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The Lean and Green Supply Chain:

A Practical Guide for Materials Managers and Supply Chain Managers to Reduce Costs and Improve Environmental Performance

Environmental
Accounting
Project
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DISCLAIMER

OVERVIEW

Companies are changing how they manage their *supply chains.*[a] Rigid, arms-length, customer-supplier relationships are giving way to alliances with upstream and downstream trading partners. For example, many companies have suppliers automatically replenish their inventory. Other companies outsource product design and development to key suppliers. **Direct interaction with supply chain partners can enable a company to reduce total inventory levels, decrease product obsolescence, lower transaction costs, react more quickly to changes in the market, and respond more promptly to customer requests.**

Essential to supply chain performance is improving the effectiveness of *materials management*—the set of *business processes* that support the complete cycle of material flows from *purchasing* and internal control of production materials, through planning and controlling work in process, to warehousing, shipping, and distributing finished products.[1] Managers can improve their materials management performance by first understanding how their decisions affect the purchasing, storage, *handling*, and asset *recovery* activities throughout their organization. Another key component of supply chain management is *logistics*—the activities to obtain incoming materials and distribute finished products to the proper place, at the desired time, and in the optimal quantities. Companies can greatly improve business performance by working with suppliers, shippers, distributors, and customers to better coordinate logistics activities.

Companies of all sizes are further enhancing these fundamental supply chain changes by considering the environmental impact — and related bottom-line effects — of their decisions and actions. They have increased their competitiveness by engaging in such environmental performance-enhancing activities as

- Reducing the obsolescence and waste of maintenance, repair and operating (MRO) materials through enhanced *sourcing* and inventory management practices
- Substantially decreasing the costs associated with scrap and material losses
- Lowering the training, material handling, and other extra expenses associated with hazardous materials
- Increasing revenues by converting wastes to by-products
- Reducing the use of hazardous materials through more timely and accurate *materials tracking* and reporting systems

[a]Several key terms are defined in the Glossary. The first usage of each term is *italicized*.

- Decreasing the use and waste of solvents, paints, and other chemicals through chemical service partnerships
- Recovering valuable materials and assets through efficient *product take back* programs.

Yet, despite the potential for significant financial gains, most supply chain managers currently do not focus on environmental concerns. One reason for this is that cost accounting systems typically hide the frequency and magnitude of the "environmental costs" that companies incur. While raw material and labor costs are directly allocated to the appropriate product or process, other costs are accumulated into overhead accounts, which are allocated proportionally (e.g., based on the number of units manufactured) to all products, processes, or facilities. This allocation method might be appropriate for many overhead costs, such as rent and upper management salaries. However, this approach can lead to inaccurate costing and ineffective decisions when significant costs—waste disposal, training expenses, environmental permitting fees, and other environmental costs—are not allocated to the responsible products and processes. For these reasons, supply chain managers often cannot achieve their overall objectives unless they tackle important environmental concerns.

Many companies have tackled this issue by using *environmental accounting* techniques to substantially reduce supply chain costs. With these costing methods, companies can systematically identify environmental costs throughout the supply chain, e.g., costs associated with management of hazardous materials, which typically are not captured through conventional accounting methods. Once the costs (or potential benefits) have been identified, companies can analyze the cost drivers and evaluate alternative cost reduction opportunities.

A number of companies have successfully applied environmental accounting methods to supply chain management decisions. Some examples from well-known companies include:

- GM **reduced its disposal costs by $12 million** by establishing a reusable container program with its suppliers.
- Commonwealth Edison, a major electric utility company, **realized $25 million in financial benefits** through more effective resource utilization.
- Andersen Corporation implemented several programs that reduced waste at its source and **had internal rates of return (IRR) exceeding 50%.**

- Public Service Electric and Gas Company **saved more than $2 million in 1997** by streamlining its inventory process to avoid product obsolescence and disposal.

On a similar note, many companies are also benefitting from chemical service programs through which they outsource such responsibilities as chemical inventory management, distribution, training, and waste management. Companies in industries as varied as the semiconductor, automotive, and aerospace industries have achieved enormous materials management cost reductions, reduced production downtime, and significantly decreased solid waste and air emissions.[2] Significant savings are possible because the costs to manage chemicals often range from 100% to 1000% (and sometimes up to 1500%!) of the costs to buy these materials.[3] With the help of the chemical service provider's expertise, environmental gains are coupled with substantial operating cost savings to achieve win-win improvements.

This guidebook synthesizes the best practices of leading U.S. companies who have saved millions of dollars while reducing or eliminating significant environmental impacts.

The key to achieving these improvements is changing the company decision-making processes to incorporate environmental information. **This guidebook provides a four-step framework for identifying and using environmental information to improve financial performance.** Supply chain efficiency and cost reduction programs will not fully succeed unless managers consider critical environmental, health, and safety activities. These steps include leveraging existing processes and systems, such as materials resource planning (MRP II) systems.

Some helpful models and checklist questions are also provided. For example, to improve inventory management, supply chain managers can apply an improved inventory management model, the Revised Economic Order Quantity (pages 26-27). By applying the four-step framework and supporting tools, managers can enhance efforts to improve operational efficiency and increase stakeholder satisfaction.

The purpose of this guidebook is to demonstrate the opportunities for improving both financial and environmental performance and to briefly review specific tools and methods. To achieve this goal, the guidebook is organized into eight sections:

- The **Introduction** presents some of the most significant opportunities for simultaneously improving environmental and financial performance.
- In **Environmental Costs & Benefits**, problems of traditional accounting systems are described and environmental costs and benefits are delineated.
- The **Decision-Making Framework** defines the four-step process to improve environmental accounting efforts.
- The **Materials Management Success Story** illustrates some of the benefits achieved and specific actions taken by one leading company.
- The **Conclusion** summarizes the four-step approach to improving financial and environmental performance.
- The **Glossary, Bibliography, and References** explain important terms and provide additional sources of information.

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INTRODUCTION

The materials management activities within most companies are undergoing fundamental changes. Companies are, among other things, reducing their supplier base, forming partnerships with key suppliers, and implementing lean manufacturing methods.

Within most companies, significant opportunities exist to improve the overall use and flows of materials.

The purpose of these supply chain initiatives is to reduce both costs and wastes. Conventional decision-making approaches commonly overlook or inadequately represent the costs and benefits that may occur in departments outside the decision-maker's area. For example, a purchasing agent can often reduce material procurement costs by switching to a new, lower-price supplier. In some cases, this change increases overall production costs, even though the engineering group may approve the switch. For example, if the new supplier uses excess packaging, the increased disposal costs could exceed the procurement savings. **In contrast, proactive purchasing managers are reducing costs by conducting *value analyses* of materials to minimize the firm's *overall* costs, forming cost-reducing supplier partnerships, demanding less or reusable packaging and influencing the material specification processes.**

These expenses are critical, because the costs to purchase, handle, store, and dispose of materials represent some of the largest operating expenses for most manufacturing companies. **Companies can increase their competitiveness by developing more efficient, responsive supply chain processes.** This is evident from the massive efforts that automotive, chemical, and other companies are expending to implement enterprise resource planning (ERP) systems and to change their relationships with both suppliers and customers.

Many companies are striving to improve their logistics and materials management processes, but important *environmental burdens* usually are not addressed. While these considerations may seem to be a more appropriate focus for the Environmental, Health, and Safety (EH&S) group than for materials managers, a number of companies have saved millions of dollars by addressing difficult-to-spot materials management expenses such as inefficient material handling steps that unnecessarily lose excessive materials to air and water. In fact, the bulk of the activities that are considered the responsibility of EH&S are actually due to the operational activities under the purview of supply chain managers. **Those managers who overlook the EH&S elements of their activities are probably overlooking opportunities to increase the responsiveness and efficiency of the supply chain.** As highlighted in Table 1 (page 4), Intel, Andersen Corporation, 3M, Commonwealth Edison (ComEd), and other leading companies have improved their purchasing, material handling, storage, *material recovery*, *disposition*, and product take back processes through environmental accounting initiatives.

While these success stories are drawn from several industries, **the common thread is a proactive, rigorous effort to incorporate environmental considerations into decision-making processes**. Substantial improvements are feasible because environmental management problems are, to a large degree, material-driven. For example, the types and costs of wastes, the significance of regulatory constraints, and the risks of improper handling are all dependent upon which materials are purchased and used within a facility.

Andersen Corporation, Intel, Commonwealth Edison, GM, and 3M have improved their operating efficiency by integrating environmental considerations into key materials management decisions.

This guidebook is intended to help companies adopt these emerging practices in order to improve both economic and environmental performance. **A four-step decision-making framework is presented that can guide a company's effort to address the costs and benefits occurring not only in a specific facility or functional area, but also throughout the supply chain.**

These practices can be integrated with other high-priority initiatives, including programs to form supplier partnerships, improve overall quality levels, and reduce inventory carrying costs. For example, a number of companies have worked with suppliers to eliminate unnecessary packaging and reduce hazardous materials quantities. In fact, some companies are significantly improving both their environmental profile and profit margins by taking a strategic approach to purchasing. They are asking suppliers (and their suppliers' suppliers) to evaluate and lower environmental costs. These approaches show that environmental insights can improve core business processes. Table 1 illustrates how strategic innovations in several core business practices have improved both the financial and environmental performance of their supply chain.

In each of the Table 1 illustrations, the roles of purchasing, inventory, or other supply chain managers were pivotal. For example, at Public Service Electric and Gas (PSE&G), the Materials Management Team led the effort to reduce disposal and other costs.[4] The team determined that the utility company was overpurchasing numerous products and inefficiently storing them in several locations within each facility. The net result was unused, excess materials that wasted storage space and eventually required disposal.

The PSE&G Materials Management Team first analyzed its inventory supply chain, particularly for its chemical commodities and paints. The inventory analysis revealed that each facility purchased materials separately from many suppliers. Since most suppliers encouraged purchasing in bulk, the facilities often had excess product. Leftover inventory was eventually sent to PSE&G's central resource recovery facility where materials were sorted, sent to disposal facilities, or, if possible, sold. The company realized that it could avoid the costs of sorting, disposing, and finding buyers for excess inventory by simply improving its purchasing practices.

The Materials Management Team narrowed PSE&G's list of suppliers from over 270 to only nine. As part of the long-term agreements that the company established with these select suppliers, the suppliers agreed to track the inventory that each PSE&G facility purchased. Thus, whenever purchasing agents from one plant called to order products, the vendor would check to see if another PSE&G facility already had the material in stock. The suppliers also committed to take back any extra, obsolete, or discontinued products. (Usually they are able to sell these materials to other customers.) By placing the responsibility on its suppliers, PSE&G eliminated the disposal of unused, excess products and, in doing so, reduced operating costs and environmental burdens.

Table 1: Supply Chain Improvements[b]

INNOVATION	RESULTS
Purchasing Several electronics companies, including Nortel and Intel, have moved away from purchasing *materials* toward receiving chemical *services* via chemical management programs. These services can include procurement, inventory management, data tracking, and waste management.	By providing incentives for suppliers to reduce material quantities and by leveraging the suppliers' expertise, these companies have achieved substantial savings and reduced wastes. Chemical management providers are no longer compensated based on the volume of chemicals they sell to their customers, but on value-added services instead. With appropriate incentives, providers are rewarded for reducing chemical usage (and costs), increasing productivity, or decreasing waste.
Materials Handling A number of companies are switching to reusable packaging systems. 3M recently launched an Eco-Efficient packaging business, and GM has a well-established reusable pallets and containers program.	By working closely with suppliers, GM successfully switched to reusable packaging systems and reduced its disposal costs by $12 million between 1987 and 1992. Additionally, reusable containers can reduce solid waste, decrease product damage during shipping, and eliminate ergonomic and safety problems (e.g., cuts while slicing open boxes).
Storage Several companies have changed their inventory storage procedures for maintenance, repair, and operating (MRO) materials by consolidating storage areas and requiring suppliers to adhere to stringent material return policies.	Public Service Electric and Gas Company streamlined its purchasing and storage processes and saved more than $2 million in 1997. The changes significantly decreased the disposal of obsolete paint and other materials, reduced storage space requirements, and lowered carrying costs. Previously, these costs had been hidden in overhead accounts.

[b]While this guidebook focuses on environmental improvements, the framework and tools are equally applicable to health and safety issues, e.g., injuries and subsequent workers' compensation claims that result from materials handling.

INNOVATION	RESULTS
Materials Recovery By focusing on their high volume material flows and striving to eliminate wastes, several companies have justified material recovery projects by applying environmental accounting methods.	Andersen Corporation (manufacturer of Andersen Windows and Patio Doors) developed a composite material from wood wastes generated during its manufacturing processes. This innovation is expected to yield a 50% return on investment and has already enabled Andersen to decrease solid lumber purchases by 750,000 board-feet.
Disposition Many companies are saving money by ensuring that major waste disposal costs are made explicit and attributed directly to the responsible product or business unit. Companies use this cost information to identify more financially attractive alternatives to disposal.	Environmental accounting techniques enabled Commonwealth Edison, a Midwestern electric utility company, to greatly reduce its landfill disposal volume. A *life cycle* accounting approach highlighted the indirect costs created by a variety of activities, including disposal. Once these costs were made explicit, the company began developing a cost-effective method for grinding tree limbs. ComEd netted $2 million annually by making and selling tree mulch instead of sending the tree limbs to landfills.
Product Take Back A variety of companies have developed cost-effective ways to recover products from their distributors and customers. By working with product designers and other functions, supply chain managers can establish systems that enable them to recover these assets and reduce manufacturing costs.	Kodak's logistics system currently recovers 70% of the cameras sold to consumers. Since its inception, over 200 million FunSaver cameras have been returned to Kodak facilities. Kodak reduces operating costs by recycling or reusing 77 to 86% of each camera's materials. One of its significant accomplishments has been developing a system that overcomes the financial and nonfinancial barriers that initially limited product returns from photo processors.

COSTS & BENEFITS

ENVIRONMENTAL COSTS & BENEFITS

Materials management decisions affect many dimensions of company performance, including operating costs, investment requirements, product quality, and meeting delivery schedules. While materials managers typically address these business objectives during the decision-making process, environmental concerns are commonly overlooked. Unfortunately, failure to incorporate these "hidden costs" not only hinders a company's efforts to reduce a variety of environmental burdens, but also hinders efforts to improve financial performance.

Materials managers typically do not address environmental concerns due to the structure of traditional cost accounting systems. While raw material and labor costs are directly allocated to the appropriate product or process, other costs are accumulated into overhead accounts. These overhead costs are in turn allocated proportionally to all business units, product lines, or facilities, typically based on gross sales or output. When significant costs are not allocated to the responsible products and processes, this approach may lead to inaccurate costing data and ineffective decision making.

Environmental costs often are misallocated in this manner. For example, take the case of a company's wastewater treatment facility. The costs of operating the facility are predominately caused by a few of the company's products whose production generates significant quantities of wastewater. If, as shown in Figure 1, the costs of operating the treatment facility are accumulated into an overhead account and allocated equally to all of the company's products, **the wastewater costs are obscured and product cost information is misleading.** In this case, product B appears to be less expensive to produce than it actually is. Figure 2 demonstrates a correction to the allocation problem and depicts the primary goal of many environmental accounting efforts: to track environmental costs directly to the responsible product, process, or facility.

When environmental costs are hidden in overhead accounts, business decisions are made without sufficient consideration of the potentially costly environmental impacts downstream of the decision. For example, product design decisions that specify the use of hazardous materials inherently increase the risk of employee exposure or other incident. Lack of awareness can be financially detrimental to a company.

Figure 1: Misallocation of Environmental Costs[4]

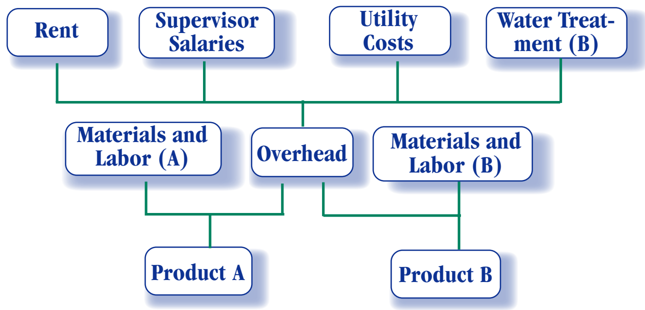

Figure 2: Improved Allocation

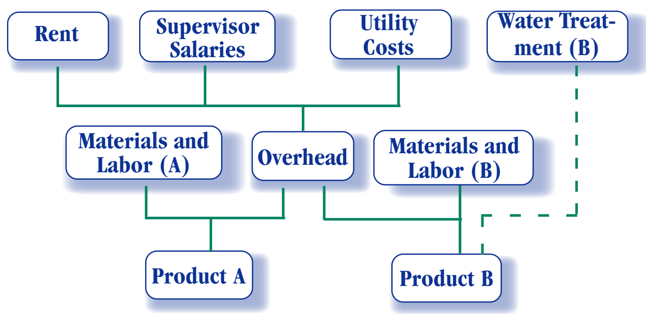

Table 2 presents a hierarchy that classifies costs based on how easy they are to measure in financial terms. This hierarchy is a useful framework for ensuring that a complete range of costs (including environmental costs) is considered.

While Table 2 shows clear delineations among the categories, considerable overlap exists, especially between the first two categories. Whether or not a cost is "conventional" or "hidden" depends upon the facility's accounting practices. For example, the costs to landfill waste materials are generally accumulated into an overhead account and would therefore be "hidden" and not incorporated into product pricing or other decisions. However, several firms have applied activity-based costing methods to make these costs "conventional" and are allocating the landfill fees directly to the products or processes that generate them.

In addition, interrelationships exist between the cost categories. For example, if a new production process

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Table 2: Cost Hierarchy [5]

COST CATEGORY	DEFINITION
Conventional (least difficult to quantify)	Material, labor, other expenses, and revenues that are commonly allocated to a product or process.
Potentially Hidden	Expenses incurred by and benefits to the firm that are not typically traced to the responsible products or processes, e.g., supervisor salaries and safety training courses.
Contingent	Potential liability or benefit that depends on the occurrence of a future event, e.g. potential occupational health and clean-up costs related to a spill of a hazardous substance.
Image/Relationship	Costs/benefits related to the subjective perceptions of a firm's stakeholders, e.g., a community group's resistance to a plant expansion or an insurer's concern about the lack of a formal environmental management system.
External (most difficult to quantify)	Costs/benefits of a company's impacts upon the environment and society that do not directly accrue to the business, e.g., the benefits of reduced traffic congestion from a company's telecommuting program.

required the use of hazardous materials, the expenses that a company might incur to clean up hazardous material spills would be classified as "contingent' costs. However, any future spills might also trigger "image/relationship" costs, such as concern among the company's employees or neighbors, and "external" costs, such as damage to a nearby aquatic ecosystem. The purpose of the cost framework is to help to identify and address the full set of consequences that might result from materials management decisions.

This cost framework is not limited to analyzing environmental costs and benefits but rather is univer-

sally applicable to any type of financial impact. For example, a purchasing agent might be able to lower the company's conventional costs by switching to another approved supplier that provides a lower-priced material. However, this switch could lead to increased waste disposal costs, a potentially hidden expense, if the new supplier shipped materials in containers with excess packaging. Similarly, delivery missteps by the new supplier could inadvertently cause a variety of contingent costs if these breakdowns resulted in significant production delays.

Decision makers are at least intuitively aware of the different cost and benefit categories, but a formal structure helps ensure that the full range of financial considerations is addressed.

It is easy for materials managers to overlook environmental costs and benefits during decision making because they tend to occur upstream or downstream of the immediate decision, e.g., a purchasing action can have materials handling, storage, and disposition repercussions. This focus on a single functional area is not limited to environmental considerations, and the resulting problems are a primary motivation for supply chain integration efforts. However, an increasing number of companies have discovered ways to reduce operating costs or otherwise improve performance by implementing practices that optimize supply chain, rather than functional area, performance.[6]

While this guidebook highlights financial benefits, improved materials management practices can also improve environmental, health, and safety performance. For example, converting to reusable containers can reduce the solid waste burdens associated with primary and secondary packaging materials, and can minimize the number of injuries caused by using razor knives to open packages. Similarly, chemical management service providers closely track material consumption and can quickly spot production floor inefficiencies that lead to material losses and resulting waste disposal.

Table 3 lists a number of financial and nonfinancial environmental considerations associated with supply chain activities. As shown, purchasing, material handling, and several other core materials management functions can substantially affect environmental performance. The table demonstrates how better materials management decisions can result from a more complete understanding of the costs that a company incurs throughout the life cycle of its products, processes, and facilities.

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Table 3: Examples of Environmental Costs and Benefits

	PURCHASING	MATERIAL HANDLING	STORAGE
Conventional	Volume of production materials purchased	Purchase price of packaging materials	Specialized storage space for hazardous materials
Potentially Hidden	Activities to certify suppliers	Efficiency gains from automated handling of reusable containers	Costs of cleaning up spills
Contingent	Reduced risk of environmental incidents by working with suppliers that have product stewardship programs	Ergonomic and safety issues, including cuts from razor knives	Employee exposure to hazardous materials and subsequent workers' compensation claims
Image/Relationship	Positive media coverage because of partnerships with "green" suppliers	Positive public image from using reusable containers	Improved employee satisfaction from reduced exposure to hazardous materials
External	Improved ecosystems through eliminating the use of hazardous materials	Accidental emissions to air and water due to spills	Decreased releases to ecosystems because of fewer and less severe spills

MATERIAL RECOVERY	DISPOSITION	PRODUCT TAKE BACK
Revenues from recovered materials	Labor and fees associated with manifesting, hauling, and dumping solid waste	Reduced material costs because of components recovered from returned products
Eco-efficiency gains, e.g., reduction of materials "lost to scrap"	Decreased environmental insurance premiums by decreasing the quantity and hazard of disposed materials	Increased shipping costs due to product returns
Decreased remediation liability due to lower volume of waste sent to landfills	Potential liabilities for cleaning up hazardous wastes that leak out of landfills	
Ability to attract investors and insurers because of savings from material efficiencies	Positive public image by avoiding the community backlash related to leaks from inadequate disposal sites	Increased customer concern about the quality of products
Reduced exposure-related medical expenses for local residents	Decreased landfill burden	Decreased mining or harvesting of raw materials due to lowered overall material requirements

FRAMEWORK

DECISION-MAKING FRAMEWORK

While the potential benefits are significant, relatively few companies are pursuing the opportunity to improve their financial and environmental performance by explicitly addressing environmental costs. A clear, simple framework can help companies begin to explore this opportunity.

The following four-step framework allows companies to pinpoint and understand the costs and environmental impacts that result from materials management decisions. **This decision-making framework is based upon the best practices of several companies that have successfully initiated and implemented environmental accounting practices.** Ideally, companies will customize this approach to best suit their own organizational needs and culture.

Figure 3: Decision-Making Framework

The Four Steps: An Overview

The four steps of the framework are discussed in detail in the following pages. To give readers a general understanding of the process, the four steps are briefly described here.

In Step 1, **Identify Costs,** a systematic review of the facility or process is conducted to determine if and where significant environmental costs occur. **This analysis enables the team to later focus where the probability for significant improvement is greatest.**

During Step 2, **Determine Opportunities,** the identified functional areas and processes are evaluated to determine which changes will likely yield significant cost savings and reduce environmental impacts. Potential changes are evaluated with criteria that can include the magnitude of potential cost improvement, the types of environmental burdens, and the barriers to change. **Step 2 yields a set of possible alternatives with significant potential for improving costs savings and reducing environmental impacts.**

These initial screening steps lead to Step 3, **Calculate Benefits**, where quantitative, and sometimes qualitative, analyses of the costs and benefits of a selected group of projects are conducted. Some of the analytical tools and methods used during this step are activity-based costing approaches, *net present value* (NPV) calculations, and risk evaluations. **The result is a summary of the merits of the current process and any proposed alternatives.**

In Step 4, **Decide, Implement, and Monitor,** the team shifts from evaluation to implementation. First, a decision is made to continue with the status quo or to pursue a new approach. Financial benefits and/or environmental improvements then occur as changes are put into action. The new practices are institutionalized as information collection processes are integrated into the company's materials resource planning (MRP II), enterprise resource planning (ERP) systems, and other information systems. After implementation, a periodic review and continuous improvement effort allows decision makers to evaluate their progress and pursue additional opportunities. **The best practices and implementation guidelines of Step 4 can enable companies to integrate key concepts into their routine materials management practices.**

This simple four-step framework can be the foundation of a company's materials management improvement effort.

A Good Start

As a company begins to apply the decision-making framework, organizational challenges will often arise. Several business practices commonly used in change management can be helpful in addressing these challenges and assuring successful implementation. These practices are as follows:

- Use cross-functional teams that include members from different divisions such as operations, purchasing, EH&S, accounting, and engineering. Due to the broad scope of these projects, insights and support from all of the groups affected by the changes are necessary.
- Obtain management support to the extent possible. As with any change effort, there is likely to be passive resistance that senior management support can help overcome. A timely and enthusiastic response by those who are affected by the changes is necessary to the success of the effort.

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- Benchmark the best practices of other facilities in your own company and other companies to minimize the risk of failure and the cost of implementation.
- Employ total quality management (TQM) tools (e.g., Pareto analyses, cause and effect diagrams, etc.) to identify and evaluate improvement opportunities. Since the goals and principles behind environmental accounting dovetail with those of TQM, these efforts can be integrated into and increase the effectiveness of existing TQM initiatives.

These TQM and related business practices will position the company for initial and sustainable success as it pursues changes to reduce resource use, lower other costs, and improve environmental performance.

Step 1: Identify Costs

Regardless of the industry, companies are being pressured by competitors, customers, and financial stakeholders to become more efficient. The first step in achieving efficiency improvements is to review materials management practices to identify areas and activities that incur significant environmental costs. These initial evaluations will shape the course of future steps and help ensure that company resources are invested wisely.

Step 1 can range from the evaluation of a specific product or process to an entire corporation. A common application is at an individual production facility. Key questions include

- Are significant material losses caused by spills or other material handling problems?
- Do ergonomic or other EH&S impacts result from poor or nonreusable packaging designs?
- Are substantial quantities of materials discarded because of quality, obsolescence, or inventory problems?
- Can material specification or other easy-to-implement changes reduce suppliers' costs (and subsequently our costs)?
- Are there valuable materials in waste streams that could be salvaged through internal recycling or sold as by-products?

There are two stages to this step: First, the organization studies its waste streams and identifies the activities that lead to environmental costs. Second, the organization attaches costs to those wastes and activities. **Two common approaches to identifying sources of environmental costs are materials tracking and EH&S performance reviews.**

Materials tracking is an assessment of what, where, why, and how much material is used, incorporated into products and coproducts, and channeled into waste streams.

The initial analyses are often limited to the largest or most regulated material streams because these are most likely to generate the highest costs. Regardless of the scale of analysis, the result is a better understanding of material flows through the facility.

Materials tracking depends on the preparation of process maps. Process mapping is typically a team exercise where all of the production steps associated with or required by a specific materials management process are visually diagramed. As an example, a team might analyze the steps necessary to receive, store, handle, and dispose a high-volume, regulated material.

Material losses incurred during each step should be depicted on process maps.[7,8] *Mass balances*, MRPs, dispensing records, and other sources can provide information on materials usage and point to the activities that generate waste.

Materials tracking activities commonly highlight larger than anticipated material losses and uncover unexpected waste streams. For example, a recent study at a semiconductor manufacturing facility revealed that roughly 12% of chemical inputs were wasted during machine setups and other nonproduction uses.[9]

Another approach to uncovering sources of environmental costs is to routinely conduct **EH&S performance reviews** of facilities' processes to determine levels of waste and pollution, health and safety risks, and effectiveness

PSE&G observed that the cost to dispose of obsolete paint and other waste MRO materials was substantial. To address this problem, PSE&G

- ***Consolidated its purchasing process for MRO materials,***
- ***Decreased the number of suppliers, and***
- ***Implemented a material return policy.***

These process changes yielded a $2 million costs savings in 1997. Additionally, the company greatly reduced its hazardous waste disposal volumes.

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of EH&S management systems. **These reviews consist of interviews with appropriate personnel, observations of day-to-day operational practices, and reviews of accounting and manufacturing records.** The abbreviated questionnaire on the pages 18 and 19 contains some key questions drawn from existing review checklists.

In comparison to materials tracking, the drawback of performance reviews is that they usually evaluate the extent to which the facility is in conformance with *pre-established criteria*. If the criteria are developed prior to a thorough study of the facility, it is possible that some problems may be overlooked because not all of the necessary or revealing questions are asked. Consequently, reviews may be less thorough and informative than materials tracking efforts. Nevertheless, if review checklists are designed well, they can be very useful in determining opportunities for improving materials management and environmental performance.

An extensive study of the electroplating industry focuses attention on storage costs. Because electroplating companies' waste treatment areas typically are large (25% of the size of production areas) and contain numerous storage facilities, storage costs present a significant opportunity for improvement.[10]

Whether materials tracking, EH&S performance reviews, or other proven methods are used to identify the sources of costs, the next stage is to conduct an activity-based costing analysis to attribute costs to the appropriate activities or problems.

For each of the activities or wastes identified in the first step , create a list of the associated environmental costs. Refer to Table 3 (page 10) for examples of the types of costs to consider. Consider also the variety of environmental requirements that follow from the identified activities. Then estimate the dollar value of wastes and related activities. This effort often reveals a variety of expensive (non-value-added) overhead costs, ranging from training and paperwork activities to hazardous waste treatment and disposal, that have not been attributed to the responsible products or processes.

Information Gathering

It will probably be necessary to consult a wide variety of information sources to collect the necessary cost and operational data. Commonly used sources include[11]

- Production records for material usage rates
- Invoice records for disposal rates and quantities
- Observations of activities and discussions with operators
- Training records for personnel training hours
- Maintenance logs for both labor costs and the frequency and length of production shutdowns
- Utility bills for the costs and usage of water and energy
- Facility blueprints for warehouse space requirements
- Procurement records for the costs of specialized handling equipment.

Step 2: Determine Opportunities

Once a company has completed the initial identification step, the next step is to determine which areas offer the greatest opportunities for improvement and then develop specific solutions that reduce costs and negative impacts. **Many companies have found that the Pareto, or 80/20, principle applies, i.e., that a few supply chain improvements provide most of the achievable gains.** At this point only preliminary evaluations have been completed, so the challenge is discerning the high-value opportunities with the limited information that has been collected. Two procedures that can be used to sort and analyze the activity and cost information obtained in Step 1 are to

- Use Pareto diagrams and other bar charts to display environmental costs by supply chain activity and to rank opportunity areas by value. (See Figure 4).[12]
- Identify root causes of wastes by constructing cause-and-effect diagrams or by continually asking *why* certain problems or procedures exist.

Once these procedures are followed, the solutions to the problems may become obvious. Other methods for identifying specific solutions are to

- Interview production personnel to understand potential opportunities for (and barriers to) change.
- Approach suppliers of the key materials and request their support to lower costs and reduce impacts. Some suppliers have developed this expertise internally and can provide this service.

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EHS Performance Review—Sample Questions[c]

Purchasing

Have suppliers supported the company's efforts to reduce the facility's quantities and costs of waste?

Are environmental, health, and safety performance criteria (e.g., flammability, biodegradability, toxicity, recyclability, and other environmental or regulatory requirements) clearly articulated in new product specifications to suppliers?[13]

Does the plant accept samples from chemical suppliers?

Are suppliers required to take back unused samples they provide?

Input Materials Summary

Attribute	Description Stream # __	Stream # __	Stream #__
Material Name/ID			
Source/Supplier			
Hazardous Component			
Annual Consumption Rate			
Purchase Price, $ per ____			
Overall Annual Cost			
Material Flow Diagram available (Y/N)			
Delivery mode			
Shipping Container Size & Type			
Storage Mode			
Transfer Mode			
Control Mode			
Empty Container Disposal/Management			
Shelf Life			
Supplier would			
accept expired material (Y/N)			
accept shipping containers (Y/N)			
Acceptable Substitute(s), if any			
Alternate Supplier(s)			

Handling

Are all raw materials tested for quality before being accepted from suppliers?

Are plant material balances routinely performed?

Does the company's personnel training program include information on the safe handling of raw materials, spill prevention, proper storage techniques, and waste handling procedures?

[c]The questions and tables in this list are taken largely from a series of Guides to Pollution Prevention published by the U.S. Environmental Protection Agency. The Guides span a wide array of industrial sectors and each includes waste minimization assessment worksheets. (Various publication numbers, all with the format EPA 625/7-9X/0XX). See www.epa.gov/ttbnrmrl/Guides.htm.

What is the injury frequency and severity rate among material handlers?____

Storage

Are specialized containers or storage facilities required to prevent environmental damage?
Is inventory used in first-in first-out order?
Is there a computerized inventory system to track inventory and material waste (e.g., barcoding, MRPII, etc.)?
What information do(es) the system(s) track? ____________________
____
Are all storage tanks routinely monitored for leaks?
If yes, describe the procedure and monitoring frequency for above-ground/vaulted and underground tanks:
____
____

Disposition and Material Recovery

Is your solvent waste segregated from rinse-water streams and other wastes?
Does the plant generate waste streams that contain valuable process chemicals or metals?
Are all empty bags, packages, and containers that contained hazardous materials segregated from those that contained nonhazardous wastes? Are containers properly cleaned prior to disposal?

Waste Sources

	Significance at Plant		
	High	Medium	Low
Hazardous obsolete raw materials			
Nonhazardous obsolete raw materials			
Spills & leaks (liquids)			
Empty container cleaning			
Container disposal			
Evaporative losses			
Off-spec materials			
Pipeline/tank drainage			
Laboratory wastes			
Contaminated wipes and gloves			
Other			

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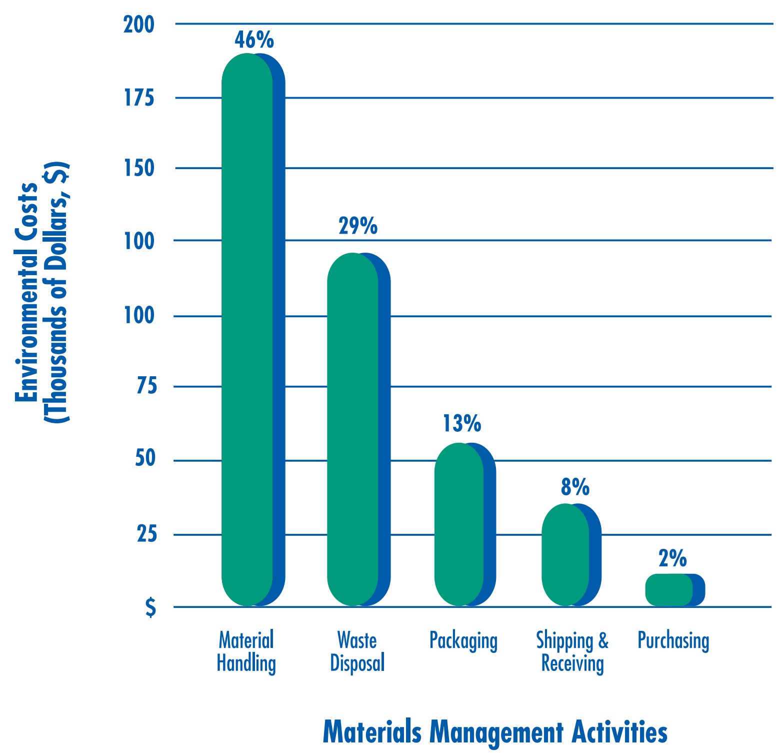
- Review the successes of other companies in the same industry.
- Apply the best practices available from trade associations and public institutions.

Since the next step, Calculate Benefits, can be time-consuming, selecting the most viable options for improvement is important. By using proven, simple ranking methods, a company can quickly focuses on its most significant opportunities.

Step 3: Calculate Benefits

Once a set of high-priority alternatives has been developed, the analytical exercise of calculating the costs and benefits of the various options begins. **One approach to the calculation process is to conduct *quantitative* evaluations, which rely on empirical data.** Two specific quantitative approaches are Internal Rate of Return (IRR) (Table 4 on page 25) and Economic Order Quantity calculations (pages 26-27).

Figure 4: Pareto Diagram



A second approach is to conduct *qualitative* evaluations, which are based on observation and judgment. These evaluations provide valuable insights when credible data are not available or quantification would be too resource-intensive.

Often, both approaches are taken. Environmental costs and impacts are quantified when possible within the project budget and schedule and qualitatively evaluated otherwise. For example, a project team could probably find the data to answer the following questions:

- How much of a particular material was landfilled last year and what were the disposal costs?
- How many pounds of hazardous materials are purchased for a specific process, e.g., painting? What portion of the company's cleaning and other MRO materials must be treated as hazardous waste? What were the medical expenses attributable to injuries caused by poor ergonomic design?
- How many times will a reusable container be used?

In addition to these environmental costs, a team will also determine the operational benefits. Increased production line efficiency and other performance improvements can greatly increase the total cost savings.

In contrast, precise quantification of the following costs and benefits may be less straightforward:

- What were the total costs due to overtime, lowered efficiency, quality defects, and other issues related to ergonomics?
- How much labor is necessary to meet tracking, record keeping, and other regulatory mandated requirements?
- How much will employee satisfaction be improved by switching from a hazardous material to non-regulated compound?
- How does the use of specialized containers and other EH&S-driven activities affect the overall productivity of manufacturing operations?

Many times, the activity-based analysis methods suggested in Step 1 answer the above questions. However, producing definitive answers is sometimes not achievable within time and resource constraints. Simply estimating a range of costs and benefits, or qualitatively describing them, often is sufficient to justify an eco-efficiency improvement investment.

Example Analyses from Andersen Corporation[14]

Andersen Corporation, the manufacturer of Andersen Windows and Patio Doors, applied several quantitative methods when evaluating an automated paint blending system. As the regulatory

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pressures and costs associated with its painting lines became more significant, Andersen began searching for ways to reduce emissions and material costs. After reviewing several alternatives, managers conducted an in-depth analysis of the most promising approach: a point-of-use paint mixing system. This "meter mix" system replaced the existing batch system. They evaluated several cost and material usage areas, including:

- Paint materials: purchasing and shipping costs
- Waste: treatment, transport, and disposal costs
- VOC emissions: associated fees
- Solvent materials: purchasing and shipping costs
- Solvent emissions: material losses and associated fees.

In addition, the managers factored in the labor and expenses associated with the following:

- Raw material handling and storage
- Waste handling, storage, and disposal, as well as related training activities to ensure that waste materials were properly handled and disposed
- Analysis, reporting, and record keeping associated with the paint line
- Material obsolescence.

Andersen Corporation is one company that has saved several hundred thousand dollars by incorporating environmental considerations, qualitatively as well as quantitatively, into its materials management decision-making.

In each of the above four cases, the team determined material usage rates or described the financial impacts. However, the team did not calculate actual dollar figures for these costs, but rather simply recognized that the total financial impacts were significant. This qualitative information provided important insights that supplemented the more precise calculations.

As shown below, installation of the meter mix system was attractive because the **quantified costs yielded an 18-month payback and 58% internal rate of return. The qualitatively evaluated activities further strengthened this decision to proceed.**

The payback calculations are relatively straightforward, as shown below.

$$P=I/M$$

Where
P = Payback period (months)
I = Investment (\$)
M = Monthly savings (\$/month)

Based on the forecasts in Table 4, the initial investment (I) was $130,100 and the monthly savings (M) during the first two years averaged $7,146. With these values, the payback period was 18 months.

The IRR calculations are more complex, but fortunately a variety of software packages, including standard spreadsheet packages can compute these values. The internal rate of return is the interest rate at which the net present value (NPV) of the investment is zero. It takes into consideration the amount and timing of the costs, savings, and revenues of the investment.[d]

The higher the IRR, the better the project. A money-saving project will have a high IRR because it will have a positive value even if the future cost savings are discounted heavily. The IRR calculations are shown below.

$$NPV = 0 = C_0 \sum C_i / (1 + IRR)^i$$

For the meter mix system,

$$NPV = 0 = -\$130{,}100 + \$85{,}655/(1 + IRR) + \$85{,}863/(1 + IRR)^2 + \$82{,}579/(1 + IRR)^3 + \$80{,}921/(1 + IRR)^4 + \$80{,}419/(1 + IRR)^5$$

[d]Similarly, companies can directly calculate the investment's NPV. The NPV is based on the company's cost of capital and considers the amount and timing of the investment's capital outlays, savings, and revenues. An NPV greater than zero indicates a profitable investment, and, as with IRRs, the higher the NPV, the better.

Solving this equation by trial and error shows that the IRR is 58%. The trial and error approach is somewhat tedious, but again, many software packages can quickly compute IRR values.

These and other analyses demonstrated the operating and environmental benefits of making this investment. Andersen Corporation has since applied this approach to numerous decisions and thereby improved its operating efficiency and reduced environmental burdens. Environmental accounting approaches helped the company achieve its goal of reducing high-priority emissions by 90%.

Most cost-estimation efforts focus on conventional and potentially hidden costs, since quantifying contingent and image/relationship costs is considerably more challenging. For example, eliminating an ergonomic problem will probably improve employee satisfaction, but what is the economic value of that increased satisfaction? The recommended approach is to quantify costs when feasible, and then to identify and qualitatively value those other costs that will better inform the decision-making process.

As the Andersen case demonstrates, by gathering and evaluating production and cost data through the use of activity-based costing, internal rate of return, net present value, and other financial analysis techniques, companies can demonstrate the economic benefits of more eco-efficient practices.

The payback and IRR methods that Andersen applied are commonly used in industry. For their purposes, the company was able to use a well-established calculation method. In other cases, managers might need to slightly modify a method to address environmental costs. For example, as shown on pages 26-27, the standard inventory management model can be easily adapted to include the costs associated with material obsolescence and subsequent disposal costs.

Step 4: Decide, Implement, and Monitor

Once the financial and environmental improvements have been estimated, the fourth and final step is to make a decision, implement the changes, and monitor progress.

Decide

Approaches to decision-making vary significantly among companies. The objective is to select the option that improves both dimensions of performance. **Some companies have adopted team decision processes that involve individuals from several different functions. Other firms have more conventional, unilateral decision processes in which the responsible manager chooses the alternative that he or she believes will be most advantageous.** A formal weighting methodology can help decision makers trade off the strengths and weaknesses of one alternative against another.

Regardless of the methodology, the preceding steps provide the financial and nonfinancial information that improves the effectiveness of this effort. The environmental and financial information is considered with a variety of other strategic concerns to enable decision makers to select the best solution for their company.

Implement

Once a decision has been made, the final challenge is implementing the change. **Many good ideas are implemented poorly or not at all. In either case, the potential savings and environmental benefits are not realized.**

The beginning organizational steps (page 13), including use of a cross-functional team, also support the implementation effort. Some additional recommendations to ensure a successful implementation include:

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Table 4: Andersen's Financial Analysis

	Year 0 (Installation)	Year 1	Year 2	Total (Years 0-5)
Investment				
Equipment	($115,541)			($115,541)
Installation and other expenses	($14,559			($14,559)
Total Investment	($130,100)			($130,100)
Costs				
Operating costs		($109,355)	($115,302)	($623,197)
Total Costs		($109,355)	($115,302)	($623,197)
Savings				
Paint Use and Waste Reductions				
Paint purchase and shipping		$110,374	$113,685	$585,991
Waste treatment, transport, disposal		$14,387	$15,106	$79,497
VOC emissions and associated fees		$162	$170	$895
Dilute Solvent Use & Waste Reductions				
Solvent purchase and shipping		$58,710	$60,471	$311,699
Solvent emission losses and fees		$560	$588	$3,094
Flush Solvent Use & Waste Reductions				
Solvent purchase and shipping		$10,687	$11,008	$56,739
Solvent emission losses and fees		$130	$137	$718
Total Savings		$195,010	$201,165	$1,038,633
Net Benefit	($130,100)	$85,655	$85,863	$415,436

Notes and assumptions

- "Operating costs" are additional costs required to operate point-of-use system
- 3 % annual increase in material and labor costs
- 5 % annual increase in all other costs, e.g., waste management

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A Revised Economic Order Quantity: Improving the Inventory Management Model

As companies establish just-in-time and other lean inventory systems, they reevaluate the lot sizes of purchase orders and production runs. **This hypothetical example demonstrates how a company could increase its overall efficiency by changing a common inventory practice—determining the economic order quantity.**

Commonly hidden in inventory management decision making are the costs to dispose of obsolete, hazardous materials. Several factors, especially ordering costs and inventory carrying costs, are typically considered when companies determine what quantity of specific materials to order. In contrast, companies rarely incorporate the risk of obsolete materials.

This example illustrates how two environmental considerations, material losses and waste disposal, can be included in this common inventory management model. This example does not address other hidden and contingent costs, such as those related to spills and worker exposure. The basic equation for determining the order quantity that minimizes total costs is

$$Q = \sqrt{2DS / HC}$$

Where
Q = Optimal order quantity (units)
D = Annual demand for material (units)
S = Procurement and setup costs per order ($)
H = Inventory holding cost rate, often 10 - 35%
C = Cost of inventory item ($/unit)

Holding costs are the costs to maintain inventory and include cost of capital (that could be invested elsewhere), warehousing costs, insurance, and other expenses. For hazardous materials, the costs of disposing obsolete materials should be considered because disposal costs, on a per unit basis, can be comparable to the initial purchase costs.

For example, many industrial paints cost approximately $3/lb, while disposal costs for these materials can exceed $1/lb.[e] If a company analyzed its hazardous waste disposals and observed that ~5% of its paint was eventually disposed of instead of used, then the company should increase its holding costs considerably.[f,g]

	Conventional	***Revised***
Annual demand (D)	4,000 lb	4,000 lb
Setup costs (S)	$50	$50
Holding cost rates (H)[h,i]	10%	15% (+ 5% for disposal)
Item cost (C)	$3/lb	$3/lb (+ $1/lb for disposal)
Order quantity (Q)	1,155 lb	895 lb

For this hypothetical case, the economic order quantity decreases by 23% when material obsolescence and the accompanying costs of lost materials and waste disposal are considered. With this approach, a company could reduce the environmental burdens and decrease the overall costs associated with paint disposal.

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[e]Several options, including recycling and energy recovery, can reduce these costs. In this case, assume that disposal is required.
[f]Losses include the purchase cost of the lost material (5% x material price) and the disposal cost due to obsolescence (5% x disposal cost).
[g]The disposal ratio (5%) could be determined empirically and would depend upon the types of materials, purchase quantities, and consumption rates. Periodic reevaluation of this ratio would be warranted.
[h]For a conventional case, assume that material price = $3/lb and that holding costs = (10% x material price).
[i]For a revised case, assume that disposal cost =$1/lb and that revised holding costs =[(10% + 5%) x material cost] + [5% x disposal cost].

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- *Review previous organizational change efforts* within the company to gain valuable insights on the reasons behind those efforts' successes and failures.
- *Establish a group that is solely committed* to conducting the cost analyses, implementing the changes, and then ensuring and reporting the successes. This group may only be necessary for an interim period.
- *Conduct one or more pilot studies* to demonstrate the benefit of this initiative and gain support for broader implementation. Pilots also enable the team to adapt to unexpected problems.
- *Provide appropriate training* for employees so that they begin developing the necessary skills.

An aerospace electronics company saved $1.1 million by successfully implementing a chemical management program. Moreover, the company tracked its performance in a number of areas and realized other impressive results. For example,

- ***Procurement cycle time dropped from fifteen days to one***
- ***Hazardous waste costs fell 75%.***

These results demonstrate how monitoring can reveal environmental and operating gains.[15]

These implementation guidelines are particularly helpful and important during the initial changes. Since most companies concurrently pursue a variety of improvement initiatives, early, substantive results may be necessary to compete against the other initiatives and increase the probability of long-term acceptance and success.

Monitor

As these new materials management practices become established, they should be periodically monitored to ensure continued progress. The monitoring effort is often part of the company's broader quality program and ensures that any performance problems are promptly addressed. **Additionally, the rapid pace of technological and environmental change necessitates an effort to continuously identify opportunities to further reduce costs and lower potential impacts.**

The team should also periodically review overall progress toward reducing the wastes and costs identified in the first step. As part of this review, and to improve the accuracy of data, gaps in information and information systems should be analyzed and communicated to those responsible for the development and maintenance of the information systems. For example, because ERP and MRP II systems already closely track the flow of materials and other information throughout a company, they present opportunities for improving and institutionalizing the collection of material loss and environmental cost information.[16] **Material managers, through their understanding of and influence over materials information systems, have access to information on wastes and costs that others throughout the organization (e.g., engineers) may need for their own quality and efficiency-building efforts. ERPs, MRPs, and even traditional accounting systems can be designed or modified to pull material, handling, disposal, and other environmental costs out of overhead accounts and charge them directly back to the responsible departments.** This will facilitate reporting this information and will make the information quickly accessible to a wide variety of decision makers.

A rigorous review process supports another crucial activity—communicating results. Success begets more success. Demonstrating accomplishments to senior management will help secure continued resources for the supply chain effort and may help improve other core business decisions. Results should be shared with other colleagues, especially design and manufacturing engineers. The cost and material information collected in Steps 1 and 2 could be key to other efficiency-improving efforts. For example, product designers might specify less burdensome materials if they understood the full costs associated with handling and disposing harmful materials. By monitoring implementation of the cost-reduction efforts, sharing information, and communicating results, supply chain managers can support further gains and justify future improvements.

MATERIALS MANAGEMENT SUCCESS STORY

One company that has markedly improved its materials management processes by applying environmental accounting tools and techniques is Commonwealth Edison (ComEd), a major midwestern electric utility. The company's cost reduction activities yielded over $25 million in cumulative savings and afforded the company a number of important environmental benefits.[17] **This abridged case study reveals how these results were**

accomplished and demonstrates the step-by-step decision-making framework.

One of ComEd's materials management successes was its Inventory Minimization Program, which enabled the company to reduce the number of hazardous materials purchased, decrease the quantity of waste, and concurrently lower the costs of buying, storing, using, and disposing solvents at its facilities. The key steps are highlighted below.

ComEd saved over $25 million and achieved a number of important environmental benefits by improving its materials management processes.

Materials Tracking

In 1993, ComEd recognized that its total cost of managing materials was greater than its initial purchasing expenses. In particular, a significant portion of the company's waste disposal costs were caused by inefficient purchasing, storage, and other materials management practices. Based upon this realization, the company initiated a materials tracking effort to identify and characterize the waste and by-product streams from its generating facilities.

At several facilities, engineering teams used a waste accounting software package to evaluate five high-priority material categories: chemicals and oils, coal by-products, PCBs, recyclables, and solid waste. The teams did not conduct extensive mass balances, but rather addressed some key questions:

- Which types of wastes were being generated at the various facilities?
- What quantities of each material were being disposed?
- What were the waste disposal costs or recycling revenues for each material?

The goal of the first step, Identify Costs, was to identify the waste streams that were significant enough to justify additional evaluation. Thus, the initial evaluation was limited to identifying the waste streams and completing preliminary analyses at a few facilities. The teams did not track emissions, spills, or other types of environmental burdens, nor did they estimate purchasing, storage, or other costs.

The approach pinpointed three high-volume and high-cost waste streams: coal ash, contaminated soil, and solvent waste. **In particular, the ComEd team discovered that the facilities annually disposed of over 500,000 pounds of solvent-contaminated materials. Since these waste solvents were regulated and accordingly disposed of as hazardous wastes, the disposal costs were substantial.**

Team Approach

The waste stream evaluation revealed a number of significant opportunities for reducing waste at its source. ComEd then focused on the company's use of solvents and alternative cleaning materials, and broadened its scope of analysis to include the complete set of materials management activities. Action committees were formed with members from all of ComEd's key materials management processes: procurement and contracting, receiving and testing, warehousing and distribution, operations, and recovery and distribution. **The team began by evaluating requirements that could constrain its ability to replace a solvent with a less costly, less burdensome cleaning material.** Three questions were answered for each cleaner:

- For which applications is the solvent best suited?
- Does the cleaner leave a residue?
- Is the cleaner corrosive to metals, vinyls, plastics, or insulations?

These questions helped the team determine which cleaners could be easily substituted and which ones could not, e.g., obviously, a cleaner that corroded metal could not be used on steel or other metallic surfaces. After determining which cleaning materials were viable substitutes for each other, the team then evaluated the product performance of each cleaner. A cross-section of personnel who used or managed the solvents rated the materials in five categories:

- Operating
- Purchasing and Supply
- Environmental and Regulatory
- Safety and Health
- Analytical.

The survey participants rated each cleaner on several criteria within each category. For example, the Purchasing and Supply criteria were

- Cost
- Vendor Performance
- Shelf Life
- Packaging Safety
- Availability of Various Sized Packages
- Storage Ease
- Dispensing Ease.

The solvents were ranked from 1 to 10 (1 being the worst rating, and 10 the best). Since some factors were considered significantly more important than others, the team assigned a weighting factor to each criteria. **A final product rating was determined by calculating a sum of the weighted criteria scores.**

The screening questions enabled the identification of substitute cleaners, and the product ratings revealed which cleaning materials had superior operating and environmental performance. **Thus, during the second**

step, Determine Opportunities, the team uncovered numerous opportunities to replace solvents with equivalent or superior performing cleaners.

Life Cycle Cost Analyses

The third step of the Inventory Minimization Program, Calculate Benefits, was a life cycle cost evaluation. The team quantified three categories of cost:

- Purchase Costs
- Inventory Carrying Costs
- Waste Disposal Costs.

Since the team had already determined the last category of costs, the team focused on the first two categories and obtained data by reviewing purchasing and warehouse records. The analyses revealed that the cost reduction opportunity was spread across several of ComEd's materials management processes. **In fact, disposal cost savings were less than one-third of the total cost savings obtainable.**

The team was also concerned about hidden and contingent costs. Since these costs were more difficult to estimate, the team qualitatively evaluated several additional cost categories, including:

- Solvent Specification Cost
- Record Keeping Cost
- Cost of OSHA and EPA Citations
- Training Costs
- Cost of Solvent Misuse.

These cost evaluations enabled the team to address the full spectrum of solvent performance, from purchasing cost to environmental considerations to operating effectiveness.

The life cycle cost analyses confirmed the opportunities to replace ComEd's current cleaning materials with lower cost, better (or at least equivalent) performing alternatives.

Results!

The Inventory Minimization Program proved to be quite successful at the two facilities that first implemented it. The teams' recommendations led to cost savings and environmental gains. **ComEd changed its procurement decision process and reduced the number of solvents from fifteen to three.**

Based upon this initial success, the program was implemented and transferred to other generating facilities. The overall results were:

- **Replacement of over 100 solvent products with nonhazardous materials**
- **Reduction of hazardous solvent waste by 88% during a two-year period**
- **Five-year estimated cost savings of over $1,000,000**

- **Considerable reduction of difficult-to-estimate costs, including those for record keeping and training.**

This initial improvement effort has since evolved into a continuous improvement effort— the New Product Evaluation Process. The purpose of this process is to ensure that ComEd continues to reduce the life cycle costs and the environmental concerns of cleaning activities. After some initial screening steps (e.g., determining if the material has special handling or storage requirements), new solvents are evaluated as described in Steps 2 and 3 with a performance evaluation and life cycle cost evaluation. **This effort has enabled ComEd to continue reducing its hazardous material use, accompanying waste, and overall costs, while helping operating personnel perform their jobs quickly and effectively.**

Since this initial success, ComEd has monitored its progress and successfully expanded its program to address several other materials management activities.

CONCLUSION

Materials managers can simultaneously improve both the financial and environmental performance of their supply chain systems. This guidebook has recommended a four-step approach to implement environmental accounting methods that can identify hidden costs or benefits and reveal opportunities to increase overall efficiency and productivity. **This approach is part of a broader paradigm that has emerged among leading corporations around the world—the realization that environmental considerations should be integrated into each and every core business process.**

Over the past few decades, there has been a gradual progression in the environmental performance of industrial firms. The old view of pollution as a "cost of doing business" has given way to a more enlightened view—namely, preventing pollution at its source makes good financial sense. **This trend has culminated in the concept of "eco-efficiency," which involves minimization of waste, conservation of scarce resources, and avoidance of persistent, toxic by-products.** The World Business Council on Sustainable Development, an influential group of corporations formed in 1990 by their chief executives, has published a series of reports demonstrating how eco-efficiency can contribute to competitiveness.[18]

A number of U.S.-based multinational companies have recognized the importance of environmental excellence to long-term success, and are positioning themselves to derive advantage from the introduction of eco-efficient products and technologies. In the electronics industry, companies such as Hewlett Packard, Xerox, and IBM have embarked upon pioneering initiatives to design environmentally conscious products and to communicate these benefits to their customers. In the chemical industry, companies such as Monsanto, Dow, DuPont, and Rohm & Haas have sought new market opportunities through the introduction of environmentally preferable processes and the exploration of biotechnology-based products. Another notable example is Interface Corporation, a manufacturer of industrial carpets, whose CEO, Ray Anderson, has made a personal commitment to transform the company into an eco-efficient, sustainable enterprise.[19]

A number of recent success stories demonstrate that reducing pollution at the source and designing products and processes in ways that enhance environmental quality will generally result in higher productivity and reduced operating costs, and may also increase market share.[20] For example:

- Proactive management of supplier environmental performance, as practiced by Hewlett Packard, can lead to product and process simplification, more efficient resource utilization, product quality improvement, liability avoidance, and an enhanced leadership image.
- Adoption of eco-efficient manufacturing methods, as practiced by 3M, can lead to more flexible plant configuration, enhanced productivity, improved community support, and a stronger influence on the evolving regulatory regime.
- Attention to the environmental services aspect of customer satisfaction, as practiced by Ashland Chemical, can lead to reduced cost of ownership, more convenient product handling and disposal, and a perception of supplier commitment.
- Finally, attention to "end-of-life" product disposition issues, as practiced by Xerox in its photocopier business, can lead to diminished waste liability, reduced cost of materials, improved asset utilization, and a strengthened linkage with customers.

By focusing on an appropriate set of these sources of competitive advantage, a company can use environmentally beneficial strategies selectively to become more competitive over the long run. Obviously, implementation of these strategies will require fundamental changes in core business processes such as product development, marketing and sales, manufacturing, supply chain management, and customer service. **In each case, environmental accounting methods are useful for systematically identifying and assessing opportunities to increase shareholder value.**

GLOSSARY OF KEY TERMS[j]

Activity-Based Costing	Accounting method that accumulates costs based on activities performed and then allocates these costs to products, customers, or processes.
Business Process	A set of logically related tasks or activities performed to achieve a defined business outcome.
Disposition	Process of discarding waste materials or obsolete products.
Environmental Burden	A release or modification to the environment, due to an industrial process, that may have adverse effects.
Eco-Efficiency	The ability to simultaneously meet cost, quality, and performance goals; reduce environmental impacts; and conserve valuable resources.
Environmental Accounting	Management accounting practices that enable the incorporation of environmental cost and benefit information into business decisions.
Ergonomics	Approach to job design that focuses on the interactions between employees and their work environment, which includes tools, equipment, heat, light, sound, and possible pollutants.

[j]Definitions adapted primarily from the following sources:

- *APICS Dictionary*, Ninth Edition, APICS, 1998.
- Joseph Fiksel, *Design for Environment: Creating Eco-Efficient Products and Processes*, McGraw-Hill, 1996.

GLOSSARY

Hazardous Waste	A waste such as chemicals or nuclear material that is hazardous to humans or animals and requires special handling.[k] Hazardous waste costs are typically substantially higher than other waste costs due the special handling, training, and recording as well as higher disposal fees that are required.
Life Cycle	A sequence of stages spanning the lifetime of a product, process, service, facility, or enterprise from inception to final use and disposition; in the case of materials, includes extraction, acquisition, manufacturing, and ultimate reuse or disposal.
Life Cycle Costs	Financial impacts associated with the life cycle stages of a material, product, process, service, facility, or enterprise.
Logistics	Activities to move incoming materials and distribute finished products to the proper place, at the desired time, and in the optimal quantities.
Mass Balance	A quantitative or engineering assessment of material flows and transformations.
Materials Handling	Process of developing and implement ing manual, mechanized, and auto mated systems to provide movement of materials throughout a facility.

[k] Please note that this APICS definition is different than the definition included in the Resource Conservation and Recovery Act. The latter should be used as the basis for hazardous waste regulatory compliance activities.

GLOSSARY

Materials Management	The grouping of management functions supporting the complete cycle of material flow, from the purchase and internal control of production materials to the planning and control of work-in-process to the warehousing, shipping, and distribution of the finished product.
Materials Recovery	Activities to prevent the release of materials into air, water, or solid waste streams and incorporate these materials back into the manufacturing process.
Materials Tracking	Assessment of what, where, why and how much material is acquired, incorporated into products and co-products, and channeled into waste streams throughout the materials life cycle.
Net Present Value	The discounted value of future earnings (cash flows minus initial investment) for a given number of time periods. The discount rate reflects the company's time value of money and commonly ranges from 10% to 15% per year.
Product Take Back	Activities to obtain used products from industrial customers or consumers, and then recycle or reuse these products.
Purchasing	Process of determining specifically which materials, supplies and services must be procured, and then obtaining those resources from suppliers.

Recovery	Process of obtaining a valuable resource from a potential waste material.
Sourcing	Process of determining the types of products and services required and establishing purchasing relationships with capable suppliers.
Supply Chain	The functions inside and outside a company that enable the value chain to make products and provide services to the customer.
Value Analysis	A systematic approach that identifies a required function of a product or service, establishes a value for that function, and finally provides that function at the lowest overall cost.

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The following references are suggested for readers interested in obtaining more in-depth information.

Environmental Accounting—General	Description
Bartlett, K.L.; Lester, R.R.; and Pojasek, R.B. "Prioritizing P2 Opportunities with Activity-Based Costing," *Pollution Prevention Review*, pp. 17-26, Autumn 1995, www.pollutionprevention.com.	Demonstrates how activity-based costing enables companies to quickly identify their largest environmental cost generators.
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Use of Environmental Information in Supply Chain Management	
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This document is a product of EPA's Environmental Accounting Project, a collaborative program with industry, trade associations, research institutions, and government agencies to increase the incorporation of environmental costs and benefits into businesses' decision-making. Environmental costs include material losses and other costs of waste, equipment and facilities used to treat or monitor emissions, and many costs typically associated with environmental management such as reporting and disposal. Increased awareness of these costs leads to the identification of financially attractive opportunities to prevent pollution and eliminate wastes. Companies can then make decisions that are both financially superior and environmentally beneficial.

The Environmental Accounting Project offers numerous educational resources that demonstrate successful approaches to integrating environmental costs into decision-making. Copies of this document and other Environmental Accounting Project products can be obtained free of charge through the Project's website (www.epa.gov/opptintr/acctg) or through the US EPA's Pollution Prevention Information Clearinghouse (telephone 202-260-1023, fax 202-260-4659, or e-mail ppic@epamial.epa.gov).

For additional examples of industrial waste reduction efforts, also visit EPA's WasteWise website at www.epa.gov/wastewise.

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