently transporting the PVC monitor housing to the landfill or incinerator. For the recycling option, following disassembly, the housing is transported for grinding and remolding. Production of virgin PVC also enters the study boundaries for recycling, crediting the option with the avoided environmental burdens of virgin PVC production.

Life-cycle inventory results are presented in Table 3-3. In this study, inventory data are not aggregated into CEBs, although some data are aggregated into broader pollutant categories (such as hydrocarbons and hazardous chemical waste). Similar to the prior study, a "less is better" impact assessment approach is used for ascertaining the environmentally preferable disposal option, monitor recycling. Recycling is the best end-of-life option in 28 out of 33 inventory categories, taking second place to incineration in four categories -- coal use, nitrates in water effluents, landfilled PVC, and other solid waste generation. Thirty of the 33 inventory categories contain negative numbers for recycling, indicating the avoided raw material inputs, environmental releases, and energy use achieved by avoiding virgin PVC production.

IBM concludes from its experience to date that life-cycle inventory results, coupled with a less is better approach to impact assessment, can be used for informing product decisions *if* and *when* conclusive data are available. However, basing product improvement decisions solely on life-cycle inventory data is not prudent due to inherent data uncertainties. The company is therefore unlikely to use such studies as a single decision tool for formulating product improvement decisions. Thus, while IBM remains committed to its ECP program, the future of further life-cycle studies is less certain. Rather than funding an LCA of a product component or material, the company opted in 1996 to contribute to industry association efforts including an LCA of end-of-life options and development of a life-cycle design tool.

LCA results must also be weighed amongst other criteria, namely performance, reliability, safety, and cost. The company may be willing to incur minor cost increases from implementing environmental improvements, but performance, reliability, and safety criteria cannot be compromised.

Table 3-3. Inventory Results for Three End-of-Life Options

		Units	Landfilling	Incineration	Recycling
Inputs	Raw Materials				
	Crude Oil (in ground)	kg	0.036	0.025	**-1.07**
	Coal (in ground)	kg	0.0002	**-0.67**	-0.44
	Natural Gas (in ground)	kg	0.0001	0.004	**-1.28**
	Limestone	kg		1.50	**-0.004**
	NaCl	kg			**-1.54**
	Water (unspecified use)	liters	0.007	-0.008	**-4.23**
Outputs	Air Emissions				
	Particulate Matter	g	0.15	33.6	**-8.37**
	CO_2	g	115	2400	**-4,000**
	CO	g	0.41	1.07	**-5.35**
	So_x	g	0.16	-13.0	**-27.5**
	No_x	g	1.17	-4.17	**-33.2**
	NH_3	g	**0.0007**	0.0143	0.0011
	Cl_2	g			**-0.004**
	HCl	g		300	**-0.48**
	Hydrocarbons	g	0.31	-13.7	**-42.6**
	Other Organics	g	0.00	-0.02	**-1.60**
	Water Effluents				
	BOD_5	g	0.0002	0.0002	-0.18
	COD	g	0.0006	0.0007	**-2.46**
	Chlorides	g			**-89.4**
	Dissolved Solids	g	0.42	0.48	**-2.65**
	Suspended Solids	g	0.0002	-0.004	**-5.36**
	Oil	g	0.005	0.007	**-0.10**
	Sulfates	g			**-9.61**
	Nitrates	g		**-0.0004**	0.00004
	Total Nitrogen	g			**-0.01**
	Sodium Ions	g			**-5.14**
	Metals	g			**-0.45**
	Solid Waste				
	Waste (hazardous chemicals)	kg			**-0.003**
	Waste (landfilled PVC)	kg	2.26	**0**	0.02
	Waste (slags and ash)	kg		1.73	**-0.10**
	Waste (other)	kg	0.00005	**-0.44**	-0.14
Energy					
	Total Primary Energy	MJ	42.18	19.85	**-103.48**
	Electricity	kWh	0.0012	-2.11	**-2.35**

Note: Bold numbers indicate best end-of-life option
Table adapted from Reference 8.

3.4 Observations

IBM's approach to LCD is, above all, a pragmatic one. The company sees the value of LCA thinking as a way of supporting its corporate commitment to product stewardship. However, multiple forces -- some unique to IBM and some associated with the electronics industry as a whole -- steer the company away from a highly prescriptive, rigid application of life-cycle techniques to one best characterized as selective, opportunistic, and flexible.

Above all, the electronics industry is one of continuous and rapid technological change. In IBM's case, this change is manifested not only in its hardware products, but in the very nature of the company itself. From an organization built on the design and manufacture of mainframe computers, the company in recent years has redefined its business as information services, encompassing both hardware and software products and services. Relying on proven product lines and proven technologies is a recipe for failure in the electronics business, and IBM's transformation in the last decade reflects this simple reality.

Rapid technological change, coupled with intense competitiveness, requires both innovation and agility among product managers. To remain competitive, managers must be given responsibility and authority to conceive new product ideas, translate these ideas into concrete designs, and move quickly from design to manufacturing. With an average 18 month time horizon from concept to market-readiness, IBM (or any electronics firm) can ill afford to impose a highly prescriptive design protocol and analytical methods which may slow a product cycle. For this reason, the company has steered away from the "textbook" approach to LCA in favor of a customized approach which accommodates the relentless drive to innovation and quick product turnaround characteristic of the electronics industry.

How does IBM's LCD program mirror these conditions? First, product managers retain a high degree of autonomy in making final design decisions. ECP sets an overall framework for considering materials choices and works on broader issues of product improvements. However, ultimate design choices are left to product managers in the belief that only they are in a position to weigh the performance, reliability, safety, and cost considerations with environmental attributes of a product. Beyond product-specific flexibility, the separation of longer-term process-related improvements versus shorter-term materials choices allows the company to pursue its product stewardship goals without compromising near term business objectives.

Second, the highly horizontal structure of IBM operations presents a continuing challenge in transferring life-cycle thinking to its thousands of suppliers. Again, the company has opted for a flexible, experimental approach, seeking to spread the message through non-coercive LCA "trials" focused on paint finishing systems, fabrication of sheet metal computer covers, and disposal options for PVC monitor housing. The approach used in these studies is not a cradle-to-grave approach, but limited to stages, inventory items, and impact categories which direct attention to major trade-offs in materials and process choices. The outcome of these exercises will inform

ECECP's subsequent materials and process guidance documents. How the results eventually affect supplier decisions remains to be seen.

Third, the PEP, the basic instrument for operationalizing environmentally-conscious design at the product level, is an evolving tool which attempts to balance the needs of short product cycles while meeting the company's commitment to product stewardship. Because design is not a simple, linear process but one involving multiple iterations and refinements, PEPs number in the hundreds each year. ECP teams at the site level, who serve as local "stewards", apply qualitative ECP metrics to design and redesign decisions. The challenge of ECP data management itself is formidable, even for a computer company the size of IBM. Looking ahead, moving toward more quantitative ECP metrics has both its benefits and risks. With the right tools, feedback to design teams on the environmental consequences of materials choices could become virtually instantaneous. At the same time, for designers to make sense of these consequences -- no matter how quantitative and how accurate -- will require translation of disparate impacts into usable decision rules. This remains a major challenge to IBM, and any other firm, which seeks to operationalize life-cycle concepts into a working LCD tool.

3.5 Endnotes

1. Louis V. Gerstner, IBM Policy Letter Number 139A, July 14, 1995.

2. IBM, ENVIRONMENT: 1994 Progress Report, p. 10.

3. IBM, *PEP Content Guidelines*, no date

4. *PEP Implementation Guidelines*, no date.

5. "IBM AS/400 Advanced Series -- Designing with a Green Pen," IBM, 1994.

6. Inder Wadehra and Anne Brinkley, "Life Cycle Assessment for Information Processing Equipment," presented to Tellus Institute, April 11, 1995.

7. Brinkley, A. *et al.*, "Ecoprofile Studies of Fabrication Methods for IBM Computers: Sheet Metal Computer Cover," presented at International Symposium on Electronics and the Environment, May 1994.

8. Brinkley, Anne, *et al.*, "Life-Cycle Inventory of PVC: Disposal Options for a PVC Monitor Housing," presented at International Symposium on Electronics and the Environment, May 1995.

4. Case Study -- Bristol-Myers Squibb Company

4.1 Company Profile

Bristol-Myers Squibb Company (BMS) is a worldwide manufacturer of health care and consumer products with research, development, manufacturing, and distribution sites spanning thirty-three countries and six continents. In 1995, BMS employed 47,000 people worldwide with total sales of $12 billion.

BMS's four core businesses, each organized as a separate group, include:

1. Pharmaceuticals, including anti-cancer, heart, central nervous system and dermatology, accounting for 58% of Company sales;

2. Consumer and personal care products, including head and cold remedies (Excedrin and Bufferin), hair care products (Clairol, Matrix), skin care products (Keri, Alpha Keri), and deodorants and anti-perspirants (Ban and Mum), accounting for 16% of Company sales;

3. Medical devices such as artificial limbs and surgical instruments, accounting for 14% of Company sales; and

4. Nutritionals, including infant formulas (Enfamil), accounting for 12% of Company sales.

4.2 Environmental Management and Policy

An effective environmental management structure, along with a solid corporate commitment to continuous environmental improvement, is essential to successfully implementing life-cycle design programs. We begin with an overview of BMS' environmental management structure and programs to understand how LCD programs are operationalized within the company's environmental management program.*

A commitment to the environment and worker health and safety appears in the Bristol-Myers Squibb Pledge, a company mission statement. To its employees, the company acknowledges its obligation to provide a "clean and safe working environment" and in communities where its plants and offices are located, "constructive action in support of ... environmental progress." A separate Environmental, Health, and Safety Policy appears in Text Box 4-1.

* This information is described in further detail in Bristol-Myers Squibb Company's *Report on Environmental Progress*, May 1995.

Text Box 4-1. BMS Environmental, Health, and Safety Policy

It is the policy of Bristol-Myers Squibb to protect the health, safety, and quality of life of its employees, customers, and the public, and to conduct all of its activities in an environmentally sustainable manner which takes into consideration the integrity of natural systems - i.e., land, water, air and biodiversity.

Bristol-Myers Squibb will strive to continuously improve its environmental, health, and safety (EHS) performance by minimizing and, where feasible, eliminating negative impacts associated with its facilities, activities, and products. Management will ensure that every employee understands the importance of, and is responsible and accountable for, integrating EHS considerations into their daily responsibilities.

Bristol-Myers Squibb, its divisions, and business functions will consider the EHS concerns of stakeholders, and work in an integrated manner to identify, evaluate, and resolve EHS impacts related to the management of resources and their related byproducts - i.e., selection, use and exposure.

To the extent feasible, Bristol-Myers Squibb will give preference to suppliers and contractors whose EHS commitment and practices are consistent with its own, and who have demonstrated environmentally-responsible products, services, and management.

Bristol-Myers Squibb, its divisions, and business functions will develop and maintain EHS performance measures, conduct regular performance evaluations, and report findings to internal and external stakeholders.

Bristol-Myers Squibb will regularly evaluate the internal and external factors driving EHS concerns, and make appropriate revisions to this policy and related programs.

Compliance with all relevant government requirements and company policies and guidelines will be the minimum acceptable level of performance for the Company's divisions, business functions, and employees.

BMS believes that communicating environmental goals and policies to staff, as well as progress towards meeting those goals is important for maintaining an informed and motivated staff. In 1993, and again in May 1995, BMS released a biennial *Report on Environment Progress* describing the company's environmental, health, and safety (EHS) programs and initiatives and documenting progress towards meeting goals. Both internal and external stakeholders (e.g., stockholders, NGOs) are primary audience for this document which is widely circulated amongst all employees.

Responsibility for transforming environmental policies into action rests with the Vice President of Environmental Affairs, Occupational Health and Safety. The Vice President is a member of the Corporate Issues Committee headed by the Company President and CEO. This committee provides a voice for keeping the President/CEO and the Board of Directors apprised of environmental, health and safety issues faced by the company.

Environmental programs, policies and procedures at BMS are initiated at the corporate level, but each business unit is responsible for implementing and overseeing its own environmental program. Business unit programs are evaluated at the corporate level, ensuring that corporate environmental goals and procedures are implemented. An Environmental Health and Safety Steering Committee, comprising one representative from each business unit within the Company, provides further overview of EHS issues and progress.

4.3 Life-Cycle Design: A Corporate Environmental Framework

BMS's **Environment 2000** program, a company-wide environmental initiative launched in 1991, demonstrates the Company's use of LCD as an overarching theme to its EHS programs. Program goals include:

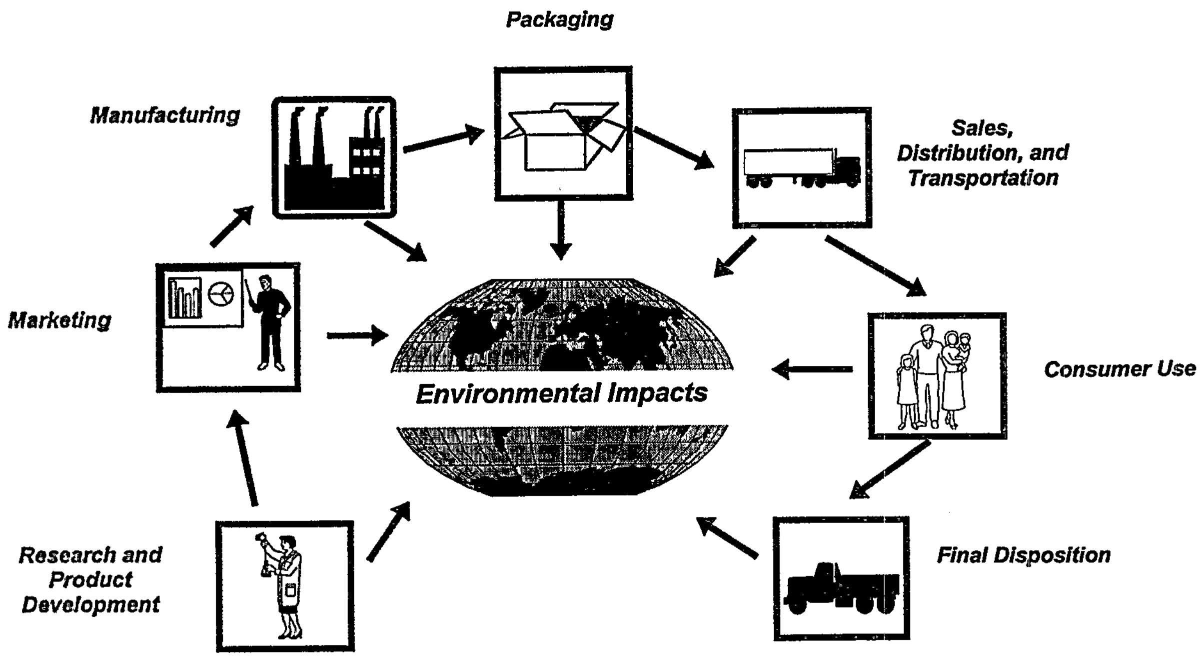
- protecting the quality of life of employees and the public;
- minimizing natural resource and environmental demands;
- eliminating accidents and regulatory noncompliance;
- measuring performance;
- communicating openly with stakeholders; and
- creating competitive products for an increasingly environmental-aware marketplace. [1]

Product life-cycle management is the cornerstone of this program, with the goal of minimizing environmental impacts of BMS's products by evaluating opportunities for improvement at each stage of the product's life cycle: design, manufacturing, packaging, distribution, use, and disposal.

To support BMS' product life-cycle management commitment, the Company in 1992 initiated its life-cycle design and redesign program known as Product Life-Cycle (PLC) review. PLCs are used to "identify and reduce negative EHS impacts at each stage of a product's life, from design, manufacturing and packaging to distribution, use, and ultimate disposal."[2] The life-cycle stages encompassed by PLCs (and shown in Figure 4-1) include:

- research and product development;
- marketing;
- manufacturing;
- packaging;
- sales, distribution, and transportation;
- consumer use; and
- final disposition.

Figure 4-1. Environment 2000 - Product Life Cycle*



*Adapted from Bristol-Myers Squibb Company, *Report on Environmental Progress,* May 1995

PLCs are initiated by assembling a cross-functional team comprising staff from purchasing, research and development, marketing, manufacturing, quality assurance, sales, customer service/distribution, packaging, regulatory affairs, accounting, and EHS. Through a series of team meetings, staff identify EHS impacts of a product, options for improving the product's EHS profile, and the costs and benefits of identified improvements.

At the corporate level, BMS has committed to conducting PLC reviews of all its major product lines by end of year, 1997. Ensuring that this goal is met is the responsibility of each division. As of May, 1995 BMS had initiated and/or completed PLC assessments for the following 13 product lines.

Table 4-1: PLC Reviews Initiated/Completed for BMS Product Lines

Pharmaceutical Group	Consumer Products Group	Medical Devices Group	Nutritional Group
Excedrin analgesic *Plastibase* compound *Pravachol* compound	*Ban* deodorant *Finale* hairspray *Herbal Essences* shampoo and conditioner *Infusium* shampoo and conditioner *Keri* lotion *Mum* deodorant *Natural Instincts* hair color *Ultress* hair color	*Active Life/Colodress Plus* ostomy pouch	*Enfamil* infant formula

In addition to **Environment 2000**, other initiatives drive the company's PLC program. BMS in 1991 endorsed the International Chamber of Commerce (ICC*) Business Charter for Sustainable Development*, a set of sixteen principles guiding environmental management of businesses. The Business Charter calls on industry to "develop and provide products or services that have no undue environmental impact and are safe in their intended use; that are efficient in their consumption of energy and natural resources; and that can be recycled, reused or disposed of safely." The Company believes that the charter is consistent with its strategy for environmental management and that it provides a useful framework for reporting progress on EHS programs and initiatives.

Many company programs and initiatives build upon BMS' PLC program. PLC reviews are an integral component of Capital Appropriation Requests (CARs). All requests for capital projects require CARs which, in turn, require review by the facility EHS coordinator. The coordinator must consider permitted environmental releases; potential for spills and explosions; hazardous and nonhazardous waste generated, stored, and disposed; disposing of raw materials, intermediates, and final products; employee health and safety risks; and energy consumption. CARs submitted for new products and/or packaging must be accompanied by an evaluation of its life-cycle impacts. For existing products, the results of PLC reviews can help substantiate CARs for projects to be undertaken for those products.

Recognizing that CARs may be biased if the full array of environmental costs and savings associated with environmental projects are not considered, BMS is striving to more fully capture these environmental costs and savings. Linking EHS costs to specific products and processes is one goal -- the pharmaceutical division uses an activity-based costing system which may be adopted for use by other divisions. Developing better methods to account for benefits of environmental projects is another related goal.

While purchasing and packaging decisions are a component of PLC reviews, separate purchasing and packaging guidelines have been issued by the company. The Environmental Guidelines for Package Development direct the business units to minimize environmental impacts of packaging by considering opportunities for source reduction, recyclability, refillability and reusability, and safe disposal (e.g., no use of heavy metals in packaging). BMS participates in the Coalition of Northeast Governors (CONEG) Voluntary Packaging Initiative which requires reporting of packaging reduction efforts, thus enabling the company to track its progress.

Purchasing guidelines direct the company's purchasing staff to consider source reduction, recycled content, recyclability, reusability, renewable resources, energy efficiency, the supplier's environmental commitment, and other environmental attributes (e.g., handling and disposal concerns) in their purchasing decisions. Purchasing staff are also expected to keep suppliers up to date on BMS's environmental commitments and objectives. Information about the company's PLC review program and some literature utilized internally by the company have been distributed to suppliers. The businesses are responsible for evaluating suppliers and giving preference to those that have EH&S commitments and practices consistent with those of the company.

The company established a best practices transfer database in 1994 to provide BMS facilities worldwide with information relevant to best design, production, and waste reduction practices, including information on benefits, costs, implementation time, and annual savings. This computer-searchable database, also available in hard copy, is accessible to all of the company's facilities, and assists the PLC review process. Information generated during PLC reviews is placed in the database after it has been reviewed and verified. This information is contained under the file heading "Product Life Cycle" so that teams participating in PLC reviews can use the database for generating ideas. Improvement opportunities identified from PLC reviews are cross referenced in other database categories as well. The Best Practices database is not intended for tracking environmental regulations, although another database is being developed for this purpose.

4.4 Operationalizing Life-Cycle Design at Bristol-Myers Squibb Company

Product life cycle review (PLC) is the nomenclature used for the Bristol-Myers Squibb Company's life-cycle design program. PLC reviews provide a method for systematically examining EHS impacts of a product, and identifying and evaluating options for improving the product's EHS profile.

BMS views life-cycle assessment (LCA) methods developed by Society of Environmental Toxicology and Chemistry (SETAC) and U.S. Environmental Protection Agency (US EPA) as overly burdensome and providing negligible additional benefits to their existing approach. Life-cycle inventories, requiring data on material and energy inputs and environmental releases associated with each life cycle stage, are considered overly data intensive and obtaining such data from raw material suppliers is often difficult as it is not readily available. In the company's view their efforts are best spent evaluating and improving processes under their control. Impact assessment is viewed as difficult, and, at this juncture, an imperfect science. To overcome these barriers, BMS has developed a semi-quantitative approach that is buttressed by numerical data, where available, enabling the company to identify improvements at various stages of the life-cycle of the product. This process recognizes LCA as a valuable conceptual framework for guiding product and process improvement, without being hindered by burdensome data requirements and lack of consensus regarding impact assessment methods.

Life-cycle stages/business activities encompassed by the PLC review include:

- Research and product development, including design and redesign of products and processes, implications of raw material use, potential manufacturing impacts, and ultimately, consumer use and disposal;

- Marketing, including identification of consumer-preferred environmental characteristics, consumer requirements, and product promotion;

- Manufacturing, a review of energy and material use and waste generations and emissions arising from product manufacture;

- Packaging; including impacts of packaging materials, filling, and disposal:

- Sales, distribution, and transportation, including product promotion, selling, transporting and storage;

- Consumer use which includes unpacking, consuming and/or operation; and

- Final disposition, including the product, its packaging, and any residual product disposed via incineration, landfilling, recycling, or reuse.

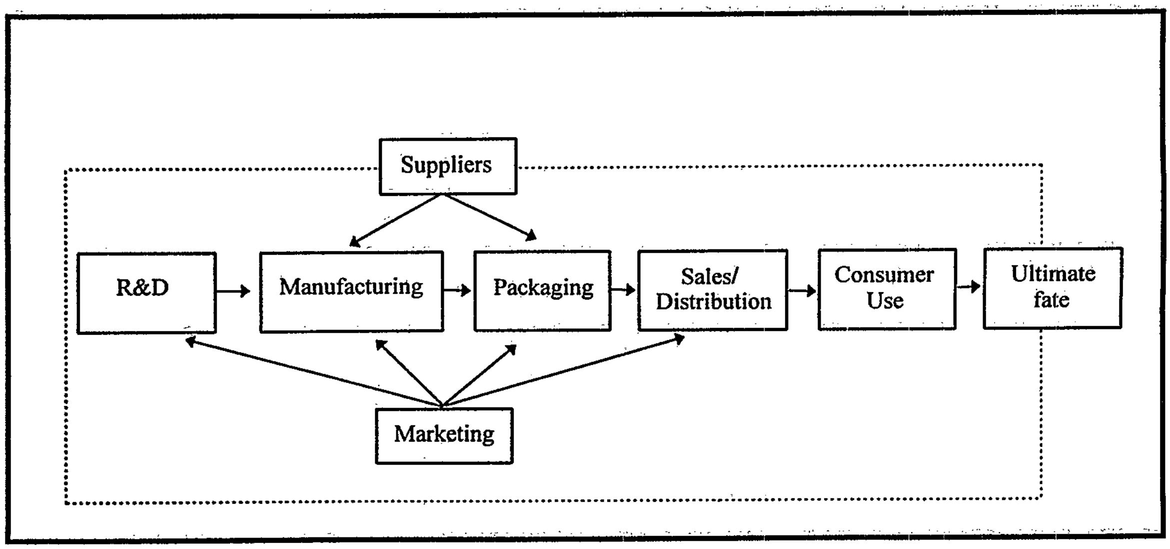
PLCs capture manufacturing and final fabrication in a single manufacturing stage and add two life-cycle stages/business functions -- product research and development and marketing. Product development is the core of life-cycle design; BMS believes including this function allows it to integrate EHS criteria into the earliest stages of product design and redesign, providing the greatest opportunities for eliminating or mitigating adverse impacts of products and processes.

All review teams include a marketing representative responsible for the product line being considered. Marketing serves many roles in PLC reviews. Marketing research identifies what the consumer wants from a product, including its performance, price, and appearance. Product environmental attributes must be balanced with these other attributes, ensuring that reliability, cost, and performance are not comprised. Thus, marketing may place constraints on product improvements. For example, eliminating the blue dye used in Ban was one improvement option identified by the Ban PLC team. However, marketing was concerned that eliminating the color would be perceived by the product's loyal consumers as a significant change. As a result, the dye was not eliminated, but an additional product in the Ban line, Ban Clear, was introduced.

Because a product's environmental attributes can give it a marketing edge, or provide a new angle for marketing a product, marketing staff provide insights to product improvement. Marketing staff also consider the environmental impacts of their activities, such as using recyclable materials or recycled content in advertising campaigns or point of purchase advertising.

Boundaries for PLCs are shown in Figure 4-2. BMS does not consider the environmental impacts arising from raw material acquisition (e.g., mining impacts). Instead, it bounds PLCs beginning with materials as received by BMS from its suppliers. For example, opportunities for reducing packaging waste resulting from raw material use (such as buying raw materials in bulk) are evaluated, while impacts incurred by BMS' suppliers during raw material manufacturing are excluded. BMS has been educating their suppliers about its PLC program, encouraging, but not requiring, them to undertake similar reviews, and providing them with literature utilized internally. Thus, BMS' PLC program encompasses "gate to grave" rather than "cradle to grave" life-cycle stages.

Figure 4-2. PLC Boundaries



BMS' approach integrates life-cycle concepts with traditional pollution prevention (P2) opportunities assessment by examining P2 opportunities in each life-cycle stage of the product and its processes. However, it goes beyond traditional corporate P2 programs by examining life-cycle stages beyond BMS' "gates," such as product use and disposal. Like P2, the PLC program looks beyond compliance and end-of-pipe treatment, examining opportunities for reducing energy and raw material use as well as reducing pollutants at their source. For example, reducing worker exposure to a hazardous chemical (by eliminating it, substituting a less hazardous or non-hazardous alternative, or improving housekeeping to reduce chemical use and exposure) is given priority over controls for minimizing exposures.

Because life-cycle stages cross staff functions within the company, PLC reviews begin by assembling a team comprising staff from multiple business functions. Thus, PLC teams may include staff from purchasing, research and development, marketing, manufacturing, packaging, and EHS. Assembling a cross functional team brings various areas of expertise to the PLC, as well as ensuring that other product and process design constraints -- e.g., cost, performance, and reliability -- are not ignored or compromised.

> The Keri PLC team, for example, consisted of staff from Bristol-Myers Products and Westwood Squibb Pharmaceutical. While Bristol-Myers Products distributes Keri Lotion, Westwood Squibb acts as a contract manufacturer, manufacturing Keri Lotion for Bristol-Myers Products. This PLC was the first to cross divisions within Bristol-Myers Squibb Company. PLC team representatives included staff from purchasing, product development, quality assurance, marketing and distribution, clinical supply, manufacturing, and EHS.

Over the course of several meetings, the team is educated about the Company's environmental, health and safety goals, and the role of PLC reviews in meeting those goals. Staff return to their respective divisions and functions to examine environmental and health and safety issues germane to their business function, and examine opportunities for reducing the identified impacts. Through subsequent meetings, team members provide their findings and seek feedback from their colleagues. Based upon several criteria (e.g., ease of implementability, costs and savings, and avoided impacts), the team then collectively decides which improvements are to be recommended to management.

4.5 The PLC Process

PLC reviews comprise eight steps typically spanning four to six months and four to six meetings of the project team. BMS hires an outside consultant whose responsibilities include facilitating the PLC team meetings, providing meeting minutes, and assembling a final report. This final report includes an overview of each step in the PLC review process and provides the list of product/process improvements recommended by the project team to management. Following is the typical sequence of events (see Figure 4-3).

Step 1 - Assembling PLC Team

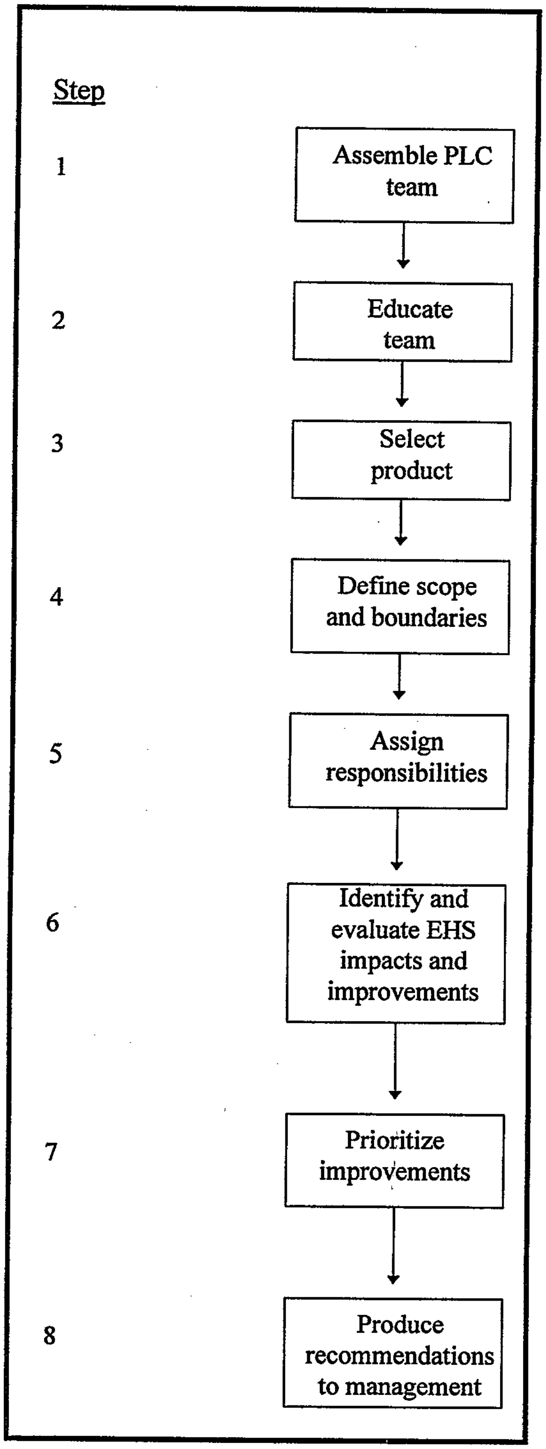
The Vice President of Environmental Affairs, Occupational Health and Safety initiates a PLC review by presenting an overview of the Company's **Environment 2000** and PLC programs to upper level managers in each business function (e.g., research and product development, marketing, manufacturing, EHS). Selecting PLC team members to represent each business function is the responsibility of these managers. Staff are chosen for their expertise as well as their enthusiasm for the process. A PLC coordinator is also selected to facilitate the review process.

Step 2 - Educating PLC Team

Introducing team members to the principles of **Environment 2000**, and how PLC review can help achieve those goals is a primary objective of the first meeting. Drawing from examples of previous PLC reviews, team members are provided an overview to the PLC approach used by BMS, and the benefits realized from prior PLC reviews (e.g., reducing environmental releases, increasing productivity, and reducing costs).

While the company has developed a generic framework for PLC reviews, tailoring the framework to the varying needs of BMS' different business units is encouraged. With different business units operating under differing regulatory frameworks, changes in product ingredients or process changes may be constrained. Thus, it may make sense to set aside certain life-cycle stages, focusing instead on those stages where improvement opportunities are most promising and numerous. For example, FDA approval of drug ingredients presents a major hurdle in reformulation of regulated pharmaceuticals, thereby constraining product reformulation options.

Figure 4-3. PLC Process



Step 3 - Selecting the Product

Because numerous products may exist under a brand name (e.g., Keri Original, Keri Silky Smooth, etc.), and conducting a PLC review for each is too time consuming, the team narrows the focus of the PLC at the first meeting by selecting a product or group of similar products under the brand name. Criteria for selecting a product may include manufacturing volume, sales volume and trends, and formulation complexity and ingredients in each. Other criteria also may be used. For example, the team may decide to use the PLC review as an opportunity to examine methods for minimizing known or suspected hazards that arise during a product's manufacture and/or use. Alternatively, if product and/or process changes are already underway for a specific product, the team may decide to focus on more mature products (i.e., older products that have already achieved their maximum market share) in the brand line which may offer greater opportunities for improvement.

Text Box 4-2. Keri Product Line

In conducting this step, the Keri team first identified the product line:

- Keri Original
- Keri Silky Smooth
- Keri Fragrance Free
- Keri Green
- Keri UV
- Keri Original 77

As the latter three products are only marketed in Canada, the team narrowed its focus to the first three products. After discussing the manufacturing and sales volumes, trends, and formulations, the team selected both Keri Silky Smooth and Keri Fragrance Free for the PLC. The principle drivers to this decision were anticipated sales trends and product formulation.

The agreed upon set of criteria (which may vary between PLCs) are used to evaluate each product and help reach consensus on the product to be reviewed by the PLC. Consensus building is an important step in keeping staff engaged in the process; all must agree with the group's decision about which product to review. An outside facilitator assists this process as a neutral party to the decision.

The team has much latitude in applying the criteria and indeed, different groups may apply them differently. For example, the team may decide to look at a product with decreasing market share since there is more pressure to achieve cost savings by reducing environmental costs or reshaping the product to appeal to the green consumer market. Conversely, the team may decide that it is more important to review a product with increasing market share, thereby reducing its environmental costs and making it more cost-competitive.

Step 4 - Defining PLC Scope and Boundaries

Goal definition and scoping -- identifying the PLC's purpose and determining its boundaries (the first step in LCA) -- also occurs in the first meeting. As shown in Figure 4-2, the boundaries for the PLC may be characterized as "gate to grave," beginning with materials received by BMS from its suppliers, and extending to product use and ultimate disposal. Impacts* arising from receipt of raw materials (e.g., packaging, mode of transport), as well as the impacts of the raw materials themselves, are included in the PLC. However, impacts linked to extraction and manufacture of raw materials and inputs into BMS products are outside the PLC boundaries. Material Safety Data Sheets (MSDSs) provide information on the environmental attributes of raw materials used by Bristol-Myers Squibb. While the company does not require LCA information or data from its suppliers, it has been educating their suppliers about its PLC program and encouraging them to undertake a similar review.

Step 5 - Assigning Responsibilities to Team Members

Team members receive BMS' PLC support document[3] at the first meeting. This document explains the rationale for undertaking a PLC review and provides an overview of the PLC review process. Organized by stages of the product life-cycle, the document outlines numerous environmental, health and safety issues which may be relevant to various stages of a product.

These stages include:

- product development;
- marketing;
- manufacturing;
- packaging;
- sales, distribution, and transportation;
- consumer use; and
- final disposition.

Background information is provided for each issue, further explaining its relevancy and identifying potential sources of information for addressing pertinent questions related to each EHS issue. For example, one EHS issue facing manufacturing is the use of hazardous chemicals in the manufacturing stage. As shown in Table 4-2, the support document lists sources of information for evaluating whether chemicals are a regulated hazardous chemicals. Pollution prevention techniques for minimizing or eliminating the identified chemicals are suggested in the document (e.g., chemical substitution), along with a framework for evaluating potential improvements to ensure that alternatives are superior to current materials, that is, they achieve net gains in environmental, health, and safety.

---

* BMS uses the term "impact" to signify potential adverse environmental effects, although they do not conduct a formal impact assessment as defined by SETAC/EPA LCA methods.

Table 4-2. Evaluating an Illustrative EHS Impact for Manufacturing

Does the production process, including maintenance activities, use materials containing a known hazard or threat to human health or materials regulated by a government agency?	Several key chemical lists can be evaluated for determining the regulatory applicability of the manufacturing process: • ACGIH Carcinogens • NIOSH Carcinogens • California Proposition 65 Carcinogens and Reproductive Toxins • Section 302 Extremely Hazardous Substances (40 CFR 355) • Section 313 Toxic Chemicals (40 CFR 372) • CERCLA Hazardous Substances (40 CFR 302.4) • CWA Hazardous Substance List (40 CFR 116.4) • OSHA Specifically Regulated Substances (29 CFR 1910.1001-1101 • OSHA List of Highly Hazardous Chemicals, Toxics, and Reactives (29 CFR 1910.119) • Clean Air Act Hazardous Air Pollutants (40 CFR 61) • Hazardous Substances (40 CFR 300) • TCLP Constituents (40 CFR 261, 265, 268, 271, and 302) • Storm Water Pollutants (40 CFR 122) • Process Hazardous Chemical List • National Toxicology Program Annual Report on Carcinogens • IARC Human Carcinogens (Groups 1, 2A, 2B)

Source: Bristol-Myers Squibb Company, *Product Life Cycle Support Document*, Dec. 1994

Similarly, Table 4-3 illustrates the support document's approach to evaluating environmental impacts associated with product packaging.

Table 4-3. Evaluating an Illustrative EHS Impact for Packaging

What is the packaging system for the product being assessed, and what are the associated environmental impacts on air, water, land, etc.?	In considering the environmental impacts of the packaging system, it is important to keep in mind the following issues: • Identify environmental burdens of energy use, and infrastructure/capital equipment required for: – exploration and extraction – cultivation, harvest, and replenishment – handling and transportation – storage and processing • Minimize environmental burdens by considering: – toxics and source reduction/substitution – recyclability, degradability, disposability – use of non-renewable resources – environmental, health, and safety risks • Consider legal implications (e.g., disposal, disclosure, taxes)

Source: Bristol-Myers Squibb Company, *Product Life Cycle Support Document*, Dec. 1994

Team members are assigned responsibility for a particular life-cycle stage according to their expertise. Using the support document and prior PLCs as a guide, team members are directed to review BMS's PLC methodology.

Step 6 - Identifying and Evaluating EHS Impacts and Improvement Opportunities

PLC participants identify and evaluate EHS impacts and potential product and process improvements using an iterative process. Between the first and second meeting, team members review the support document to assist them in identifying EHS issues relevant to their segment of the product life-cycle, and identify potential opportunities for improving the product's EHS profile. Seeking assistance from other team members, as well as outside staff, is encouraged, recognizing that PLC expertise is multi-functional.

Estimates of material and energy savings, avoided pollution, and costs and savings incurred by each opportunity are included in this review. For example, if an R&D team member recommends a formula change, such as reducing the amount of an ingredient, each staff function would evaluate the change based upon their expertise. The representative from manufacturing would estimate the amount of material savings while purchasing would translate this into a cost savings. If the new formula required new equipment, manufacturing and engineering personnel would evaluate equipment costs, installation and labor costs, differences in energy use, etc.

Improvement opportunities are aimed at eliminating, not transferring, emissions to another media. The team considers not only the quantity of emissions, but also relative toxicity, since a process modification may leave an emission volume unchanged although a less hazardous material is emitted.

At the second meeting, team members present their findings to the group. Ensuing discussions provide cross-fertilization of ideas and feedback, generating new ideas and identifying additional information and data.

Between the second and third meeting, the team completes the analysis of impacts and improvement opportunities, using this information at the next meeting to prioritize improvement opportunities.

> Forty-five potential improvements were identified by the Keri PLC team at the second meeting. These improvements include reformulations, packaging changes, process changes, and identifying and reducing product returns which must then be disposed.

Step 7 - Prioritizing Improvement Opportunities

Previously identified improvement opportunities are revisited at the third meeting, with an eye towards selecting the most promising options. These are the options that will be recommended for implementation to management.

Each option is evaluated using three criteria:

1. ease or difficulty of implementing;
2. costs for implementing; and
3. benefits of implementing the option (e.g., reduced costs, increased productivity).

These criteria inform the final determination of the priority each option should receive (e.g., high, medium, or low).

Time and resources required for implementing an improvement are important drivers for determining ease or difficulty for implementing an option. This criterion considers laboratory testing, new clinical testing, regulatory filings, and market testing required when changes are made to a product and/or process. Physical space limitations are also weighed for improvements requiring floor space in the manufacturing line or inventory storage. Technological feasibility -- whether an option is technically proven -- is another component of the criterion.

Anticipated costs (criterion 2) and benefits (criterion 3) of an improvement option include one-time capital costs and annual operating costs, including those that may arise from production effects (e.g., decreased cycle time, increased performance); changes in energy and raw material requirements; and changes in amounts and types of releases to the environment (including work environment).

Table 4-4 provides illustrative cost and savings categories that may be incurred from reformulating Keri Lotion, i.e., decreasing or eliminating an ingredient. On the cost side are items such as consumer testing for acceptability of the reformulated product, stability testing to determine affect on shelf life, clinical testing, and the cost of generating new art work for the product label.

Table 4-4: Potential Costs and Benefits of Product Reformulation

Costs	Benefits
Consumer testing	Raw material savings
Stability testing	Decreased cycle time
Clinical testing	Reduced utility costs
Changing product label	Reduced waste disposal costs
	Reduced pollution control costs
	Reduced manifesting, recordkeeping, and reporting costs
	Reduced worker training costs
	Reduced insurance costs
	Reduced transportation and storage costs

On the savings side, raw material savings are a prominent benefit of reformulating the product. Other potential savings include decreased batch manufacturing cycle time (e.g., decreased process cleaning time) and reduced waste disposal costs by eliminating disposal of the ingredient's packaging. If the eliminated ingredient required refrigeration or heating, utility costs would be reduced .

Eliminating or reducing the use of an ingredient may have positive effects on pollution control and waste management costs. Dust collection systems required for ingredients generating nuisance dusts and medical surveillance programs required for occupationally hazardous ingredients may be eliminated. Staff time required for tracking, reporting, and manifesting hazardous materials may be reduced. Pollution control costs may be reduced by eliminating ingredients exerting biological oxygen demand (BOD) on aqueous waste streams (e.g., from process cleaning) or ingredients that contribute to air emissions. Insurance costs associated with use of flammable and/or hazardous materials also may decrease.

Costs and benefits for implementing an improvement may be quantitative or qualitative, and may or may not be monetized. Monetizing costs and benefits, while at times difficult, has the advantage of converting the impacts of an improvement option into a standard, easily understandable metric for managers -- dollars and cents. At this stage of the PLC review, direct costs and savings are often monetized, while indirect and less tangible costs are not. For example, the product development team member noted that cost savings attributable to reformulating Keri Lotion include reduced raw material costs, reduced energy needs, and reduced process time. Only the easily quantifiable raw material cost savings were monetized, whereas the decrease in process time was estimated, but not monetized. Energy savings were neither quantified nor monetized. For projects requiring substantial capital expenditures subject to standard appropriations request, these initial estimates are refined and expanded to obtain a more comprehensive financial picture of a proposed improvement

Once each improvement option is evaluated using the three criteria, its priority is ranked as either high, medium, or low. An improvement option easily implemented, not incurring capital costs, with numerous benefits would be a "high" priority option. However, options that are difficult to implement may still be deemed a priority if the benefits outweigh the costs. Ranking an improvement's priority is also based upon whether profitability -- payback, internal rate of return, or other indicator -- is likely to occur in the short or long term.

Step 8 - Produce Recommendations to Management

High priority improvement options identified in Step 7 are recommended by the team for approval by management. The final report generated from the PLC review identifies each option, presents estimates of monetary costs and savings, and qualitatively describes EHS benefits (such as reduced worker exposures, less hazardous waste generated). An appointed team member presents and reviews the report with management to obtain approval for the priority improvements.

PLC reports are sporadically reviewed to determine whether business and/or market changes warrant reprioritizing the lower priority improvements. For example, while eliminating the blue dye in Ban was an improvement option identified by the Ban PLC team, the option received low priority due to Marketing's concern that eliminating the color would be adversely perceived by the product's loyal consumers. Rather than eliminating the dye, an additional product in the Ban line, Ban Clear, was subsequently introduced.

4.6 Observations

Recognizing LCD as a valuable conceptual framework for identifying and evaluating process and product improvements, BMS has developed a semi-quantitative approach for identifying improvements. This approach, known as product life-cycle review, systematically reviews those stages of the life-cycle over which BMS is wholly or substantially responsible, but extends beyond the company's gates by including product use and disposal. By so doing, the BMS process has some elements of product stewardship wherein producers consider, if not take full responsibility for, use and disposal of the products they manufacture.

BMS recognizes many benefits to its PLC program and approach. PLC reviews provide opportunities for reducing EHS impacts of the company's products and processes. Reducing these impacts translates into cost savings for the company, helping to create cost- and environmentally-competitive products. BMS has completed 18 PLC reviews and identified improvement opportunities with potential savings of $2.8 million.

PLC reviews improve the reception of Environmental Health and Safety staff by product and operations managers. As noted by one EHS staff member, when EHS staff functions were primarily compliance-driven, staff were negatively viewed as environmental "police." However, with the company realizing cost savings as a result of PLC reviews, the role of EHS has been boosted and PLC has evolved into a contributor to broader objectives of product quality, customer satisfaction, and market competitiveness.

The cross-functional project teams are credited with bringing together a diverse staff working together to assess and improve EHS performance. The varying areas of expertise provided by team members allows cross-fertilization of ideas. An objective of BMS's **Environment 2000** initiative is to make staff realize that environmental protection is the responsibility of each and every employee. Cross-functional project teams help achieve this goal, placing responsibility for improving environmental performance beyond EHS staff and squarely in the mainstream of all traditional business functions.

The BMS PLC process reveals several challenges and opportunities a company faces when implementing a PLC review program. First, identifying a team leader to take ownership for the process is important. Due to organizational and staff function changes, leadership changed over the course of the Keri PLC review. As a result, the process at times was delayed and an anticipated four to six month process required ten months.

Second, because implementing changes to a successful product can be difficult, PLC reviews provide a vehicle for affecting product improvements that may otherwise be neglected. For example, changing product ingredients may not be a business priority if that product has a large and/or increasing market share. However, under the umbrella of a PLC review, management may be more willing to examine such changes, especially if they result in lower EHS impacts and costs. Thus, team members should avoid *a priori* decisions, carefully examining each and every product and process improvement. Since it can be difficult convincing company stakeholders to leave their hats at the door (e.g., marketing staff may be very reluctant to alter a successful product), explicitly stating this goal in the first meeting helps to better define expectations for the team.

Third, product improvements may be unfairly rejected on economic grounds if the broad array of costs and savings resulting from an improvement are not assessed. Thus, it is important to consider the comprehensive inventory of costs and savings, going beyond direct conventional costs (e.g., labor, equipment, and raw materials) to include indirect costs (e.g., compliance costs, insurance) and probabilistic costs (e.g. liability costs incurred by spills). Raw material cost savings by themselves may be significant enough to warrant eliminating an ingredient from a product. In such cases, expending further staff time to quantify other benefits may not be necessary.

Finally, further quantifying potential costs and savings may be warranted, however, if the improvement option appears unprofitable or has a borderline profitability (as indicated by a long payback period, or a low internal rate of return, for example). Other avoided costs may be the driver of an improvement option's benefits. Eliminating the use of a hazardous chemical, for example, may eliminate numerous compliance costs such as worker training and medical surveillance; hazardous waste tracking, manifesting, and hauling; and permitting. By not quantifying these benefits, an opportunity for improving a product may be missed. The challenge is striking a balance between an initial economic screening using selected cost items and a more comprehensive analysis which may identify critical but neglected cost items. PLC reviews may thus benefit by including staff with expertise in capital budgeting and environmental cost accounting. While PLC reviews usually include an accounting staff person, such representation was lacking for the Keri PLC.

4.7 Endnotes

1. Bristol-Myers Squibb Company, 1995. *Report on Environmental Progress*, May.
2. *Ibid.*
3. Bristol-Myers Squibb Company, 1994. Product Life Cycle Support Document (U.S. Version), Dec.

5. Case Study -- Armstrong World Industries

5.1 Company Profile

Armstrong World Industries, Inc. is a manufacturer and marketer of interior furnishings and industry products that include:

- floor coverings, including flooring and adhesives;
- building products, including acoustical ceiling and wall systems, and grid suspension systems; and
- industry products such as insulation for industrial equipment, gaskets, and specialty rubber parts.

The company employs 10,000 people at its 49 plants worldwide, including the United States, Canada, Mexico, England, France, Germany, Italy, Spain, Switzerland, Netherlands, India, Australia, and China.

In recent years, Armstrong has undergone numerous changes, selling its furniture subsidiary (Thomasville furniture) and combining its ceramic tile operations with Dal-Tile International. In addition to changes in its product lines, the company has reorganized its management structure with the goal of moving additional corporate-level environmental and R&D programs down to the business units.

These recent changes affected this case study in several ways. Initially, product stewardship was the responsibility of the Product Environmental Performance program, a segment of the company's Environmental, Health and Safety (EH&S) group. This corporate-level program was eliminated in 1996. Some of this group's functions have been transferred to Armstrong's business units, but other efforts, at least in the interim, have been discontinued. These organizational changes provided an unexpected opportunity to document how LCD fares in the face of corporate restructuring that has characterized large U.S. firms throughout the 1990's.

5.2 Environmental Management and Policy

Until 1994, environmental management responsibilities at Armstrong were divided across two groups: Safety and Health, overseeing occupational safety and health compliance, and Environmental Affairs, overseeing environmental compliance and providing periodic environmental assessments of Armstrong's production facilities. Because of a growing overlap in regulatory responsibilities between these groups, they were combined in 1994, forming the Environmental Health and Safety (EH&S) group.

In late 1996, the company implemented a second wave of EH&S restructuring to better integrate environmental management systems into its business units. Previously, day-to-day management of Armstrong's environmental policies and initiatives chiefly rested with the EH&S group, a corporate-level group. However, environmental initiatives, including the company's Product Environmental Performance program, were not sufficiently percolating down to Armstrong's business units, the level at which decisions are made about what a product contains and how it will be manufactured. To bridge this gap, Armstrong established environmental steering committees within each of its four business units.

Text Box 5-1. Corporate Policy on the Environment

Armstrong recognizes the importance of protecting the environment and using resources intelligently. We are committed to exercising environmental stewardship in our dealings with customers, employees, government, and community neighbors and in meeting an obligation to future generations.

Our overall goal is to make sure that our activities as a corporation are in harmony with the natural world around us.

Armstrong's policy on the environment embodies these aims:

1. To exercise care in the selection, use and conservation of energy and raw materials, especially natural resources, to assure that we are not wasting such resources.

2. To make use of research and production technology to provide for the protection of our environment in workplaces and communities and to seek to reduce risk to the earth, its waters and atmosphere.

3. To be prepared for emergencies and to act promptly and responsibly to protect people and the environment should accidents or incidents occur.

4. To make only products that are environmentally compatible in their intended use by our customers and consumers, and to accompany them with adequate information for their intended use, maintenance and disposal.

5. To prevent pollution at the source, to reduce waste, to make use of recycling in all our operations and to take care that we dispose of unneeded materials in an environmentally appropriate manner.

Source: ***Environment, Health & Safety Progress Report*, 1995**

Armstrong's environmental policies are jointly established by the President's Office and the Board of Directors. The company's Corporate Policy on the Environment (Text Box 5-1) includes commitments to manufacturing environmentally compatible products using production methods that protect the workplace and community environments. The company's Environmental Health and Safety Review Committee, chaired by Armstrong's Executive Vice-President, is charged with overall management of these policies. Other committee members include the Senior Vice-President of Human Resources; Vice President of Public Affairs; Senior environmental attorney; Director of Environment, Safety, and Security; and the Manager of Safety, Health, and Hygiene.

The Environmental Health & Safety Coordinating Committee, comprising the Vice President of Manufacturing from each division, a representative from Human Resources and the legal department, and the Director of Environment, Safety, and Security, provides a link to the manufacturing divisions. This committee is responsible for implementing new environmental programs.

It is the responsibility of each business unit's Environmental Steering Committee to establish the environmental strategy of the business unit and to monitor the environmental activities of the unit to ensure implementation. To provide continuity and a bridge between the company and business units, the corporate level Director of Environment, Safety, and Security and the Manager of Safety, Health, and Hygiene (whose primary responsibility is industrial hygiene), are members of each Steering Committee. Other committee members include personnel from product development teams, legal department, and the Vice President of Manufacturing for the business unit.

Plant managers are responsible for environmental compliance at their facilities. Three basic requirements must be fulfilled by plant managers: (1) completing a plant-level pollution inventory quantifying non-product outputs; (2) using inventory results, P2 plans must be filed quarterly; and (3) a multi-media third party audit must be completed every three years.

Three times a year (since January, 1991), Armstrong produces an environmental newsletter, *Environmental Releases*, distributed to employees around the world. A series of articles have presented an introduction to LCA and examples of how the ideas are being put to use in the company. The company's Annual Report provides a list of yearly environmental accomplishments; a separate environmental report, first produced in 1995 and currently being updated, further describes the company's environmental initiatives and progress. This report will be updated biennially.

Additionally, Armstrong's business units recently began issuing separate brochures reporting environmental efforts germane to each unit. Armstrong's Building Products Operations brochure describes the business' activities conforming with the P2 hierarchy (reduce, reuse, recycle), environmental life-cycle "information" for the company's acoustical mineral fiber ceiling panels (an example is provided in Figure 5-2), and an environmental index of selected products. For each product, the index provides the recycled content, a description of the product's durability (e.g., cleanable, paintable, warranty lifetime), and the light reflectance value indicative of energy use. A comparable brochure is being prepared by the company's flooring unit. These brochures are distributed to Armstrong's customers -- specifiers (e.g., architects) and end users.

5.3 Product Environmental Performance

In 1990, Armstrong created its Product Environmental Performance program as a corporate-wide initiative. Emerging product environmental issues, including indoor air quality (IAQ), were the primary driver of this initiative. Product Environmental Performance expanded environmental issues beyond plant compliance to IAQ issues arising from use of Armstrong's products and product stewardship initiatives for continuous environmental improvements of products.

This corporate-level program was one of the key programs whose mission, in Armstrong's view, was not effectively translated into the activities of its business units. Thus, the program was disbanded at the time of the reorganization. Disseminating the program's core objective -- product stewardship -- is a remaining challenge as Armstrong adjusts to this reorganization. Nonetheless, it is worthwhile looking at the central elements of the program prior to its discontinuation and integration into other Armstrong programs.

Prior to reorganization, a life-cycle framework was established to support and provide background to Armstrong's product environmental performance program. It provided "an organized, comprehensive way for measuring environmental burdens associated with a business, product, process, or other activity; for assessing the impact of these burdens on the environment; for identifying options for improvement; and for making decisions regarding the implementation of such options."[1] Armstrong focused its efforts in three directions:

1. developing process chains to map the life cycle of Armstrong's products,
2. developing life-cycle inventory data that are linked to these process chains, and
3. developing an environmental checklist for new product/process development.

Assessing the impacts of its *current* products and identifying opportunities for mitigating those impacts were the goal of the first two activities; minimizing impacts of *future* products was the goal of the third activity.

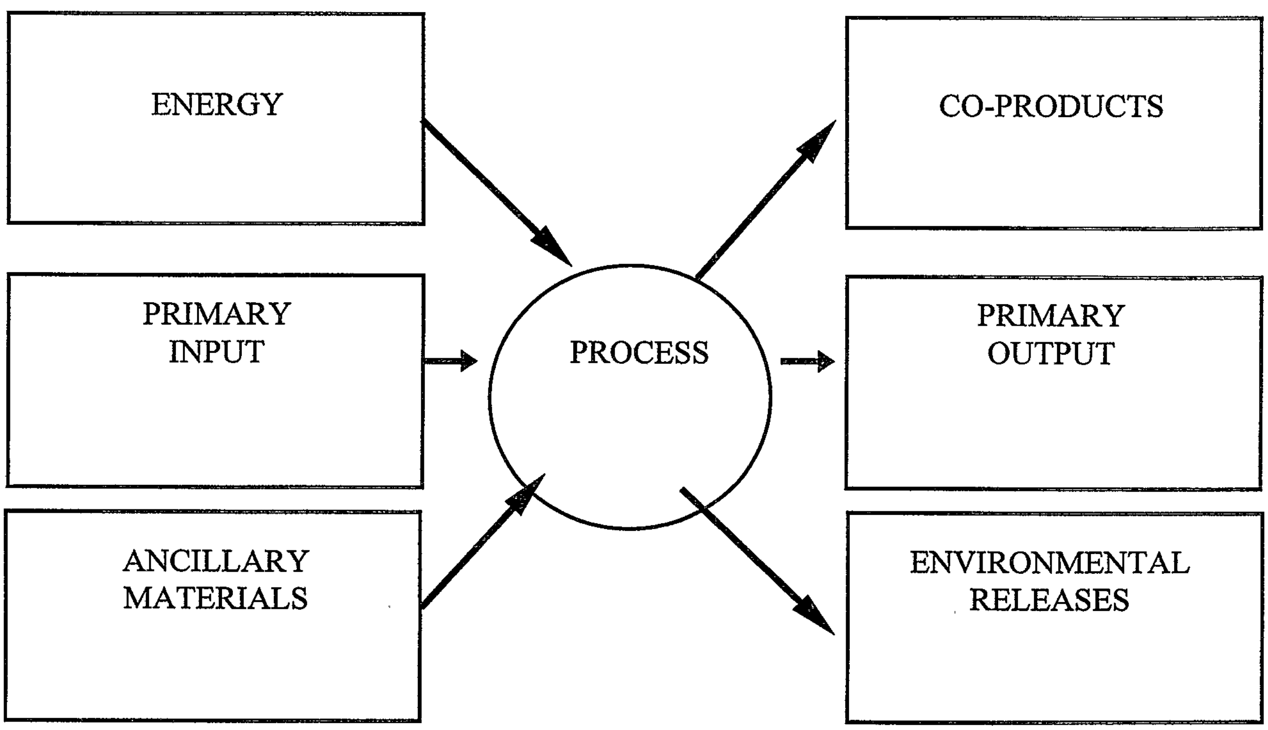
A first step in launching the Product Environmental Performance program was developing a methodology and framework for assessing the total environmental performance of Armstrong's products. The LCA framework described in EPA and SETAC documents provided the backbone to the company's methodology, though adaptations occurred to meet the company's needs.

Armstrong began by developing detailed process flow diagrams of the production processes for floorings and building products (Armstrong's major products) using off-the-shelf graphics software. A generic version of the graphical map is presented in Figure 5-1. At the center of the map is a "process" defined to include processes, actions and activities. Inputs to the process include:

- energy materials and their sources required for the process (e.g., fuel oil, gasoline, electricity),
- primary inputs, defined as "the key or fundamental elements that are operated upon by the process and lead to the "Primary Output" of the process," and ancillary materials, i.e.,

additional inputs needed to complete the process such as water, packaging, and maintenance materials.[2]

Figure 5-1: Generic Production Process



Next, spreadsheet software was used to link life-cycle inventory data to the graphical maps. Substantial efforts were directed towards collecting these data; Armstrong collected much of the necessary life-cycle inventory data for those portions of the production chain residing within Armstrong's "gates" -- i.e., manufacturing, sales and distribution.

Extending the life-cycle inventory boundaries beyond Armstrong's gates to upstream processes (e.g., raw material acquisition and processing) required an outreach effort with approximately twenty key suppliers to obtain information about their process inputs and environmental releases. An initial letter to suppliers from the President of Armstrong Flooring requested these data to support Armstrong's Product Environmental Performance program. Responses to this effort was mixed -- several Armstrong suppliers were familiar with LCA and were already actively using the life-cycle framework to assess their own products and processes. In other cases, the life-cycle framework was a new concept to many suppliers.

The level of detail and data quality provided by suppliers was highly variable. A major obstacle to obtaining supplier data was confidentiality. Overcoming this hurdle required additional Armstrong contact and persuasion of managers at the supplier company. In many cases, however, suppliers simply did not have the data available and expending resources to collect data were not considered a priority.

The company avoided using generic, industry average data as its relevance to Armstrong was considered limited. For example, while life-cycle inventory data are available for polyvinyl chloride (PVC), PVC formulations used for packaging applications differ from PVC formulations used by Armstrong's floor manufacturing operations. Generic data which focus on PVC packaging formulations do not account for these differences. Because Armstrong lacked complete inventory data from suppliers, and because it considered generic inventory data as a poor substitute for missing data, the company did not have complete inventory data for any of its products.

Currently, Armstrong is continuing to map process chains, but instead of collecting complete life-cycle inventory data, the company has narrowed its data collection efforts to raw materials, energy use, and waste generation at the plant level. In the company's opinion, consensus is lacking on appropriate metrics for life-cycle inventory data. Until methods further evolve, it is hesitant to use more substantial resources for collecting data. At this juncture, Armstrong does not plan to further pursue life-cycle inventory data from its suppliers.

Total Environmental Assessment

To assist internal data collection for its Product Environmental Performance program, Armstrong instituted a plant-based computerized data collection system known as TEA (Total Environmental Assessment). TEA is comprised of five modules. The first module is equivalent to a plant-level life-cycle inventory, encompassing raw material and energy inputs and output data (including air and wastewater emissions, and solid and hazardous waste) on an annual basis. These data were, by and large, routinely collected by Armstrong's facilities prior to implementing TEA as part of Armstrong's facility pollutant inventory. All plants worldwide annually file a pollutant inventory, an element of Armstrong's environmental management system instituted in 1991 to more expansively examine opportunities for minimizing environmental burdens arising from its manufacturing facilities. This inventory quantifies yearly emissions to air and water on a pollutant-by-pollutant basis, extending beyond compliance-based pollutants to including for example CO_2 and non-hazardous solid waste, in addition to hazardous waste. Data consistency across facilities is ensured by using a standard inventory regardless of a facility's location.

The second TEA module is an environmental management system enabling the facility to track progress towards improvements identified by audits. The third module is a calendar documenting timetables for permits while the fourth module tracks facility violations. The last module is a database of environmental standard operating procedures (SOPs), developed by the individual facility, but based upon generic SOPs issued at the corporate level.

Eleven of Armstrong's plants are currently using some elements of TEA -- nine in the United States, one in the Netherlands, and one in Germany. To minimize system costs, Armstrong augmented its staff with university students for installing and setting up the TEA computer system. For example, University of Illinois at Urbana-Champaign students were involved in developing and installing TEA at Armstrong's tile manufacturing plant in Kankakee. In collaboration with students from Oklahoma State University, Armstrong recently implemented the most advanced version of TEA in its Stillwater facility.

Using TEA data, Armstrong has identified processes to target for improvement. Improvement options are identified and evaluated across various criteria, including resources such as labor required for implementing the improvement, and capital expenditures. The facility's industrial engineer makes final decisions based upon a cost benefit analysis, weighing the costs of implementing the improvement against the project's benefits, using criteria such as return on investment (ROI). Prioritization of improvement options also is heavily influenced by external factors, including regulations and stakeholder (i.e., customers and public) concerns. VOC regulations, for example, catalyzed switching from VOC-containing printing inks to water-based inks and substituting water-based adhesives for VOC-containing adhesives.

TEA data have also provided insights to the origin of some IAQ issues. Armstrong discovered that some of their IAQ issues were arising from impurities in raw materials. As a result, they are working with their suppliers to provide a cleaner raw material. TEA data have also assisted in making recycled content decisions, enabling higher recycled content in some products such as ceiling products with a recycled content of approximately 79%.

Information from TEA is shared among plants manufacturing the same product. Using this information, decisions regarding process changes can be initiated at different levels, including individual plants, a group of plants (that meet on a regular basis), and from the corporate level. For example, the decision to eliminate 1,1,1-TCE was initiated at the corporate level by the Vice President of Manufacturing, although the plants using the chemical and Armstrong's R&D Division were involved in examining substitutes. Armstrong uses mineral spirits to control the viscosity of plastisol, a coating for PVC flooring, resulting in off-gassing of mineral spirits after the flooring is laid. Armstrong decided to make plants aware of the situation through personal communication and an educational seminar with the plant environmental coordinators and plant managers. However, process change decisions must be initiated by the business unit's Vice President of Manufacturing.

Armstrong generates "Life Cycle Information" sheets from TEA data integrated into the company's LCD framework to communicate environmental information to some of its major customers, such as WalMart. These sheets provide a descriptive overview of the processes required for obtaining the raw materials entering Armstrong's plant, processes occurring at Armstrong, installation/use/maintenance activities, and recycling/waste management opportunities. As shown in Figure 5-2, the life cycle information sheet for Corlon sheet flooring, no data are provided in

Figure 5-2. Corlon Information Sheet

LIFE CYCLE INFORMATION

Armstrong CLASSIC AND STANDARD CORLON SHEET FLOORING

There are an increasing number of requests for information on "Life Cycle Analysis" of building materials. Although Life Cycle Analyses on various products have been published, there currently is not a consensus in the scientific community on what factors should be considered in a Life Cycle Analysis and how these factors should be measured and interpreted in terms of environmental impact.* Thus, many of the Life Cycle Analyses which are being distributed are simply the opinions of the authors. Currently there is an ASTM subcommittee working to develop a consensus standard on how a Life Cycle Analysis should be conducted. Until this subcommittee reports its findings, we are providing specifiers with Life Cycle information (not a Life Cycle Analysis) of Armstrong Classic and Standard Corlon Sheet Flooring.

1. Raw Materials Stage
   - Limestone is a common natural material available in great supply. Obtained locally for reduced transportation costs.
   - Polyvinyl chloride resin is a cost effective polymer derived from oil or liquefied natural gas and salt (sodium chloride). PVC resins are used in many applications from flooring to upholstery, medical tubing, toys, etc. Manufacturers of PVC resins use liquified natural gas or petroleum reacted with chlorine from the salt to form vinyl chloride monomer. The PVC manufacturing process rigorously strips the monomer from the resin complying with all safety and health regulations.
   - In addition to limestone and polyvinyl chloride, plasticizers, stabilizers, and colored pigments are added to improve the product and provide the function and aesthetics for this commercial product.
   - The backing used on Classic and Standard Corlon products is made from inorganic filler, a latex binder, and non-respirable organic and inorganic fibers.

2. Manufacturing Stage
   - The raw materials are compounded at moderate temperatures to form the finished product.
   - Some scrap is recycled during the manufacturing process; additional scrap material is used for floor mats or rugs with the remaining scrap being disposed of in an approved landfill.

3. Installation/Use/Maintenance Stage
   - Classic and Standard Corlon are designed to be installed over wood, concrete, and selected existing floor coverings, eliminating the cost of removal and disposal of existing flooring.
   - Use of medium to low VOC adhesives will minimize emissions during installation. Only Armstrong's S-235 and S-200 are recommended for the installation of these floors.
   - Recycled and recyclable packaging material are used to package Classic and Standard Corlon Sheet Flooring.
   - The amount of trim scraps produced during the installation process is very small and can be disposed of in any landfill which accepts construction wastes.
   - Standard and Classic Corlon are very durable floors containing a high percentage of natural materials.
   - Armstrong does not formulate or intentionally add asbestos, 4 PCH, or lead in the manufacture of Corlon Sheet Flooring.
   - Under laboratory conditions with sophisticated, analytical equipment, very low amounts of VOC's can be detected from Classic and Standard Corlon which ultimately diminish to a non-detectable level after 30 days.
   - Classic and Standard Corlon do not have an absorbant surface, and therefore, do not act as a sink absorbing and remitting VOCs and other pollutants.
   - Classic and Standard Corlon require initial and continuing maintenance for best performance and appearance.

4. Recycle/Waste Management Stage
   - Classic and Standard Corlon can be selectively installed over existing flooring, thus eliminating the need for removal and disposal processes.
   - Currently there is little opportunity for the recycling of Corlon Sheet Flooring in the U.S.
   - Disposal of Classic and Standard Corlon can be made with no known harmful impacts on any landfill which accepts construction wastes.

*Canadian government document "Principles and Guidelines for Environmenta Publicity and Advertising" published July 1993.

©1994 Armstrong World Industries - April 1994

these sheets. Similar sheets have been prepared for additional commercial products, including acoustical mineral fiber ceiling panels, floor tile, vinyl sheet products, and adhesives, and included in environmental stewardship program reports prepared by the business units.

Successfully implementing the TEA system (including data collection) requires a plant employee, usually the environmental manager, to assume system "ownership." The Vice President of Manufacturing will implement the system only if requested by the facility. By portraying TEA as an environmental management tool, rather than a product improvement tool, the company has had some success with implementing TEA at certain production facilities. To date, environmental management standards emerging from ISO 14000 have not been a driver for TEA adoption, but may become a more important factor in the future if these standards gain wide acceptance.

New Product Development Process

For new products, Armstrong has introduced LCD concepts into its New Product Development Process via a checklist, *Environmental Checklist for Product Transfer Points.* Checklist custody is transferred to appropriate staff as a product moves from R&D, to factory testing, to full scale production, ensuring that environmental information is similarly transferred. The goal of this checklist is to provide environmental management oversight of R&D projects and, to early on, uncover and mitigate environmental concerns. The overarching framework ensures compliance with Armstrong's Corporate Policy on the Environment and seeks to ensure minimum environmental and occupational health and safety impacts arising from R&D and subsequent manufacturing activities, compliance with legal and regulatory requirements, and minimum impacts from product use and disposal.

Ensuring that only approved chemicals are used in new products is one function of the checklist. Before introducing a new chemical in the manufacture of a new or existing product, its MSDS must be submitted and its use approved by the Environmental Health and Safety Review Committee, a corporate level group. An approved chemical list resides on Armstrong's computer system and is accessible to all business units. MSDS-type information must be supplied on the checklist, including a list of special handling precautions and required protective equipment for chemicals included in the product's formulation.

A series of questions requires information about environmental releases resulting from the product's manufacture, including VOCs, Title V Hazardous Air Pollutants (regulated under the Clean Air Act), and hazardous waste generation. Moving beyond manufacturing impacts, an LCD perspective is embodied in questions about the product's packaging, and use, including exposures resulting from consumer use or installation.

R&D staff view the checklist as a valuable screening tool in the product development process. Challenges to routinizing use of the checklist include gaining its acceptance from the business units' R&D product development teams. Because regulations and permits may change, the checklist may require updating during the R&D process. Armstrong plans to eventually transfer the checklist from paper to a computer-based system. Presumably, updating such a system will be easier. Employees using the checklist oftentimes lack an understanding of environmental management and must consult with environmental engineering staff to successfully implement the checklist.

5.4 Observations

Initially, Armstrong's Product Environmental Performance program was largely reactive, driven by stakeholder concerns about indoor air quality (IAQ) from off-gassing of chemicals contained in building products. In response, the company established its program to carefully examine material inputs and identify opportunities for reducing IAQ problems. Increasing customer requests for information about the environmental impacts of the company's products, coupled with the company's desire to continuously improve its products, became the principal drivers of Armstrong's Product Environmental Performance program.

The program's goals and scope were bold -- mapping out all the processes for manufacturing Armstrong's major products; collecting life-cycle inventory data for these processes, including data beyond Armstrong's "gates", i.e., upstream data from suppliers, and downstream data for waste disposal; and implementing facility-level computer systems for collecting these data. The program had an internal champion, the program manager, whose chief responsibility was overseeing and implementing the program. However, a key ingredient to success was missing -- allocation of sufficient resources in the business units manufacturing the products. This left the program vulnerable as the company went through major restructuring of its operations.

Building upon ongoing corporate reorganization, including a realignment of the company's EH&S management structure, the company addressed this problem. The functions of the Product Environmental Performance program were reallocated to the business units, along with general EH&S responsibilities, placing these responsibilities squarely in the purview of the business units. By moving product environmental performance responsibilities to the business units, responsibility was placed in the hands of the staff who actually make decisions about a product's design and manufacture. Given the extensive resources necessary for collecting firm-specific life-cycle inventory data, trying to collect information beyond the firm's gates was perhaps overly ambitious. Thus, the program's breadth was altered by discontinuing upstream and downstream data collection efforts.

Armstrong currently faces typical transitional challenges of reorganization, translating and strengthening its corporate commitment to product environmental improvement to an operational level. This is a slow process of internal marketing, education, and capacity-building as it transfers responsibilities from the corporate to business unit level. Ultimate success hinges heavily upon the ability to mesh life-cycle information systems with more traditional compliance reporting systems as the responsibilities of the business unit managers broadens from compliance to proactive environmental management. Doing this in a way that minimizes resource requirements and maximizes value added to the business units will go a long way to ensuring long-term success.

5.5 Endnotes

1. Personal communication from Dr. James Tshudy, former manager, Product Environmental Performance.

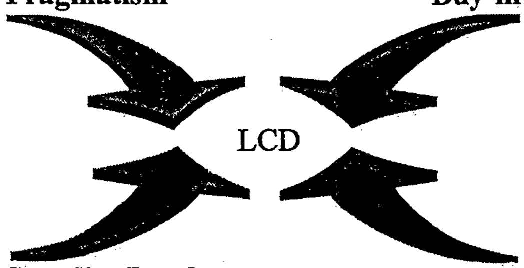
2. Tshudy, J.A., "Environmental Life Cycle Analysis: The Foundation for Understanding Environmental Issues and Concerns," presented at 33rd Annual Conference of Metallurgists, Toronto, Ontario, August 20-25, 1994.

6. CONCLUSIONS

Armstrong, BMS, and IBM demonstrate a range of LCD practices, demonstrating the reality that there is no one size fits all approach in transforming LCA approaches into a working decision-support tool. While all three LCD programs continue to evolve, our study suggests a number of themes that serve as valuable lessons both for other firms and for government initiatives aimed at advancing LCD practices.

Figure 6.1 illustrates the elements that comprise LCD.

Figure 6-1. Elements of Life-Cycle Design



Motives. LCD initiatives are likely to be driven by linked environmental and economic pressures. Moving beyond compliance to stay ahead of regulatory trends, improving customer (either distributor or final consumer) service and product quality, and creating green market opportunities, typically provide the impetus to building and sustaining an LCD program.

BMS's LCD program documents the strongest link between environmental and economic improvements. The company has completed product life-cycle (PLC) reviews for eighteen of its products. The environmental improvements identified in these reviews has yielded a potential savings of $2.8 million. This economic benefit does not include potential revenues arising from the sale of "green" products; thus the potential benefit may be greater.

Pragmatism. Selective, non-prescriptive, customized, and flexible describe the approaches to LCD adopted by Armstrong, BMS, and IBM. For these firms, rigid protocols simply do not mesh with business reality. For example, while BMS has developed a generic framework for PLC reviews, the framework is tailored to the varying needs of BMS' different business units to account for the differing regulatory frameworks under which each unit operates. When conducting a PLC for a mature product, BMS's pharmaceutical division is likely to set aside product reformulation options, for example, as such reformulations require approval from the U.S. Food and Drug Administration (FDA), an expensive and timely process.

Product cycle time and trade-offs with other design criteria (e.g., performance, reliability, safety, cost) necessitate an adaptive approach to LCD. The shorter the product cycle and more competitive the marketplace for the firm's products, the greater the need for adaptability. Electronics firms, such as IBM, facing an average 18 month time horizon in translating product concepts to market cannot afford LCD methods which may delay a product cycle. Thus, the company separates *product* development processes from *process* development processes, and under its product stewardship program, uses separate procedures for identifying environmental improvements for each.

Buy-in. An effective environmental management structure, coupled with a solid corporate commitment to continuous environmental improvement, is key to a successful LCD program. Armstrong, IBM, and BMS have each established corporate environmental policies emanating from high levels within each company. Translating these polices into actions requires educating and achieving buy-in from employees across many levels of the company. All three companies educate their employees via environmental reports (separate from their corporate Annual Report) which are circulated to employees, in addition to external stakeholders (such as stockholders and NGOs).

Each company engages staff in its LCD programs via differing mechanisms. Both Armstrong and BMS have used traditional top-down approaches. By contrast, IBM uses both a top-down and bottom-up approach, involving staff from affected divisions of the company when establishing or revising any of its environmental policies. Thus, when IBM established a new corporate instruction on Environmentally Conscious Products (ECP), staff from all of IBM's hardware divisions were involved with drafting the instruction. This draft was forwarded to the division presidents for formal review and concurrence and then forwarded by a Vice President to senior management.

When a corporate level program is not successful in percolating its goals down to the business units, the program is susceptible to abandonment, as evidenced by Armstrong's experience. The company's corporate Product Environmental Performance program was not effectively translating program goals into the activities of its business units, the level at which decisions are made about what a product contains and how it is manufactured. The program was discontinued, and its mission, along with general EH&S responsibilities, was placed squarely in the purview of the business units. One result of this realignment, however, was that the internal program champion was reassigned to other duties before program proponents were cultivated at the business units. Thus, the company currently faces the challenge of developing this ground-level support.

Streamlining. Complex, resource-intensive LCD systems may contain the seeds of their own undoing. They are tougher to market internally and more vulnerable to orphaning during business downturns and restructuring. Because LCA skepticism is abundant in the business community, organizational change can easily turn into a reason to slow or halt an LCD program which is viewed as too costly or lacking division or facility-level buy-in and concrete benefits.

Reducing the stages and impacts is one way of making LCD affordable and relevant to internal decision-making. All three companies practice such streamlining in some form, especially in the upstream extraction, transport, and intermediate manufacture stages of the product cycle. Armstrong is the only company that attempted to collect life-cycle inventory data for the complete life-cycle of its products. Doing so required an outreach effort with approximately twenty key suppliers to obtain process input and environmental release data. Armstrong had mixed success with these efforts -- the level of detail and data quality provided by suppliers was highly variable. Obstacles to collecting these data included confidentiality concerns and a lack of resources for collecting data that were not considered a priority by the supplier.

Using LCD as a tool in its ECP program, IBM has focused on upstream production stages to assess how the tool can be used in selecting materials and processes with minimum environmental burdens at the part and subassembly level. Eighty percent of a computer's weight is comprised of structural parts. Thus, by examining the materials comprising those parts, e.g., metals and plastics, IBM focuses on the greatest opportunities for reducing the environmental burdens of its products.

While streamlining always runs the risk of missing a major indirect or upstream/downstream environmental impact of a product or process, it does reflect the boundaries of corporate stewardship commonly defined by most U.S. firms today. However, at least on the downstream-side of the product cycle, customer demands for higher levels of product service are likely to drive firms to steadily expand their LCD programs to include downstream use and post-use impacts. This trend is part of the larger and emerging concept of extended product responsibility that is emerging in both Europe and the U.S.

Suppliers. Supplier relations as a component of LCD programs are uneven and slow to evolve. Our collaborating firms generally show an arms-length, non-coercive relationship with suppliers when it comes to implementing LCD programs. Liability and proprietary concerns, and a reluctance to impose costly data development requests, are some of the impediments to more aggressively bringing suppliers into the LCD fold. IBM uses a unique approach to overcome these hurdles, hiring consultants to work with their principal suppliers. These consultants sign confidentiality agreements with the suppliers in order to obtain necessary data. These data may then be supplemented with secondary data from the literature. This arrangement enables the company to distance itself from potentially proprietary information.

Nonetheless, without supplier involvement -- including information exchange between customer and supplier essential to support final design decisions -- the absence of upstream inventory data will continue to impair a comprehensive life-cycle perspective on product design and redesign.

Teamwork. The most effective LCD programs are those that recognize the cross-functional nature of LCD, and integrate multiple business functions into the LCD process. Product designers, materials engineering, process engineers, operations, marketing, and accounting/finance are all party to making LCD work. The reason for this straightforward: LCD cannot, and should not, be defined as a purely or even predominantly "environmental" initiative. Instead, the language that sells internally is process improvement and optimization, customer service, product differentiation, and market competitiveness. LCD programs which speak only to environmental benefits are bound to flounder, or peak early at a low-level of buy-in. But to communicate the multiple benefits of LCD requires an audience drawn from multiple business functions, each of which sees its value to running its segment of the business.

These themes point to a future in which LCD gradually continues to make inroads into corporate product development, but in diverse and often diffuse ways throughout the product life cycle. In the mid-term, realizing the benefits of LCD will require its integration in standard business functions such that each such function sees its benefits. This kind of seamless integration will help LCD avoid the risk of being another "environmental" program which costs, rather than saves, and constrains, rather than strengthens, the market position of the firm and its products.

Paradoxically, the future may see a reversal in this kind of environmental handicap. In the longer term, LCD may enable a firm to achieve its voluntary, or mandatory, sustainability objectives. This may occur by uncovering opportunities for reducing life-cycle impacts, dematerializing production systems and, more generally, helping firms achieve eco-efficient operations -- higher value products and services with less material input per unit output. Government initiatives such as this study which help shape LCD as a working, flexible decision-support tool will contribute to achieving this long-term objective.