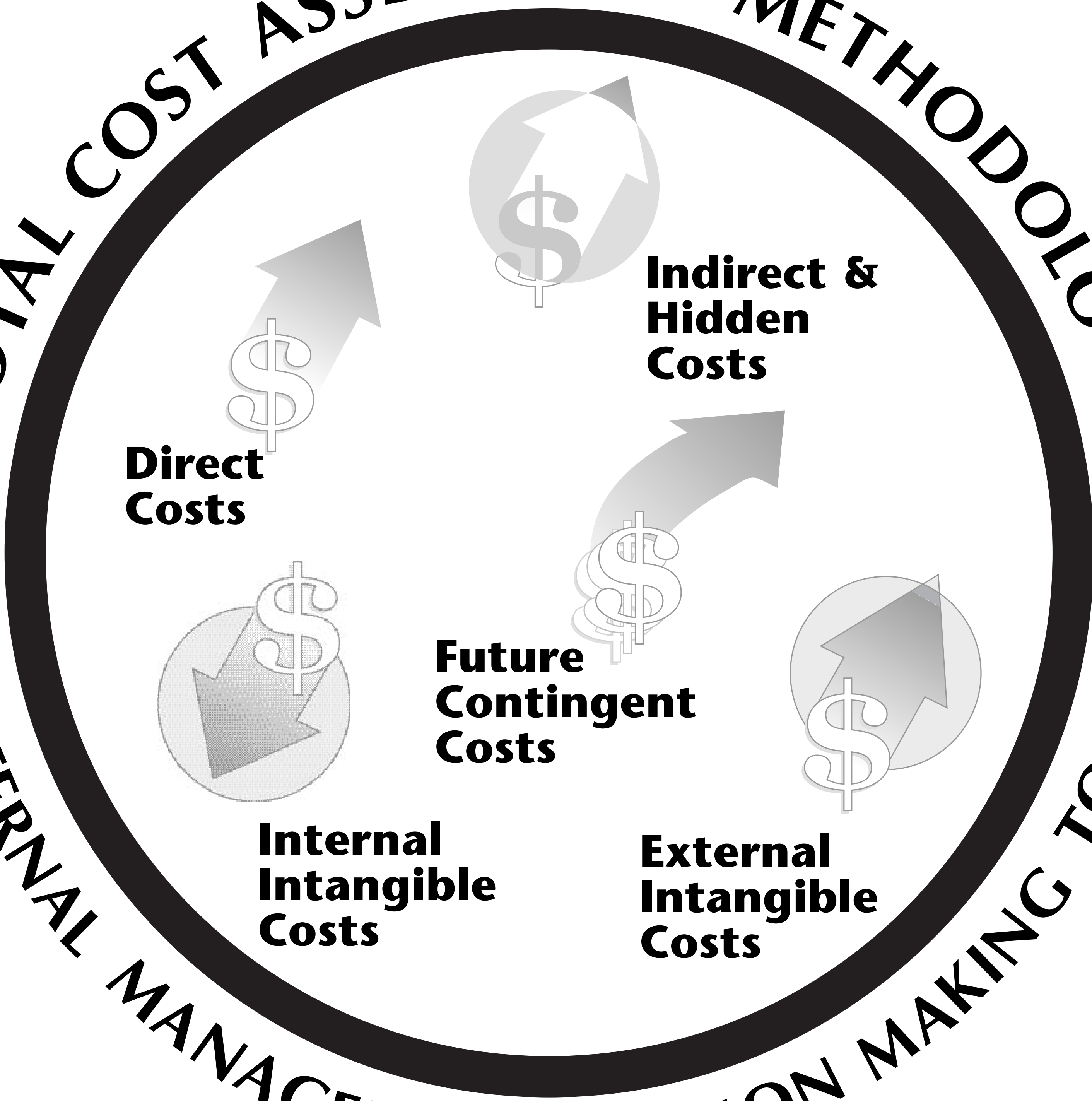
CENTER FOR
Waste Reduction
TECHNOLOGIES

TOTAL COST ASSESSMENT METHODOLOGY



INTERNAL MANAGERIAL DECISION MAKING TOOL

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AIChE

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Foreword

This work was performed under a research contract to the American Institute of Chemical Engineers' (AIChE) Center for Waste Reduction Technologies (CWRT), with partial funding from the Department of Energy and the National Business Roundtable's Industrial Pollution Prevention Council. The contract is supported by team of industrial firms who collaborated to produce a Total Cost Assessment (TCA) methodology that is broadly applicable to many industrial sectors. This work is the sole work product of this team, shown below.

Industrial Collaborator	Representative
Bristol-Myers Squibb	Jesse Hunter
The Dow Chemical Company	Duane Koch
Eastman Chemical	Jill Murphy
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Georgia Pacific	Lawrence Heim
Merck	Laura Tyls
Monsanto	Earl Beaver
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	Paul Cichy
SmithKline Beecham	David Constable

Dr. David Constable of SmithKline Beecham led the TCA team. Arthur D. Little, Inc., served as both the research contractor and a program collaborator.

Acknowledgments

The AIChE's Center for Waste Reduction Technologies (CWRT) wishes to acknowledge the Total Cost Assessment industrial collaborators who generously provided their time, knowledge capital, experience, and enthusiasm for this program. This collaborative effort has resulted in the development of a standardized, yet flexible, approach to understanding and managing the environmental and human health costs associated with produces or processes.

The value of this collaborative approach to Total Cost Assessment is in the accumulation of the best thinking and definition of needs that reside within today's corporations. This Task Force surveyed the best industrial practices and developed a method that closely fits the needs of industrial organizations. The pilot testing of the methodology, using actual industrial processes, allowed the Task Force to validate assumptions and produce a robust and flexible process.

The AIChE's CWRT also wishes to acknowledge the knowledge capital and funding provided by the National Business Roundtable's Industrial Pollution Prevention Council to advance this program, as well as the funding provided by the U.S. Department of Energy.

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This total cost assessment (TCA) methodology is designed for internal managerial decision-making. When a corporation must decide between alternative projects, all potential environmental and health costs should be fully considered. This methodology provides the framework for that decision process, as well as the framework for estimating baseline costs that have a much broader and potentially longer timeframe. Potential industrial users include:

- Product/process engineers in the design stage of new products and processes
- Engineers in the assessment of environmental projects
- Business managers and analysts in developing product and business strategy

The model and concept were developed to be sufficiently flexible to meet the needs of these user groups, with a sufficient level of documentation and instruction to produce consistent results. In addition, it is envisioned that this work will be improved upon in the future as industries and other groups use the methodology, and refine it based on their experiences.

Background

Total cost assessment is a dynamic and emerging concept that seeks to provide a process for quantifying all environmental and health costs, both internal and external, associated with a business decision. The TCA methodology is based on a life cycle approach. Prior to the development of this tool, a standardized, industrially-accepted approach to conducting a TCA was not publicly available. The architects of the TCA methodology presented in this manual have charted a path to a standardized, yet flexible, approach to account for environmental and health costs that meets the needs of a broad range of industrial sectors. The American Institute of Chemical Engineers (AIChE's) Center for Waste Reduction Technologies (CWRT) initiated a collaborative Task Force consisting of ten major corporations to develop this approach. The corporations represent the chemical, pulp and paper, pharmaceutical, and other consumer products industries. The value of this collaborative approach is in the accumulation of the best thinking and definition of needs that actually reside within these corporations. The industrial collaborators for the TCA development provided their time, knowledge, capital, experience, and enthusiasm towards this approach.

TCA is defined as the identification, compilation, analysis, and use of environmental and human health cost information associated with a business decision. The purpose of this project was to develop a methodology that encompasses a broad decision-making perspective and incorporates sustainable development considerations. It is also envisioned that the TCA methodology will provide insight to managers seeking to improve their understanding and management of all environmental and health costs associated with the development of new products, processes, and manufacturing sites. TCA is a comprehensive process to identify potentially hidden environmental and health costs and to mitigate future risks and contingent costs for industrial processes, products, or sites. Uncovering and recognizing environmental costs associated with a product, process, system, or facility is important for good management decisions. Attaining goals such as reducing environmental expenses, increasing revenues, and improving future environmental performance requires paying attention to current and potential future environmental costs. Whether or not a cost is "environmental" is not critical; the goal is to ensure that relevant costs receive appropriate attention.

Costs that are generally considered in corporate planning processes and project evaluations are those that the company pays for directly, such as capital and operating costs. Costs that may not have been previously considered are generally associated with allocated overhead charges and/or potential future costs. Potential future costs include potentially hidden impacts on the environment, human health, and ecology, as well as internal intangible costs. TCA will not replace existing capital project and product development cost estimating practices, but is intended to complement these existing cost estimating practices for improved decision-making. This methodology brings focus to environmental and health costs frequently not fully considered, such as contingent risks, intangible internal costs, and potential future costs associated with external impacts.

Approach

The CWRT collaborative Task Force developed a method aimed at fitting the needs of industrial organizations which is pragmatic enough to be used in industrial decision-making. This process is designed for individual companies to incorporate their specific goals and policies. The pilot testing of the methodology, using actual industrial processes, allowed the Task Force to validate assumptions and produce a more robust and flexible process. This TCA methodology was developed in two steps -- first, as a manual method using spreadsheets, and second, as a software tool.

In developing the TCA methodology, the Task Force surveyed current approaches to TCA and best industrial practices[1]. The Task Force also sought input from the U.S. Environmental Protection Agency (EPA), international regulatory bodies, insurers, accounting, business, trade, and academic organizations, and other professional societies to ascertain the existing state of best practices, many of which were incorporated into this methodology. The intent was to develop a process that has external, as well as internal, credibility in identifying environmental and health costs incurred, costs avoided, and cost saved. With this insight into the decision-making process, companies will be encouraged to incorporate environmental and health improvements in new projects and to implement environmental and health improvements throughout the firm.

[1] Background information available from CWRT by calling (212) 591-7424

Total Cost Assessment (TCA) Methodology

Implementation of the TCA process must be accomplished by cross-functional teams, bringing together designers, chemists, engineers, production managers, operators, financial staff, environmental managers, purchasing personnel, public relations staff, marketing personnel, business managers, and/or accountants. These groups may not have worked together before with a focus on the environment. Because TCA is not solely an accounting issue, and the information is distributed among all of these groups, communication is necessary to develop a common vision and language, and to make those visions a reality.

A key assumption is that the alternatives under consideration are economically viable and practical. The TCA methodology may include life cycle inventory information, that may have already been collected or that may need to be collected by the company.

The TCA methodology consists of six main steps with a final step being a feedback loop providing input into the company's main decision process. The purpose of the first three steps is to clearly define what aspects of the project or alternatives are important enough to carry forward and to fully evaluate. Once the first three steps have been completed, the financial inventory is developed for each project or alternative. The steps are as follows:

1. *Goal Definition and Scoping*:
   Clearly identifies and defines the project and purpose of the total cost assessment.
2. *Streamline the Analysis*:
   Refines the first step by connecting the objectives and other elements of the decision at hand to sustainability metrics and impact categories; also provides for the incorporation of life cycle information and other relevant information (e.g., results of brainstorming sessions).
3. *Identify Potential Risks*:
   Evaluates the relative importance of the impact categories and the current feasibility of expressing the costs for each attribute of an alternative or project.
4. *Conduct Financial Inventory*:
   Focuses on defining costs, as follows:
   - Type I: Direct costs for the manufacturing site. Direct costs of capital investment, labor, raw materials, and waste disposal. May include both recurring and non-recurring costs. Includes both capital and operating and maintenance (O&M) costs.
   - Type II: Potentially hidden corporate and manufacturing site overhead costs. Indirect costs not allocated to the product or process. May include both recurring and non-recurring costs. May include both capital and O&M costs. May include outsourced services.
   - Type III: Future and contingent liability costs. Potential future contingent costs include fines and penalties caused by non-compliance, future liabilities for clean-up, personal injury and property damage lawsuits, natural resource damages, and industrial accident costs.

- Type IV: Internal intangible costs. Costs that are paid by the company. Includes difficult to measure cost entities, including consumer acceptance, customer loyalty, worker morale, worker wellness, union relations, corporate image, and community relations.
- Type V: External costs. Costs for which the company does not pay directly. Costs borne by society, including deterioration of the environment by pollutant dispersions that are currently in compliance with applicable regulations.

5. *Conduct Impact Assessment*:
   Review costs to determine the largest cost contributors for each category and to assess how that information may be best incorporated into the overall decision process.
6. *Document Results*:
   Document the assumptions and results for each scenario and cost decision.
7. *Feedback to Company's Main Decision Loop*:
   Feedback to the main decision process within the company, recognizing that the total cost assessment is only one element or input to an overall decision process that includes many types of information.

The application of the Total Cost Assessment methodology to internal decision-making processes will provide a more complete assessment of environmental and health related costs and/or benefits for corporations and will contribute to improved long-term competitiveness.

1.0 Introduction

Total cost assessment (TCA) has been studied and defined by a variety of groups in the past, and there are differences and some confusion about the definition of TCA. In this project, TCA has been defined by a collaborative group of ten companies to be the identification, compilation, analysis, and use of environmental and environmentally-related human health (E&H) cost information. This definition of TCA encompasses all internal, as well as external costs, associated with a business decision. TCA has emerged as one of the foremost items on the environmental agenda of business in the 1990s, due to both internal economic incentives and external pressure from stakeholders. Industry has recognized that sustainable development is a desirable goal and that TCA is a useful tool to reach this goal.

Under the sponsorship of the AIChE's Center for Waste Reduction Technologies (CWRT), a focus group of 10 transnational companies, together with Arthur D. Little, Inc., was formed to develop an "industry-standard" approach to TCA. The group's goal was to design a methodology that would begin to make TCA an objective and quantitative costing approach with practical applications aimed at improving business and E&H-related decisions. The main goal of the group was to develop a pragmatic approach that could be used by companies to support and improve internal decision-making functions, and to mitigate E&H impacts, before they occur, at the most economic cost. Ideally these improved decisions would be enabled through TCA, because the cost implications of E&H issues would be described and communicated in more effective and familiar business terms (e.g., costs of future and contingent liabilities, both internal and external). The methodology was designed to have external, as well as internal, credibility in identifying and managing E&H costs incurred, costs avoided, and costs saved. In addition, the methodology was designed to encourage the incorporation of E&H improvements in the planning process and the implementation of E&H improvements throughout the firm.

The TCA methodology described in this manual is designed for internal managerial decision making. The methodology can be applied to compare project alternatives or to determine baseline status, and will improve the understanding of the E&H costs and impacts related to products and processes. TCA is not designed to replace existing capital project and product development cost estimating practices, but to further enhance these costing exercises by focusing attention on the potentially hidden E&H costs and impacts. It also includes E&H costs and environmental, human health, and ecological impacts (e.g., contingent risk and liability, intangible internal costs and external impacts and costs) that traditionally have not been included in project cost estimating practices. Potential users of the TCA methodology are product or process designers developing new products or processes, engineers assessing environmental projects, or business managers and analysts developing product and business strategy.

Benefits of Collaborative Approach to Developing a TCA Methodology

The primary benefit of using a collaborative approach to TCA was the development of a methodology that broadly meets industry's needs. The process has been shaped by the collective experience of large transnational industrial firms. This experience has been used to develop a method to identify hidden E&H costs and a process to identify and mitigate future E&H risks and liabilities for industrial processes. In developing the TCA methodology, the team sought input from the U.S. EPA and international regulatory bodies, E&H insuring organizations, accounting and business trade and academic organizations, and other professional societies to ascertain the existing state of best practices, many of which were incorporated into the TCA methodology.

Approach

The first portion of this work began with a survey to identify the existing status and capabilities available to implement TCA[1]. The survey indicated that, while there were currently (i.e., the end of 1997) several tools available (e.g., P2Finance, PRECOSIS, RACER/ ENVEST) which attempted to itemize and quantify all costs associated with a process or product, there were no comprehensive methodologies. The principal gaps in currently available TCA methods included a lack of externality data, a lack of initial thorough impact assessment, and gaps in the estimation of future potential liabilities. Thus, the CWRT TCA Work Group developed an "industry-focused" TCA approach, intended to account for E&H costs and to meet the needs of a broad range of industrial sectors. The TCA Work Group developed a manual TCA approach, with spreadsheet templates, that was then incorporated into an electronic version which embodies the reasoning and processes deemed important by the group. The Work Group intended that this TCA methodology should be improved upon in the future. Therefore, this document serves in part as a means to preserve the contributions made by the TCA Work Group and allow an extension of this group, or others, to make additional contributions to the TCA method presented. The TCA methodology incorporates a life cycle approach, allowing the user to look processes from cradle-to-grave or from gate-to-gate, depending on the application.

> TCA is one method to assess and reduce E&H costs and to provide information that can be used reliably to promote more efficient use of energy and raw materials.

Need for TCA

Since the 1992 Earth Summit in Rio, the business community has become increasingly aware of the need to achieve sustainable industrial operations, and to reduce the global environmental impacts of their operations. The concept of "sustainable development" embodies balancing further economic growth and social progress with protecting the environment from further damage, principally by using the earth's resources responsibly and by conducting industrial operations responsibly. There is considerable pressure from

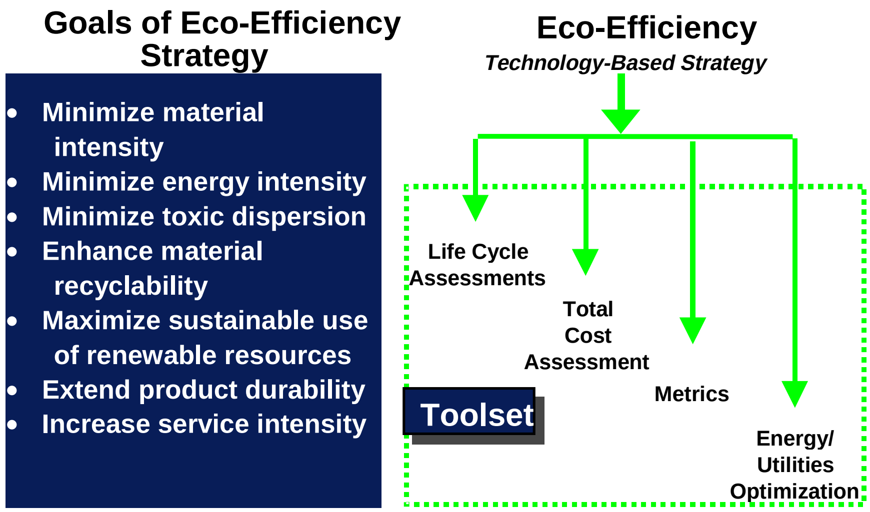
[1] Available from CWRT by calling (212) 591-7424

within companies and from global business organizations, governments, banks and insurers, as well as from the public, to design products, processes, and services that are "sustainable" and "eco-efficient." These pressures require the consideration of both the economic and ecological impacts of industrial operations.

Society expects business to contribute to economic development and social progress, and to reduce E&H impacts through improved performance. But business must remain successful to create more wealth. Continued economic development is needed to improve quality of life throughout the world. Zero growth is not an option. The concept of "sustainable development" balances further economic growth and social progress with protecting the environment from further damage, principally by using the earth's resources responsibly and by conducting industrial operations responsibly. Companies are under pressure from customers, investors, employees, legislators, and, increasingly, banks and insurance companies, to become more eco-efficient.

Eco-efficiency (Figure 1-1) is a management philosophy that integrates the goals of both business and E&H excellence by creating the bridge by which corporate behavior can achieve sustainable industrial operations. Although it is a new and still evolving concept, the eco-efficiency vision is to simply produce more from less with a reduction in potentially negative impacts. Reducing waste and pollution, while utilizing fewer energy and raw material resources for production are goals that hold inherent benefits for business and the environment. These E&H benefits will, ultimately, save money and increase profits for businesses through a reduction in the E&H costs and liabilities that may be associated with producing goods and services. TCA can be used by companies to achieve their sustainability and eco-efficiency goals through the objective identification of all risks and costs that are associated with various processes and decisions.

Figure 1-1 The Link Between Eco-Efficiency and Total Cost Assessment



Source: *Arthur D. Little, Inc.*

Most cost accounting systems were designed and implemented prior to today's regulatory- and policy-driven E&H climate, thus they do not track and report costs associated with sustainability and eco-efficiency. These costs are frequently buried in overhead accounts and are not visible, not well managed, and often not well understood. When these E&H costs are "hidden," they are more susceptible to being poorly managed. Because the number and stringency of E&H regulations and policies has increased significantly since the 1970's in the U.S., and will most likely continue to increase, hidden or poorly understood E&H costs have become an increasing liability for industrial organizations. Internationally, there is increasing public and regulatory pressure to assess the environmental characteristics of products and processes. In addition, pressures for external reporting of pollutant discharges have created new potential future liabilities (both for future compliance with regulatory requirements and for civil actions) and public image issues with consumers.

> These increasing internal and external pressures to reduce impacts to the environment and human health have created a desire within many enterprises to have the capability of making better-informed decisions regarding their operations – how to achieve the greatest reduction of human health and environmental impacts, and reduction of future liabilities, while effectively managing costs.

In addition to the desire to implement "eco-efficiency" goals, there are many factors driving companies to implement TCA. Pollution of the environment and human health impacts have become more prominent economic, social, and political concerns throughout the world. Steps are being taken at the national and international level to protect the environment and to prevent or reduce the effects of pollution on both the environment and human health. Investors and their advisers are applying pressure because of their concern regarding how an enterprise's E&H performance affects its financial health and how financial information relating to such performance can be used to assess the enterprise's E&H risk and liabilities. Creditors have similar needs with the added possibility of having to assume the responsibility for rectifying environmental damage if a debtor defaults on a loan for which it has pledged land as security. Owners and shareholders are particularly interested because of the potential impact environmental costs may have on the financial return on their investment in the enterprise. Other interested parties could include customers, suppliers, regulators, and the general public.

In the United States the magnitude of E&H regulations has quadrupled in the past ten years. To comply with these programs (termed "involuntary" costs), vast resources are expended by companies in reporting, remediating, litigating, paying fines, paying fees and obtaining permits, not to mention internal training programs to support these activities. According to the U.S. Department of Commerce, the operating costs for pollution abatement alone totaled over $18 billion in 1993. In 1994, the total operating and capital costs for these activities across all sectors in the United States was $121.8 billion, with the manufacturing sector alone accounting for $7.8 billion. Since1994 was the last year the U.S. Department of Commerce collected such pollution control data, the trend of increasing costs for these activities in subsequent years is not known.

Potential drivers for completing TCA are listed in Table 1-1.

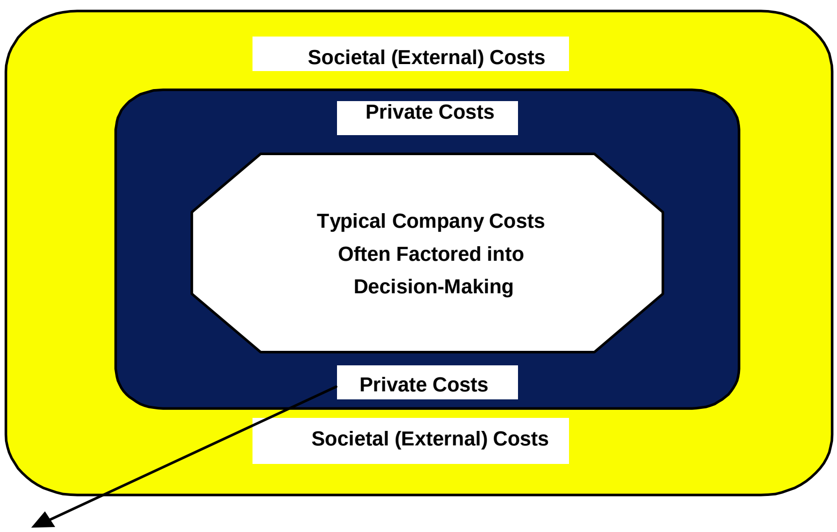
Table 1-1 Internal and External Drivers for TCA

Driver	Purpose/Description of Driver
E&H cost monitoring/ management	To provide greater visibility and understanding of E&H costs and, subsequently, to better manage those costs. Develops better understanding of current costs and supports forecast and impact assessment of future regulations and costs
External public reporting	For Securities and Exchange Commission (SEC) requirements for disclosure of liabilities
	For Financial Accounting Standard (FAS) No. 5 on contingency costs
	In response to customers, environmental organizations, host communities, and non-government organizations (NGOs)
Investor interest	Banks and lender liability: environmental considerations and their management have become part of credit-customer pricing and company investment rating. Banks are looking at, not only, a company's risk but also their opportunities in rating their credit
	Financial institutions: including insurance companies and investment fund managers, use qualitative and quantitative information to assess a company's E&H performance
Internal decision support	Making informed decisions: future reductions in E&H footprint will require a more precise understanding of the costs, risk and long-term benefits associated with E&H improvements
	Capital budgeting, operations costs, and strategic planning
Involuntary vs. voluntary costs	Involuntary: examples include obtaining permits, the Superfund Act, toxics reporting initiatives. Potential future involuntary programs may include eco-taxes, which could be fees on the destructive use of natural resources, carbon taxes and taxes or fees for greenhouse gases generation
	Voluntary: to motivate business through marketing and trade implications. Examples include ISO 14000, Germany's Blue Angel (eco-labeling) program, EMAS, pollution prevention, EPA 33/50 program
International import/export and non-domestic implications	Non-domestic operations: must comply with a multitude of varying regulatory requirements as function of state/region/country of operations location
	International trade pressures: many trade agreements contain relatively new language on trade restrictions based on E&H considerations (genetically engineered products, 19 eco-label programs in Europe, EU Brussels directive to increase recycling of packaging by 25 to 45 percent in Europe by the year 2000)

Source: Adapted from: *Environmental Cost Accounting for Chemical and Oil Companies: A Benchmarking Study,* USEPA-742-R-97-004, June 1997, by David Shields, Beth Beloff, and Miriam Heller, Institute for Corporate Environmental Management at the University of Houston; also sponsored by the Business Council for Sustainable Development - Gulf of Mexico, prepared for EPA's Environmental Accounting Project, and *Total Cost Assessment for Chemical Manufacturers: Best Industrial Practices,* Volume I, Phase I for Center for Waste Reduction Technologies, October 1997.

Informed E&H decision-making requires understanding the total cost consequences of a decision. Figure 1-2 illustrates the scope of E&H costs, including external (or societal) costs (U.S. Environmental Protection Agency, 1995). The center box represents companies' costs that are typically considered in conventional decision-making. The next box (private costs) includes the typical costs plus other internal E&H costs that are potentially overlooked in decision-making, including regulatory, voluntary, up-front, operational, back-end, overhead, future, contingent and image/relationship costs. These "private costs" include internal intangible costs (e.g., costs that could be experienced by a company related to delays in permitting etc., due to reputation with regulators and others). The box labeled societal represents E&H costs external to a company. These are costs that are incurred as a result of a company affecting the environment or human health, but for which the company is not immediately held legally or fiscally responsible. These "externalities" include environmental degradation and adverse effects on humans, property, and welfare associated with emissions/activities that are performed in compliance with regulatory requirements. The figure does not directly portray the benefits which may be associated with a decision.

Figure 1-2 Scope of E&H Costs



Private E&H costs potentially overlooked in decision making: Regulatory, voluntary, up-front, operational, back-end, overhead, future, contingent, and image/relationships.

Source: Adapted from USEPA . 1995. *An Introduction to Environmental Accounting*

A better understanding of internal E&H costs will benefit a company. Recent examples reported[1] include:

[1] Daryl Ditz, Janet Ranganathan, and R. Darryl Banks (eds.), *Green Ledgers: Case Studies in Corporate Environmental Accounting* (Washington, DC), World Resources Institute, 1995).

- Amoco Petroleum: "environmental costs made up at least 22 percent of the nonfeedstock operating costs of Amoco's Yorktown oil refinery. This compared to Amoco's preinvestigation estimate of 3 percent. The largest components were costs of waste treatment, maintenance of environment-related equipment and meeting environment-related product specifications."
- DuPont: "for one DuPont pesticide, environmental costs represented 19 percent of the total manufacturing cost. The largest components were general overhead (including taxes and training and legal fees) and depreciation and operation of pollution control equipment."
- Novartis: "Environmental costs of one Novartis additive were a minimum of 19 percent and possibly a higher proportion of manufacturing costs (excluding raw material). The most obvious costs were operation and depreciation of wastewater treatment and solvent recovery equipment, which alone totaled 15 percent of non-raw material manufacturing costs. Others were hidden, but no less significant -- some line managers estimated that up to 25 percent of their time was spent on environmental considerations."

1.1 Objectives of the CWRT TCA Methodology

The objectives of the TCA methodology are to understand the cost significance of E&H-related decisions, activities, and consequences in the past, present, and, especially, the future. Relevant process information, policies, and legal and other requirements are identified that create the current business environment and affect the E&H aspects of the company. That information is used to simulate scenarios and build predictive models to show the cause and effect of process and product decisions on E&H issues, and to predict potential costs to the company.

A multidisciplinary approach is used to achieve a systematic portrayal of current and future costs, benefits, and vulnerabilities of alternatives. The systematic nature of the interrelationship between proposed technology and E&H costs require a change from a short-term, single-dimensional approach to a systems-based, comprehensive set of practices that consider the long term. By focusing on systems, one can look at the various effects that different alternatives can generate. For instance, a study that shows shredding is more cost-effective than dismantling may not have considered that the material shredded could be fit for reuse and therefore retains residual value that would be lost without recycling. Also, dismantling and reusing the material would minimize the external effect on the environment. Systems-focused thinking allows the user to consider a scenario that involves reuse and to calculate the benefits and the costs of reuse.

Guidelines are established to examine monetary benefits and costs of E&H factors during strategic business planning processes. To ensure that E&H considerations are integrated into operations, current business planning processes need to be "seeded" with these effective guidelines, in order to identify potential opportunities and desired goals, as well as regulatory constraints and future liabilities and costs to the company.

A further objective of this TCA methodology is to provide the user with a comprehensive tool that is flexible. The user can tailor the TCA to meet specific project needs. Not all cost elements described are applicable to or need to be included in every analysis. The TCA method does not necessarily conform to GAAP or FASB standards, although these principles can be retained in the approach if the user desires. The TCA is primarily intended to augment internal decision-making processes. However, some users may want to include TCA-based results in external reporting. Therefore, the method can be applied and documented in a sufficiently transparent manner (e.g., all assumptions reported and professional judgments documented), in order to be credible. The methodology provides a structured, yet flexible, decision-oriented process for users.

A recommended approach to implementing a TCA program within a corporation is to form a multi-disciplinary team to participate in the problem definition, scoping, and goal-setting phase of the TCA. The multi-disciplinary team should include representatives with a vested interest in reducing corporate costs, reducing the environmental footprint, and improving the health and safety aspects of their manufacturing processes. Depending on the nature of the project planned, a successful multi-disciplinary team might consist of the functions shown in the box below.

Recommended TCA Multi-Disciplinary Team

- Manufacturing
- Design/R&D
- Engineering
- E&H
- Transportation
- Marketing
- Facilities
- Purchasing
- External Affairs
- Inventory Control
- Business Unit Management, including:
  - Insurance
  - Legal
  - Finance/Accounting

1.2 Scope of the TCA Methodology

Table 1-2 defines the scope of this TCA methodology. The scope of a TCA may range from an assessment of the fully allocated cost of a decision to an assessment of differential costs, as described below:

- Fully Allocated Costs. Evaluates the total costs associated with the decision under evaluation. The range of costs included are categorized as conventional, potentially hidden, contingent, and image and relationship costs. Both private and societal costs are included. Fully-allocated costs are, typically, used during the pre-production, production, distribution, consumer use, and end-of-life phases of process/product development.
- Differential Costs. The differential cost between two options is determined by calculating the baseline cost of option 1 and considering only the difference in the costs incurred by option 2. Differential costs are more appropriate when considering numerous options in the design/R&D phase and, to a lesser extent, the prototype phase of product/process development.

Table 1-2 Scope of the CWRT TCA Methodology

Scope	Decision Elements Included
Intended use	➥ Internal, managerial decision making
Applications	➥ Capital budgeting decisions, costing determinations, process/product design decisions and performance evaluations ➥ Comparison of alternative products/processes/services
Range of costs	➥ Includes costs incurred, cost savings, and avoided costs ➥ Includes direct, indirect, recurring, non-recurring, and other related costs incurred or estimated in the design, development, production, operations, maintenance, and support of products, processes, or services provided by users and manufacturers of chemicals ➥ Includes capital costs, installation costs, operating costs, and disposal costs over the life cycle of the product/process/service ➥ Includes direct, indirect, contingent liability, internal intangible, and external costs ➥ Includes both operations internal to an organization and operations that are outsourced to external organizations
Range of cost categories	➥ Current costs for past practices: current expenditures to clean up pollution caused decades ago ➥ Current costs for current practices: current E&H expenditures that relate to current production ➥ Future costs for past practices: forecast of future costs (e.g., toxic tort, human exposure at remediation site) for past practices ➥ Future costs for current practices: forecast of the impact of more/less stringent future regulations, changing technology, and the changing cost of technology on existing products or processes ➥ Future costs for future practices: forecast of E&H impacts of products or processes currently in the R&D phase when they ultimately go to full manufacturing
Range of operations	➥ New, modification, optimization, and decommissioning of existing and new products, processes, or services ➥ Long-range strategic planning, including both vulnerabilities and opportunities ➥ Impact assessments

Source: *AIChE's CWRT TCA Work Group*

Range of Costs

The E&H costs that are included in the CWRT TCA methodology are listed and described in Table 1-3.

Table 1-3 E&H Costs Included in the CWRT TCA Methodology

Cost Type	Definition
Type I: Direct costs for the manufacturing site	Direct costs of capital investment, labor, raw material and waste disposal. May include both recurring and non-recurring costs. Includes both capital and operations and management (O&M) costs.
Type II: Potentially hidden corporate and manufacturing site overhead costs	Indirect costs not allocated to the product or process. May include both recurring and non-recurring costs. May include both capital and O&M costs. May include outsourced services.
Type III: Future and contingent liability costs	Liability costs include fines and penalties caused by non-compliance and future liabilities for forced clean-up, personal injury and property damage.
Type IV: Internal intangible costs	These are costs that are paid by the company. Includes difficult to measure cost entities, including consumer acceptance, customer loyalty, worker morale, worker wellness, union relations, corporate image, community relations and estimates of avoided costs – fines, capital, etc.
Type V: External costs	Costs for which the company does not pay directly. These costs are borne by society and include deterioration of the environment by pollutant dispersions that are currently in compliance with applicable regulations.

1.3 Applications of the TCA Methodology

The TCA methodology described in this manual is designed for internal managerial decision-making, particularly in situations where analyses of risks, costs and benefits are possible from many perspectives. The methodology can be applied to compare project alternatives or to determine baseline status, and will improve the understanding of the E&H costs and impacts related to products and processes. TCA is not designed to replace existing capital project and product development cost estimating practices, but to further enhance these costing exercises by focusing attention on the potentially hidden E&H costs and other external costs. It also includes E&H costs (contingent risk and liability, intangible internal costs and external impacts and costs) that traditionally have not been included in project cost estimating practices. The TCA approach is a life cycle approach, taking a wider view of potential E&H risks and costs.

Table 1-4 shows examples of applications that could benefit from a better understanding of E&H costs. The list is not necessarily exhaustive. In many of these decision contexts, environmental cost information is treated as just another cost of doing business, as it is in product pricing or product mix. In other situations, the environmental cost information may play a unique role in the decision process, for example, in waste management decisions, pollution prevention alternatives, or market-based environmental options.

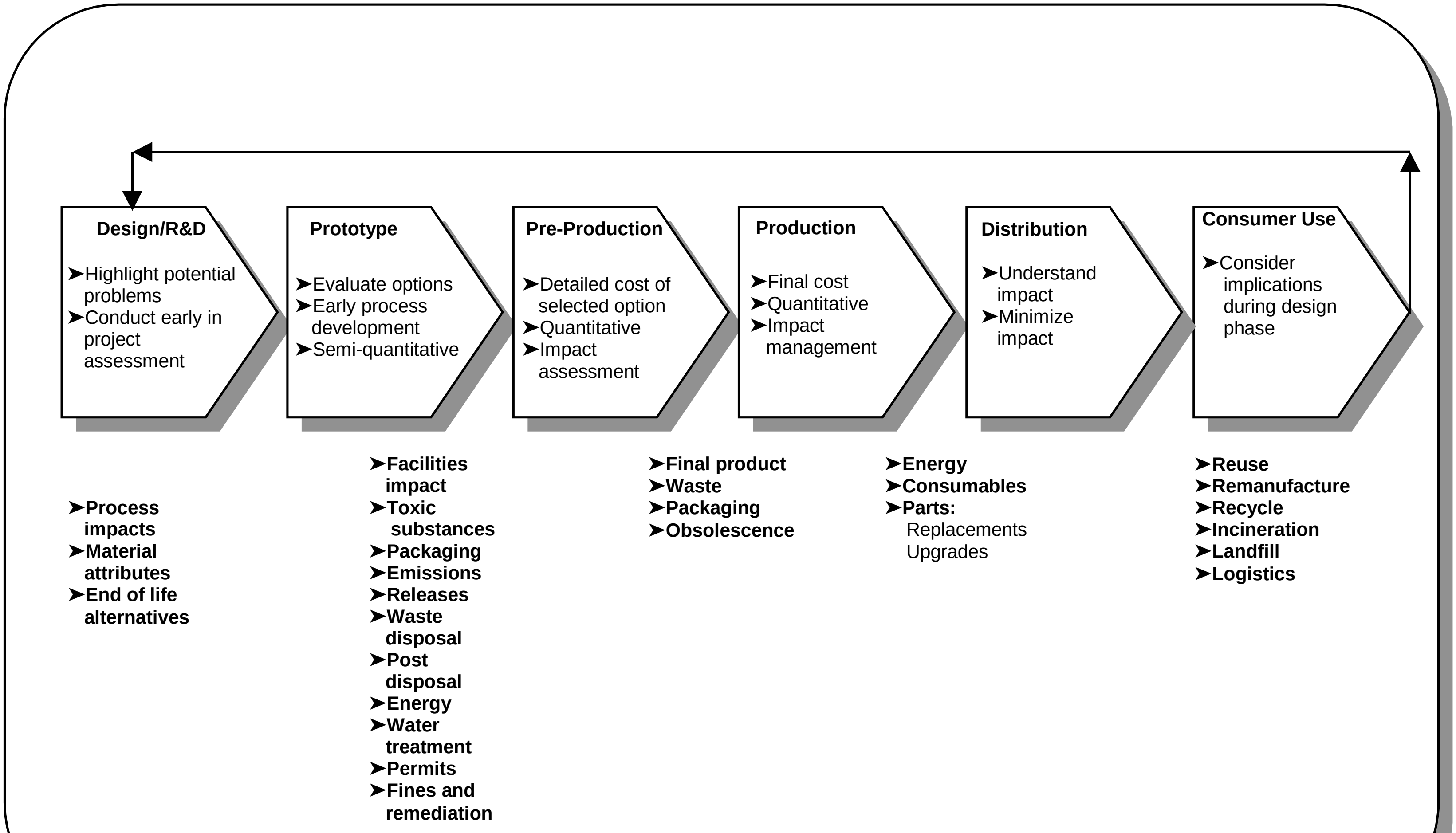
Table 1-4 Examples of Applications That Can Benefit from TCA

Decisions	Examples
Internal/external Benchmarking	How is your company doing against competitors? How are individual plants doing, on a comparative basis.
Process Development	TCA can lead to better decisions for making process modifications or for designing new manufacturing processes.
Product Pricing	TCA can lead to better understanding of what a particular product costs to produce. For products with price flexibility (differentiated products), this may be reflected in price adjustments.
Product Mix	TCA can be beneficial with commodity products, for which the price is market-driven. The company may choose to adjust their product mix to maximize overall profitability.
Waste Management Decisions	Better understanding of environmental cost structures will lead engineers and managers to make more cost-effective choices in treating and disposing waste.
Pollution Prevention Alternatives	A better understanding of current environmental costs, as well as that of prospective alternatives, will result in better capital expenditures.
Materials/Supplier Selection	Companies committed to environmentally responsible manufacturing understand that a "cradle to grave" mentality is necessary. Through better sourcing of materials, companies can push environmental responsibility up the supply chain.
Facility Location/Layout	Decisions regarding siting a facility benefit from TCA, particularly if a site is located in an area in non-attainment with the National Ambient Air Quality Standards (NAAQS) or if the location increases distribution and transportation costs.
Outbound Logistics	These issues pertain to finished product, by-products, and waste. Packaging has significant environmental implications, if the packaging must be destroyed to use the product. Is additional cost of design and materials worth the investment, if the environmental liability might be reduced. For by-products and waste, off-site disposal raises the risk of future liabilities.
Market-Based Environmental Options	An active market in SO_2 and other pollution allowances is developing. Understanding the cost of reducing these emissions is key to establishing values for these allowances.
International Environmental Standards	TCA can be used as part of a management system to comply with ISO 14000, which requires that environmental standards be documented and followed. Certification may be required to maintain the customer base.
Public Relations/ Lobbying	Understanding the cost of this activity, and the costs of not participating in this activity, will help to rationalize the level of investment to be made.
Training	The best level of training (from a cost-benefit point of view) is easier to determine if the E&H benefits are quantifiable.

Source: Arthur D. Little

The TCA approach may be utilized at the process or product development stage or at other phases, as shown in Figure 1-3. The typical scope of a TCA may start within the walls of a facility, then move to supplier-partnering to select more environmentally benign materials or components of the process or product at competitive or lower costs. Then, when faced with customer or marketing requirements, companies may try to capture the total cost of ownership for the customer. During the design phase of a project, actual data collection is minimized and impacts assessed in a more qualitative manner. With each progressive move toward advancing the product or process into full production and distribution, the TCA process becomes more quantitative. The TCA process should also include any portion of the manufacturing process that is out-sourced.

Figure 1-3 Applications of the TCA Methodology



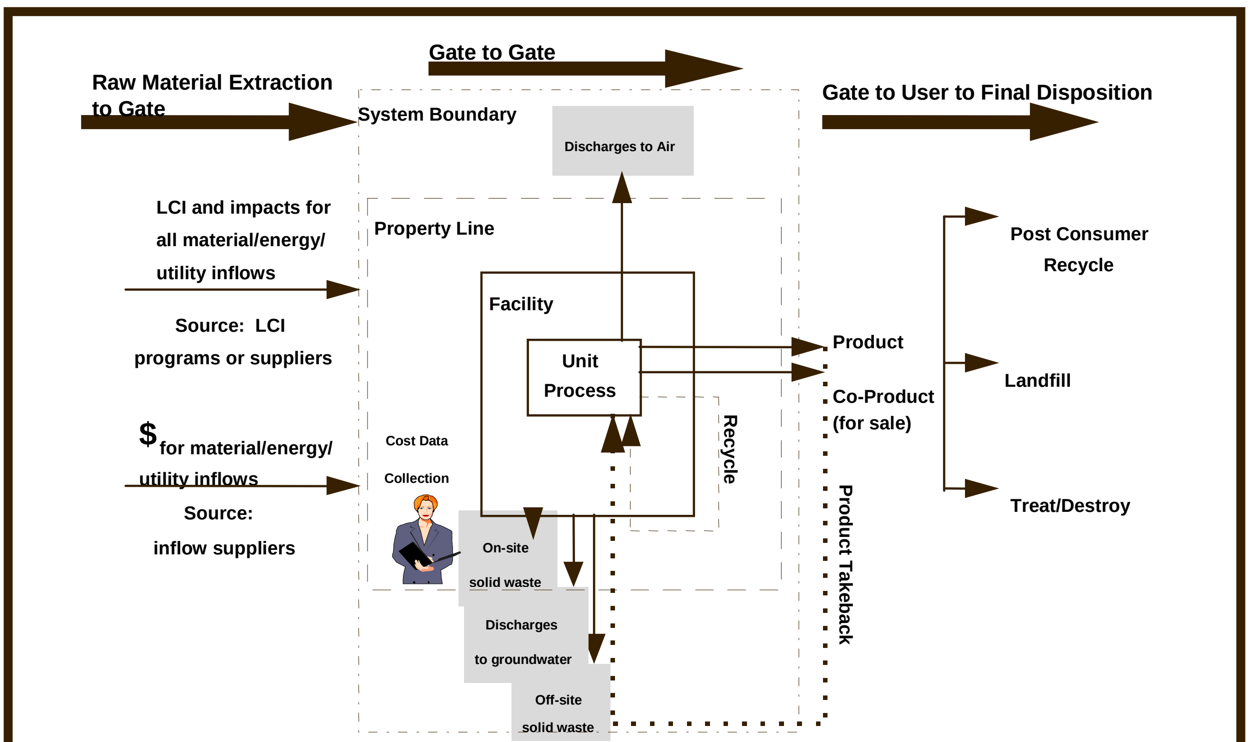
Source: Adapted from "Environmental Impacts on Life Cycle Costs", Jeannie C. Wood, President, Life Cycle Dimensions, Bedminster, New Jersey

1.4 The Relationship Between Life Cycle Assessment and Total Cost Assessment

The TCA method has the capability to evaluate the full life cycle perspective, considering the E&H implications from raw material extraction to end-of-life of the product/process (Figure 1-4). In some cases, a life cycle inventory for the product or process may have already been completed and available for incorporation into the TCA methodology. From a practical point of view, the intent is not to require a new and complete LCI for every TCA analysis, but to provide the use of "nearest neighbor" information as well.

Life cycle inventory is part of life cycle assessment (LCA), a method for examining the cradle-to-grave consequences of making and using products or services. LCA traditionally uses a quantitative approach to delineate material inputs and outputs. LCA, with its systems-oriented, cradle-to-grave scope, is an important tool for examining environmental impacts. LCA adopts a holistic approach by analyzing the entire life cycle of a product, process, package, material, or activity. However, since LCA is an emerging technology, upstream suppliers and downstream customers may not have the necessary data to provide data on all inputs and outputs.

Figure 1-4 Life Cycle Perspective



Source: Arthur D. Little

This life cycle perspective is consistent with the definition offered by the Society for Environmental Toxicology and Chemistry (SETAC), which states that "the life cycle concept is based on the recognition that a 'cradle-to-grave' perspective is critical to any evaluation" and "an inherently integrated concept. It is the best way to allow for the evaluation of economic, environmental, and energy dimensions of a problem at the same time."

Life cycle stages encompass:

- Extraction and processing of raw materials
- Manufacturing, transportation, and distribution
- Use/reuse/maintenance
- Recycling and composting
- Final disposition

It is not the intent of a LCA to analyze economic factors. However, the LCA can be used to create scenarios upon which a TCA can be performed.

We provide below a brief overview of LCA, to illustrate the integration of an LCA perspective into TCA; Appendix 1 provides additional background on LCA. These sections are not complete or rigorous descriptions of LCA.

LCA consists of four components, illustrated in Figure 1-5. These components are defined as:

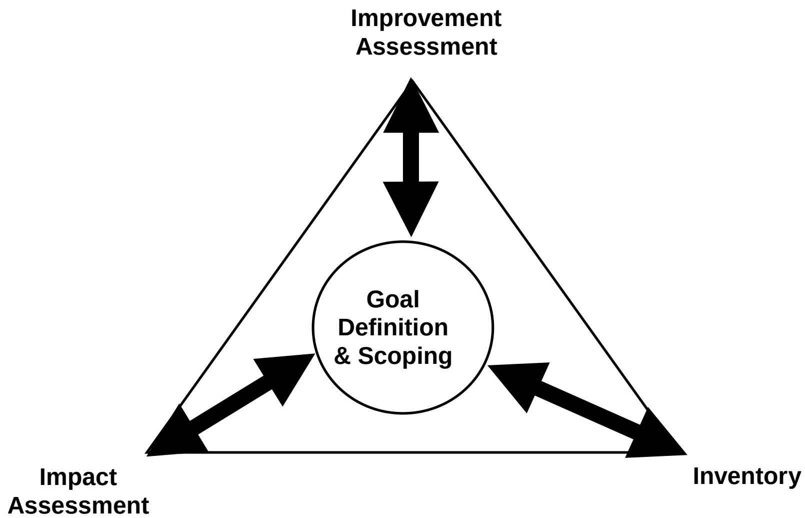
➥ ***Goal definition and scoping:*** the definition of the study purpose and objectives, the identification of the product, process, or activity of interest, the identification of the intended end-use study results, and the key assumptions employed.

➥ ***Life cycle inventory (LCI) analysis***: the identification and quantification of raw materials and energy inputs, air emissions, water effluents, solid waste, and other life-cycle inputs and outputs.

➥ ***Impact assessment:*** the qualitative and quantitative classification, characterization, and valuation of impacts to ecosystems, human health and natural resources, based on the results of the LCI.

➥ ***Improvement assessment:*** the identification and evaluation of opportunities to achieve improvements in processes that result in reduced environmental consequences, based on the results of the LCI or impact assessment.

Figure 1-5 The Life Cycle Assessment Framework



Source: *"A Technical Framework for Life Cycle Assessment",* SETAC, 1991.

Since TCA is a support tool for making informed decisions regarding E&H improvements, having a detailed understanding of the pollutants generated and the human health exposure effects for a product or process is essential. The outputs from the LCI can serve as inputs for the TCA methodology, where they are translated to an economic value. The detailed understanding of the LCI output also can allow better management of the costs driven by E&H requirements and provide focus for cost and risk reduction efforts.

For example, during the R&D phase of a project, the LCI output can be used to influence the design of a new process to minimize the probability of pollutant discharges, thus avoiding the additional cost of control technology during manufacturing. In new product development, the LCI output may guide the user to select raw materials that produce less pollution or waste from the finished product, or, as demonstrated by the case study provided in Appendix 1, to make better decisions regarding product configuration. The combination of the LCI with the TCA brainstorming sessions can also allow for the identification of potential risks, thus providing a means to minimize these risks. There are numerous examples of decisions during all phases of manufacturing that could benefit from understanding both the E&H impact and the associated cost of that impact to the industrial organization and to society.

However, the greatest benefit that TCA derives from using LCI or LCA inputs for the economic assessment for a project is the inclusion in the decision-making process of types of costs that were excluded previously. By translating the LCI/LCA inputs into economic assessments for contingent risk and liability, intangible effects, and external effects, a more comprehensive picture of the current and future costs and impacts becomes apparent.

One of the greatest obstacles, however, for both LCI/LCA and TCA is the availability of data for some materials and processes. Gaps and omissions in inventory data are inevitable due to many factors,[2] including:

- The differences in unit operations among alternative systems
- The lack of data for all inputs and outputs
- The overall quality of the data (e.g., completeness and representativeness)
- The complexity of environmental processes

Section 3 provides definitions and discussion of the CWRT TCA methodology, and will further elaborate on the interaction of LCI/LCA and TCA.

[2] "Evolution and development of the conceptual framework and methodology of life-cycle impact assessment." SETAC Workgroup on Life Cycle Impact Assessment. January 1998. SETAC Press.

2.0 Background

This section provides background and definitions of various environmental accounting approaches, to provide background for the TCA methodology. It also provides additional background with regard to the environmental costs that are included in the TCA methodology, and the relationship between LCA and TCA.

2.1 Definitions of Environmental Accounting Approaches

Environmental cost accounting methods may include:

- A firm's private costs only (i.e., those that directly affect the firm's bottom line), or
- Both private and societal costs, some of which do not show up directly or even indirectly in the firm's bottom line

Table 2-1 shows the synonyms commonly used in environmental cost accounting and their definitions. To add to the confusion, many life cycle terms are also used in connection with environmental cost accounting (also shown in Table 2-1). Even the life cycle terms that refer to the costing process are ambiguous. For example, some people view life cycle costing as referring only to private costs, while others view it as including both private and societal costs.

Table 2-1 Definitions of Environmental Cost Accounting and Life Cycle Terms

Term	Definition
Environmental cost accounting	Used to refer to the addition of environmental cost information into existing cost accounting procedures and/or recognizing embedded environmental costs and allocating them to appropriate products or processes
Full cost accounting	Used to describe desirable environmental accounting practices. In the accounting profession, full cost accounting is a concept and term used in various contexts. In management accounting, full costing means the allocation of all direct and indirect costs to a product or product line for the purposes of inventory valuation, profitability analysis, and pricing decisions
Full cost environmental accounting	Embodies the same concept as full cost accounting but highlights the environmental elements
Total cost accounting	Often used synonym for full cost environmental accounting and is a term that appears to have origins with environmental professionals. It has no particular meaning to accountants
Total cost assessment	Has come to represent the process of integrating environmental costs into a capital budgeting analysis. It has been defined as the long-term, comprehensive financial analysis of the full range of private costs and savings of an investment. Adding to the confusion, the acronym for total cost assessment (TCA) is the same as the acronym for total cost accounting (TCA)
True cost accounting	Less used synonym for full cost accounting. As defined by the US EPA, this term encompasses both private and societal costs, where full cost accounting encompasses costs that affect the bottom line.
Life Cycle Terminology Term	**Definition**
Life cycle design	Defined as an approach for designing more ecologically and economically sustainable product systems, integrating environmental requirements into the earliest stages of design. In life cycle design, environmental, performance, cost, cultural and legal requirements are balanced
Life cycle assessment	Described as a holistic approach to identifying the environmental consequences of a product, process or activity through its entire life cycle and to identifying opportunities for achieving environmental improvements. By itself, life cycle assessment focuses on environmental impacts, not costs
Life cycle analysis	Used as a synonym for life cycle assessment. The U.S. EPA uses the life cycle assessment term. Neither term addresses the costs and revenues of environmental consequences and improvements

Table 2-1 Definitions of Environmental Cost Accounting and Life Cycle Terms (continued)

Life Cycle Terminology Term	Definition
Life cycle cost assessment	Highlights the costing aspect of life cycle assessment. It has been called a systematic process for evaluating the life cycle costs of a product, product line, process, system or facility by identifying environmental consequences and assigning monetary value to these consequences
Life cycle accounting	Used to describe the assignment and analysis of product-specific costs within a life cycle framework including usual, hidden, liability and less tangible costs
Life cycle cost	The U.S. Office of Management and Budget defines this term as the sum total of the direct, indirect, recurring, non-recurring, and other related costs incurred by or estimated for the project in the design, development, production, operation, maintenance, and support of a major system over its anticipated useful life span. More recently, life cycle cost has been defined in an Executive Order as the amortized annual cost of a product, including capital costs, installation costs, operating costs, maintenance costs, and disposal costs discounted over the lifetime of the product. The term may also be used more expansively to include societal costs.

Source: Adapted from *"An Introduction to Environmental Accounting As a Business Management Tool: Key Concepts and Terms",* US EPA 742-R-95-001, June 1995.

2.2 Definition of Environmental Costs

Environmental costs may be defined in different ways, depending on the intended use of the information (e.g., cost allocation, capital budgeting, process/product design, or other management decisions). A cost may not be clearly defined as environmental. Some costs may be classified as partly environmental and partly not. The ultimate goal is to ensure that relevant costs receive appropriate attention (EPA, 1995).

Although there are many different ways to categorize costs, conventional accounting systems typically classify costs as:

- Direct materials and labor
- Manufacturing or factory overhead (i.e., operating costs other than direct materials and labor)
- Fixed or variable
- General and administrative (G&A) overhead[3]

[3] General and administrative costs may be pooled with sales costs (i.e., SG&A) or as part of technical, sales, and general administrative (i.e., TSGA).

- Research and development (R&D)

Environmental expenses may be grouped together into some, or all of these categories by different companies. To focus more attention on environmental costs during managerial decision making, the U.S. EPA's *Introduction to Environmental Accounting* and the Global Environmental Management Initiative (GEMI) environmental cost primer use similar organizing frameworks. These frameworks distinguish costs that generally receive management attention, termed the "usual" costs or "direct" costs, from costs that may be obscured because they are grouped as overhead or R&D costs. These costs are distorted through improper allocation to cost centers, or simply overlooked and are termed "hidden," "contingent," "liability," or "less tangible" costs[4]. Figure 2-1 lists examples of these costs under the labels "conventional," "potentially hidden," "contingent," and "image/relationship" costs (EPA, 1995).

[4] The EPA's *Pollution Prevention Benefits Manual (October 1989)* introduced the terminology distinguishing among usual, hidden, liability and less tangible costs. This framework was largely adopted in *Finding Cost-Effective Pollution Prevention Initiatives: Incorporating Environmental Costs into Business Decision Modeling (1994, Global Environmental Management Initiative (GEMI)),* which uses the terms direct, hidden, contingent liability, and less tangible costs, and was incorporated into EPA's *Introduction to Environmental Accounting*, 1995).

Figure 2-1 Examples of Environmental Costs Incurred by Firms

Potentially Hidden Costs		
Regulatory	**Upfront**	**Voluntary (Beyond Compliance)**
Notification	Site studies	Community relations/outreach
Reporting	Site preparation	Monitoring/testing
Monitoring/testing	Permitting	Training
Studies/modeling	R&D	Audits
Remediation	Engineering and procurement	Qualifying suppliers
Recordkeeping	Installation	Reports (e.g., annual environmental reports)
Plans		Insurance
Training		Planning
Inspections	**Conventional Costs**	Feasibility Studies
Manifesting	Capital equipment	Remediation
Labeling	Materials	Recycling
Preparedness	Labor	Environmental studies
Protective equipment	Supplies	R&D
Medical surveillance	Utilities	Habitat and wetland protection
Environmental insurance	Structures	Landscaping
Financial assurance	Salvage Value	Other environmental projects
Pollution control		Financial support to environmental groups and/or researchers
Spill response	**Back-End Costs**	
Stormwater management	Closure/decommissioning	
Waste management	Disposal of inventory	
Taxes/fees	Post-closure care	
	Site survey	
Contingent Costs		
Future compliance costs	Remediation	Legal expenses
Penalties/fines	Property damage	Natural resource damage
Response to future releases	Personal injury damage	Economic loss damages
Image and Relationship Costs		
Corporate image	Relationship with professional staff and workers	Relationship with lenders
Relationship with customers	Relationship with insurers	Relationship with communities
Relationship with investors	Relationship with suppliers	Relationship with regulators

Source: *"An Introduction to Environmental Accounting as a Business Management Tool: Key Concepts and Terms",* USEPA 742-R-95-001, June 1995.

EPA (1995) defines these costs as follows:

1. The conventional costs of using raw materials, utilities, capital goods and supplies (shown within the dashed line in Figure 2-1) are usually addressed in cost accounting and capital budgeting, but are not usually considered environmental costs. However, decreased use and less waste of raw materials, utilities, capital goods, and supplies are environmentally preferable, reducing both environmental degradation and consumption of non-renewable resources. It is important to factor these costs into business decisions, whether or not they are viewed as "environmental" costs.

2. Potentially hidden costs that may include upfront environmental costs, which are incurred prior to the operation of a process, system, or facility, and can include costs related to siting, design of environmentally preferable products or processes, qualification of suppliers, evaluation of alternative pollution control equipment, etc. Whether classified as overhead or R&D, these costs can easily be overlooked when managers and analysts focus on operating costs of processes, systems, and facilities. Second, regulatory and voluntary environmental costs incurred in operating a process, system or facility may traditionally have been treated as overhead, and thus may not receive appropriate attention from managers and analysts responsible for day-to-day operations and business decisions. The magnitude of these costs also may be more difficult to determine as a result of their being pooled in overhead accounts. Third, while up front and current operating costs may be obscured by management accounting practices, back-end environmental costs may not be entered into management accounting systems at all. These environmental costs of current operations are prospective, meaning they will occur at more or less well-defined points in the future. In bringing these potentially hidden costs to light, it also may be useful to distinguish among costs incurred to respond to past pollution not related to ongoing operations; to control, clean up, or prevent pollution from ongoing operations; or to prevent or reduce pollution from future operations.

3. Costs that may or may not be incurred at some point in the future, called contingent costs, can best be described in probabilistic terms, including their expected value, their range, and/or their probability. Examples include the costs of remedying and compensating for future accidental releases of contaminants into the environment (e.g., oil spills), fines and penalties for future regulatory infractions, and future costs due to unexpected consequences of permitted or intentional releases. These costs may also be termed "contingent liabilities" or "contingent liability costs." Because these costs may not currently be recognized, they may not receive adequate attention in internal management accounting systems and decision-making for the future.

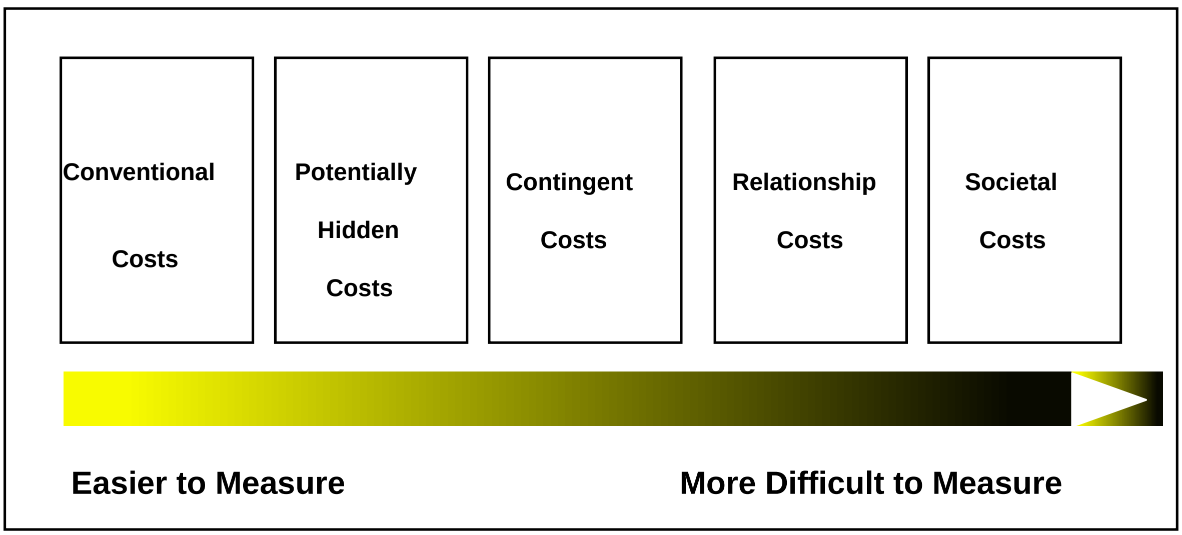
4. Some environmental costs are called "less tangible" or "intangible" because they are associated with subjective (though potentially measurable) perceptions of management, customers, employees, communities, and regulators. These costs have also been termed "corporate image" and/or "relationship" costs. This category can include the costs such as annual environmental reports, community relations

activities, costs incurred voluntarily for environmental activities (e.g., tree planting), and costs incurred for pollution prevention award/recognition programs. The costs themselves may not be "intangible," but the direct benefits that result from relationship/corporate image expenses often are. Corporate images and relationships are also likely be associated with the market share of a corporation.

As previously shown in Table 1-3, these costs are included in this TCA methodology.

When environmental accounting extends beyond conventional costs to include potentially hidden, future, contingent and image/relationship costs, firms may find it more difficult to assess and measure certain environmental costs, as illustrated in Figure 2-2.

Figure 2-2 The Spectrum of Environmental Cost



Source: "An Introduction to Environmental Accounting As A Business Management Tool: Key Concepts and Terms," EPA 742-R-95-001

3.0 Total Cost Assessment Methodology

The objective of this TCA methodology is to provide a disciplined and standardized approach to improve business decisions by better evaluating the complete realm of potential E&H costs that are experienced by companies, and that may impact the environment and society. This is a very ambitious goal that is difficult to attain for numerous reasons including limited resources, incomplete understanding of technical issues, and different social perspectives. However, the awareness and understanding that these are real cost impacts is growing, as is the knowledge that quantifying these cost impacts is important for improving business decisions.

3.1 Overview

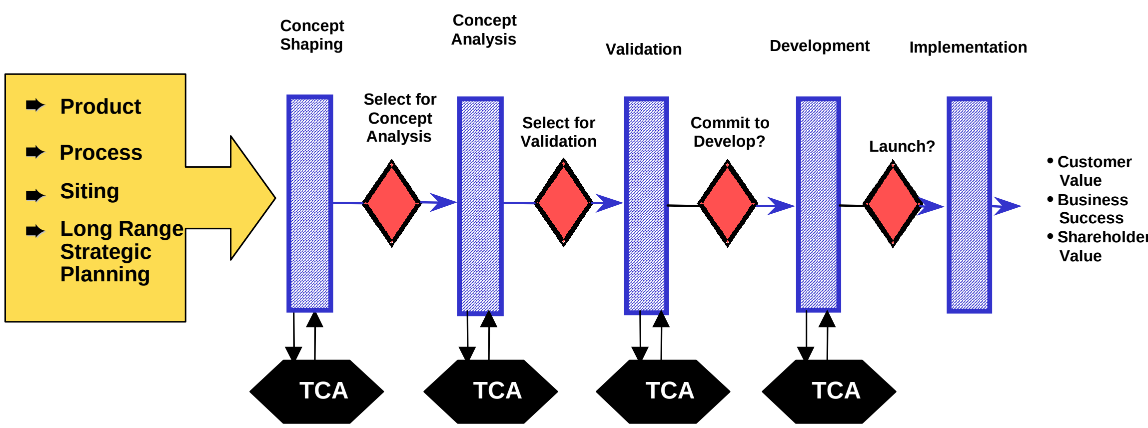
The approach presented in this chapter recognizes that the broad range of costs potentially incurred by a company can be categorized in many ways. These cost types were introduced in earlier chapters as Types I through V. From a decision-making perspective it is important to recognize that some costs are well defined and understood, while others are less well understood in terms of both a consequence and a probability of occurrence. Some of these costs may be direct costs that are routinely allocated in bundles across a company's operational groups, while others are related to potential future contingent costs, such as possible remediation activities or impacts on market share.

During the normal course of industrial product or process development, modification, or termination, the cost assessment of operations from research and development (R&D) to project implementation are understood. However, E&H costs, a subset of overall project costs, have frequently been underestimated or neglected. This TCA methodology prompts the practitioner to consider all the potential E&H costs, which can potentially impact the company as a result of decisions made relative to a specific project or product implementation. In some cases, this approach will include identifying E&H costs that are directly experienced by a company, but are often not directly visible in the day-to-day internal cost accounting systems. The TCA practitioner will be able to develop more comprehensive cost estimates that include E&H costs that may be associated with less tangible risks.

It is envisioned that the TCA tool will be useful in various phases of projects and for a wide variety of decisions. Figure 3-1 offers a view of the applications and areas where the tool may provide a basis for an improved decision.

Regardless of the application, the information provided by the TCA tool will largely consist of costs for certain aspects of a project, and a more complete description of risks that a project may pose now and in the future. While this TCA approach attempts to identify benefits and costs avoided as well as actual costs, the developers recognize that additional information is needed to ensure that a sound business decision is made. Therefore, the TCA tool does not represent a stand-alone decision tool. Instead it has been developed to incorporate environmental and health issues more effectively than has been done in the past in the business decision process. It is also intended to help bridge the gap between hard and soft financial values and the currently non-monetized concept of corporate sustainability goals.

Figure 3-1 Where Does TCA Fit in the Overall Framework of Project Evaluation?



The manual TCA method was beta tested at several sites; the findings of these beta tests are incorporated in the discussions below.

3.2 TCA Method

An overview of the TCA method, and a detailed discussion of each step of the TCA is presented in this section. The flowcharts presented in this section provide a schematic view of the TCA process.

3.2.1 Overview of the Method

Following is an overview of the TCA method; each step is described in greater detail in the following subsections.

The general procedure and concept for applying this TCA method and its related spreadsheets is outlined in Figure 3-2. This approach consists of six main steps with a final step that is actually a feedback loop into the company's main decision process. The first four steps of the TCA approach are further defined with more detailed concept flow charts in Figures 3-3 through 3-6, respectively.

The purpose of the first three steps is to clearly define what aspects of the project or alternatives are important enough to carry forward and to cost. Once these first three steps have been completed, the financial inventory is developed for each project or alternative. This is shown as a shaded area on Figure 3-2.

Figure 3-2

Overview – Total Cost Assessment Methodology

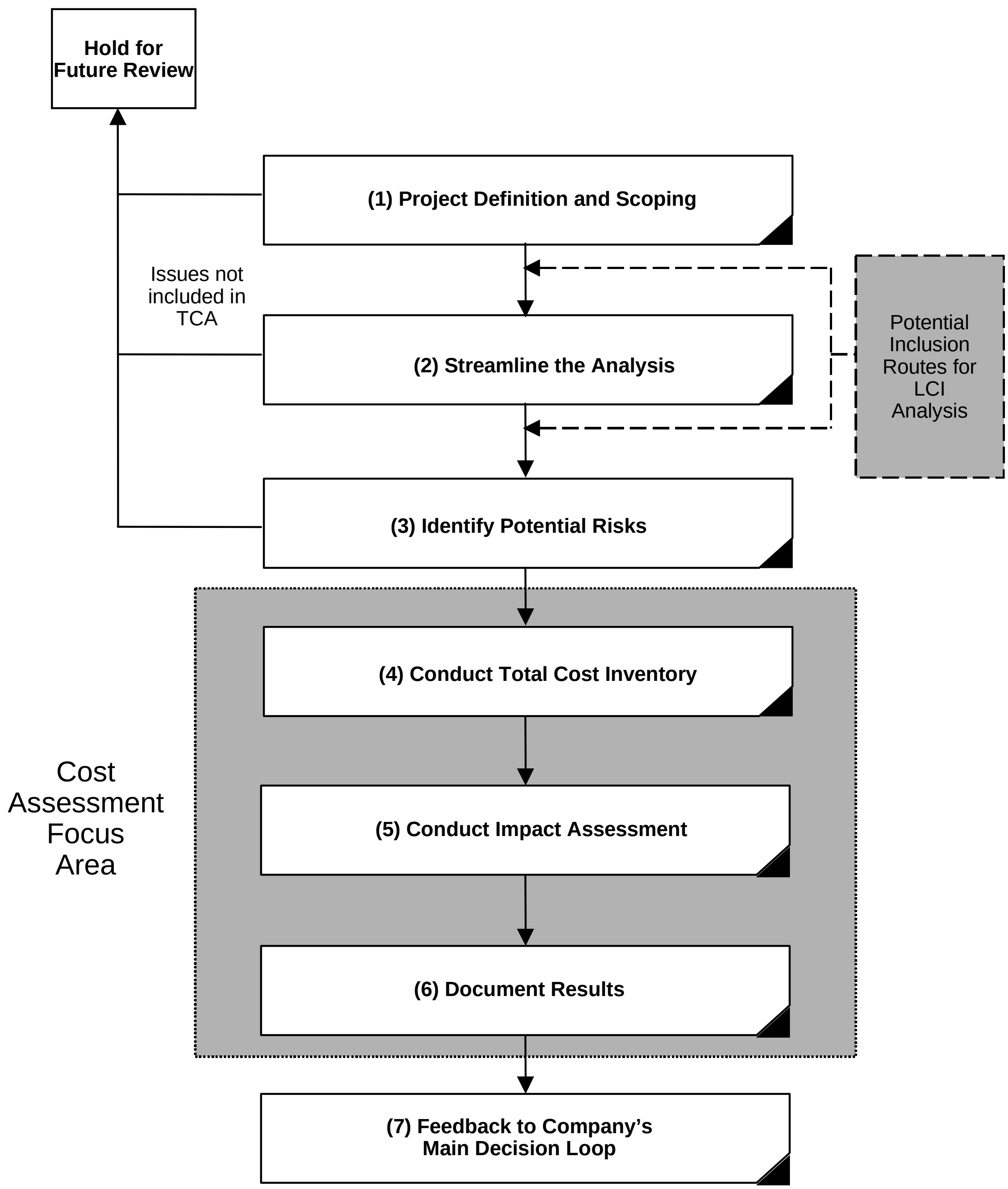


Figure 3-3

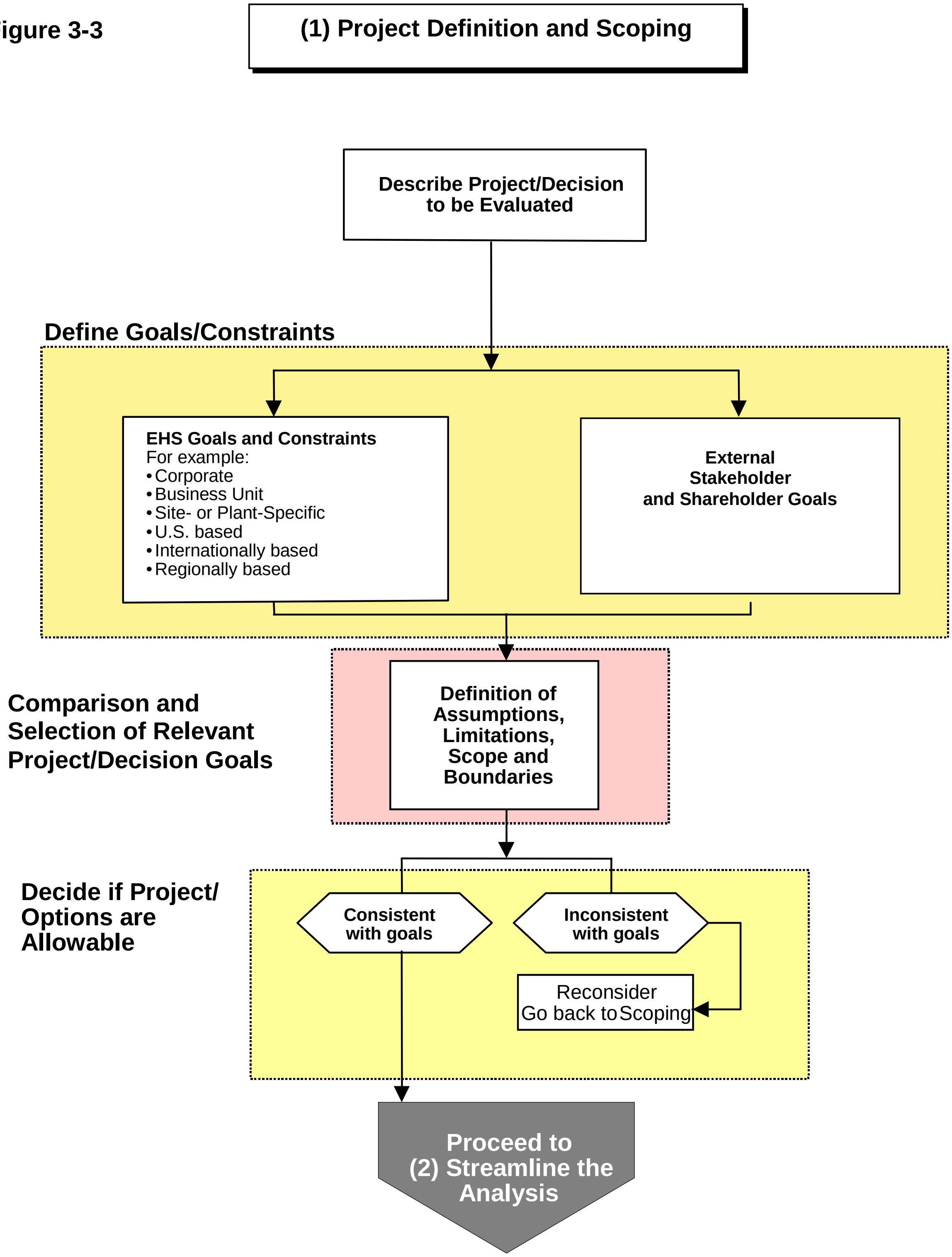

(1) Project Definition and Scoping
Describe Project/Decision to be Evaluated
Define Goals/Constraints
EHS Goals and Constraints
For example:
• Corporate
• Business Unit
• Site- or Plant-Specific
• U.S. based
• Internationally based
• Regionally based
External Stakeholder and Shareholder Goals
Comparison and Selection of Relevant Project/Decision Goals
Definition of Assumptions, Limitations, Scope and Boundaries
Decide if Project/ Options are Allowable
Consistent with goals
Inconsistent with goals
Reconsider Go back to Scoping
Proceed to (2) Streamline the Analysis

Figure 3-4

(2) Streamline the Analysis

From Step 1

↓

Define Impact Categories from LCI/LCA/Brainstorming Results

↓

Review Impact/Categories

Examples include:

1. Sustainable Metrics:
   - Material Intensity
   - Energy Intensity
   - Resource Depletion
   - Pollutants and Toxics
     - Greenhouse gases
     - Photochemical ozone creation potential
     - Eco-toxicity
     - Human health effects
     - Acidification
     - Eutrophication
2. Type III, IV, and V Impact Categories in Cost Spreadsheets
3. Others such as LCI Characterization Scheme, Product Social Impact, etc.

↓

List/Select Life Cycle/Process Steps Included in Analysis

↓

List scenarios of concern (from LCI)

↓

Proceed to (3) Identify Potential Risk

Figure 3-5

(3) Identify Potential Risks for Type III, IV and V

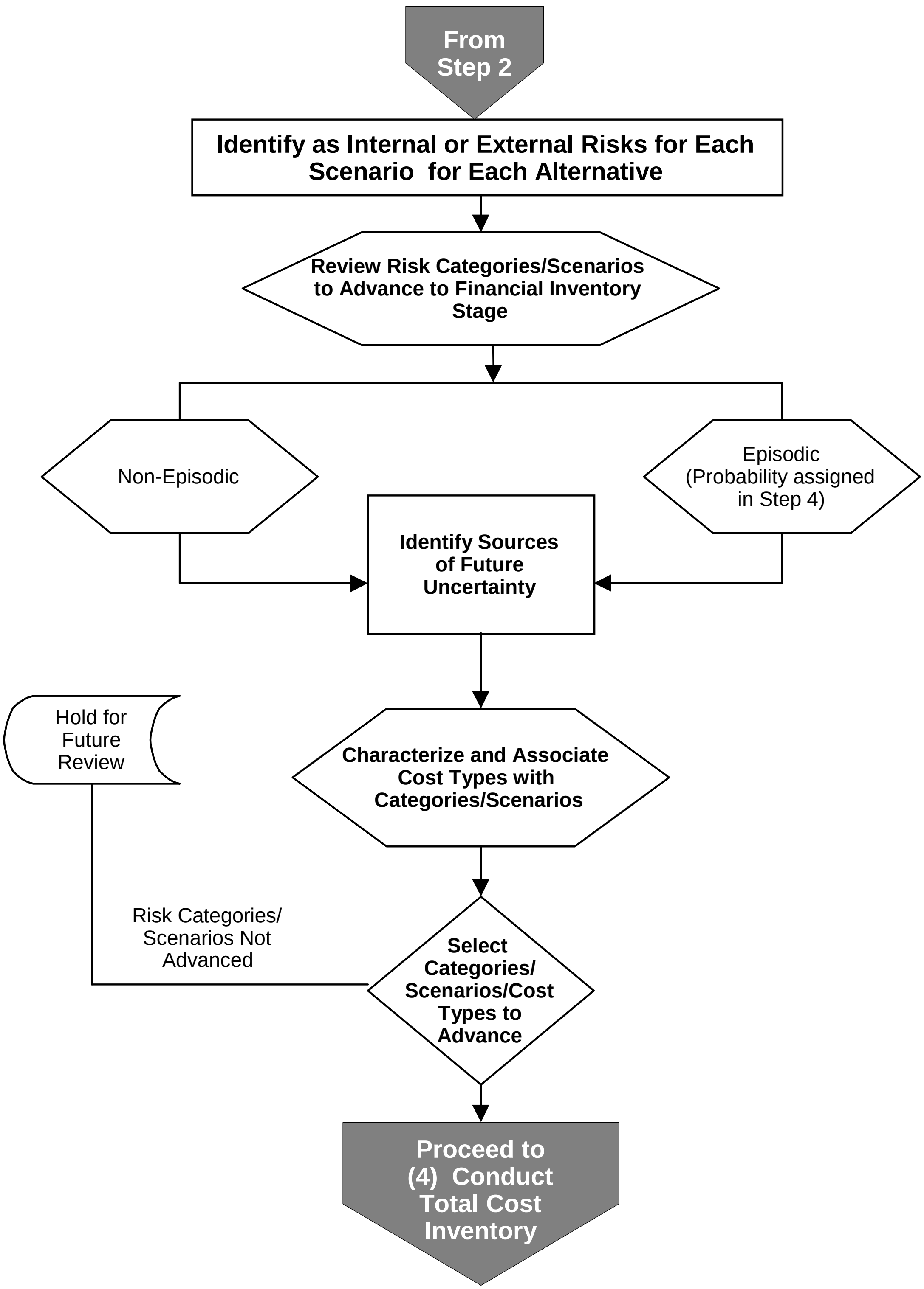
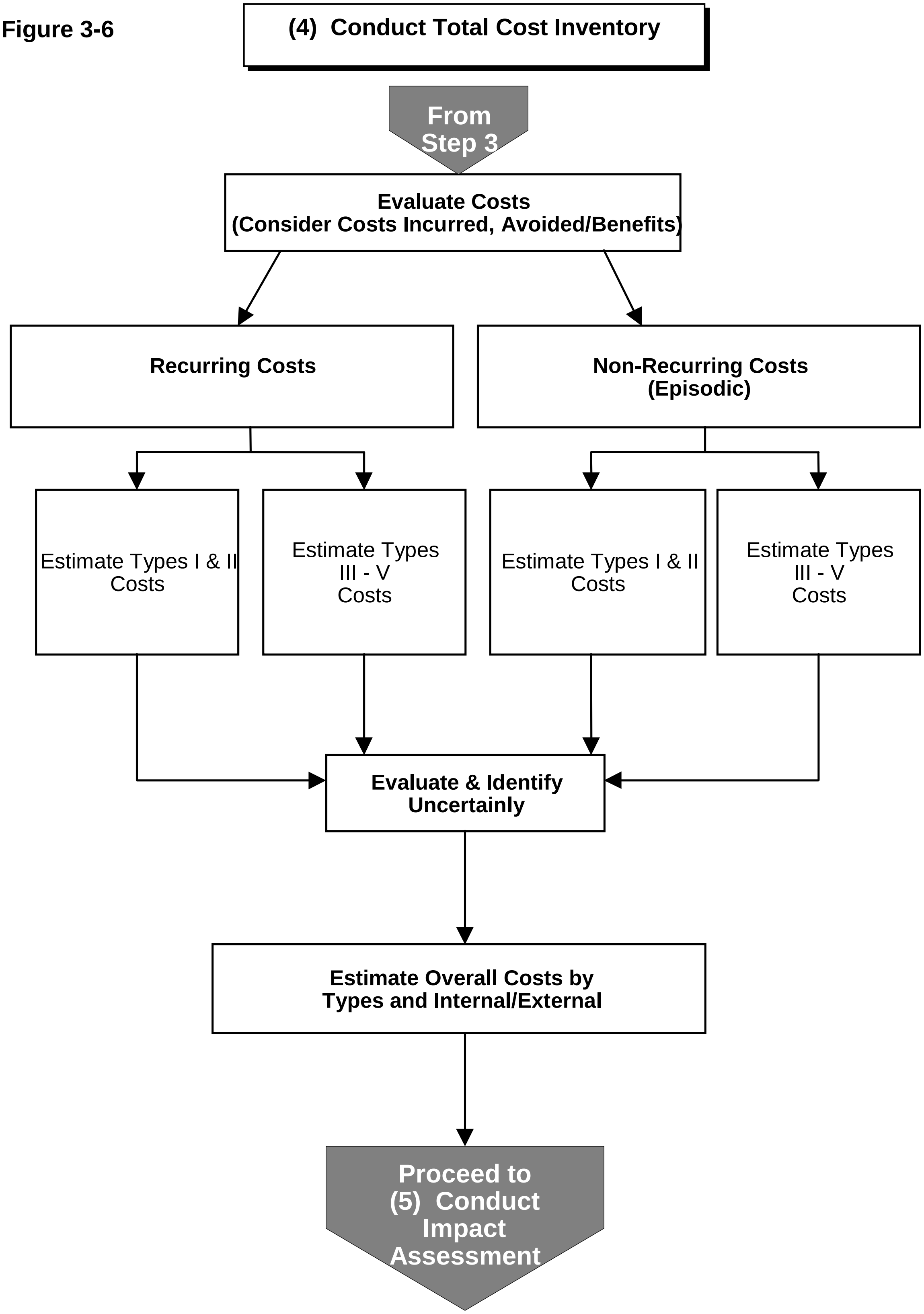


Figure 3-6


(4) Conduct Total Cost Inventory
From Step 3
Evaluate Costs (Consider Costs Incurred, Avoided/Benefits)
Recurring Costs
Non-Recurring Costs (Episodic)
Estimate Types I & II Costs
Estimate Types III - V Costs
Estimate Types I & II Costs
Estimate Types III - V Costs
Evaluate & Identify Uncertainly
Estimate Overall Costs by Types and Internal/External
Proceed to (5) Conduct Impact Assessment

The first step, **Goal Definition and Scopind**, requires a clear identification and definition of the project and purpose of the TCA analysis. A Goal Definition and Scoping Spreadsheet is contained in Appendix 2 to ensure that certain goals and constraints are considered in the process.

The second step, **Streamline the Analysis**, refines the first step by connecting the objectives and other elements of the decision at hand to sustainability metrics and impact categories. This step also provides for the incorporation of life cycle information and other critical information (e.g., results of brainstorming sessions). A risk identification and screening spreadsheet is supplied in Appendix 2 to help identify critical E&H aspects of a project or alternative.

The third step, **Identify Potential Risks**, evaluates the relative importance of the impact categories based on the current feasibility of expressing the costs for each category for an alternative or project. The hierachy that is presented in the TCA process requires that a clear definition of the issue/decision to be investigated is created. From this definition, alternatives or options are defined. Each alternative or option can have numerous and unique risk/cost scenarios. In this third step, all the scenarios that will be costed for each alternative are defined and the cost drivers (e.g., compliance obligations, remediation costs) are specified.

The beta testing of this methodology showed that the entire TCA process is really performed in an iterative manner. This is particularly true for the third step, since it may take several discussions with other project members to determine how to best identify and cost risks associated with a certain scenario. Nevertheless, at completion of step three, each alternative should be thoroughly mapped so that the actual costing and analysis functions can begin.

The fourth step, **Conduct Financial Inventory**, focuses on two different costing approaches. The first costing task is to define the Type I and II costs, which are derived from a company's internal cost accounting system. The second costing task is to evaluate the Type III, IV, and V potential costs. This group of cost categories is likely to have significant uncertainties associated with establishing the magnitude of the cost and probability of occurrence, as well as identifying the type of cost that may actually be expected. Therefore, the TCA methodology focuses significant attention on Types III, IV, and V costs. To assist the user, several cost databases and descriptions of how some cost values could be represented have been developed. These cost databases are defined and summarized in later sub-sections of this chapter.

The fifth step**, Conduct Impact Assessment**, involves conducting data analysis and review as part of an impact assessment. This step addresses the fact that the TCA has developed and assigned costs from very different sources of data, that may have different reliability and uncertainty profiles. Therefore, at this point in the TCA, it is important that the costs be reviewed to determine the largest cost contributors for each category and to assess how that information may be best incorporated into the overall decision process. For example, a review of total Type I and II costs would likely provide an assessment of the costs that are best understood by a company (although not in all cases). The user may want to include some or all of the Type III costs developed in Step 4 with the Type I and II costs to assess how these costs may change the analysis or decision. The same approach could be used to include the Type IV and V costs in the analysis. Obviously, this will depend on the project or alternative that is being evaluated and the degree of confidence that the user has in the costing approach. It is often useful to include Type III, IV, and V costs under two different risk profiles. One risk profile could represent the most probable future scenario, while the other future scenario may be representative of a more worst case situation.

The sixth step in the TCA, **Document Results**, is to document the assumptions and results of the TCA. It is important to carefully document the TCA process. The spreadsheets that are provided allow for comments and descriptions for each scenario and cost decision. Nevertheless, additional documentation regarding the use of life cycle information and other company-specific data may be critical to the usefulness of this analysis. This is particularly true for those impact categories that may have been identified as important potential E&H impacts, but are not currently feasible to cost in the analysis.

Finally, as shown in Figure 3-2, the last step, **Feedback to Company's Main Decision Loop**, is a feedback loop to the main decision process within the company. This step recognizes that the TCA is only one element or input to an overall decision process that needs to include many types of information. More importantly, the TCA process recognizes that improvements in communications and information sources do not replace good judgement, but should enhance the opportunities for good judgement to make greater contributions to economic value and societal needs.

3.2.2 Manual TCA Methodology

The manual TCA methodology is a spreadsheet-based evaluation tool. There are two main sets of spreadsheets:

1) The first set of spreadsheets acts primarily as a qualitative tool to query the user to make sure that corporate goals and other critical project constraints are identified and accounted for in the TCA project scoping and evaluation.
2) The second set are cost spreadsheets, that act as a checklist to ensure that a comprehensive set of E&H costs are represented, and also provide the cost recordkeeping and summation functions. Since in most situations it will not be important to break out all the separate cost items (as listed in the spreadsheet), a comment field is available to document each cost. This will help to ensure that these separate cost items are included in the larger cost categories and ensures that the analysis is documented.

These spreadsheets are contained in Appendix 2 and the use of the spreadsheets is explained later in this section.

The first set of spreadsheets, combined with LCI/LCA/Company Brainstorming session results and scenario definitions, are used to define the TCA project and the alternatives or options that are to be costed in the TCA. In practice the user will most likely rely on a multi-functional team of experts that cover the relevant areas (e.g., internal cost accounting, production operations, marketing and sales, etc.) to define the attributes or scenarios that will be evaluated as part of any project or alternative. This first set of spreadsheets is intended to assist this team in developing a thorough framework. For each alternative, a separate set of cost spreadsheets will be developed. In this manner each alternative can be evaluated and then significant cost drivers, uncertainties, and overall risk can be evaluated.

3.2.3 Steps of the TCA

3.2.3.1 Goal Definition and Scoping

Before a TCA is begun, the purpose for the activity must be defined, because TCA studies are performed in response to specific questions. The nature of the questions determines the goals and scope of the study. TCA studies are, typically, comparative in nature, and are used in making a decision. A company may be deciding whether to fund or promote a new process, a new product, or a different type of package for the product. Consumers may be faced with a choice that industry wants to influence in an environmentally positive manner. The *Goal Definition and Project Scoping* step is crucial in defining a focused TCA.

The type of decision relates to establishing the basis for analysis. There are four types of decisions that are fairly typical for these types of analyses. These are:

Baseline analysis: evaluate existing baseline process or product to determine its impact on the environment and the cost associated with production and with that impact

Baseline vs. baseline analysis: compare existing process or product with other existing processes that are competing for existing manufacturing consideration or capacity or for benchmarking competitors' processes or products

Baseline vs. new analysis: compare existing process or product with new products or processes

New vs. new analysis: compare new processes or products for purposes of selecting future industrial operations with the lowest impact, risk and cost

The practitioner defines the scope of the project by making applicable choices in the spreadsheet or documenting the scope in another manner. By selecting the choices that apply to a specific decision, and characterizing the choices as mandatory or desirable, the boundaries of the decision can be established.

Corporate, Business Unit, and/or Site Goals and Drivers

Many corporations have voluntary E&H programs that can impact the decision analysis. For instance, if a company has a voluntary initiative to reduce greenhouse gas emissions by a targeted amount, accompanied with a deadline, this could potentially impact the project decision. Alternatively, if a company has a Sustainable Development program that strongly encourages energy efficiency and dematerialization, this policy can also drive costs incurred or can produce cost reductions. A properly framed goal statement will include cost drivers at all levels of the corporation. This prevents having to modify the results of the decision following implementation.

The spreadsheet has four worksheets that contain possible corporate, business unit, and/or site goals and drivers. They include potential sustainability, environmental, siting and human health policy impacts. The spreadsheet can be modified by the user to include external stakeholder's goals related to the community, shareholders, or other stakeholders.

Sustainability. In this worksheet, the seven goals of eco-efficient industrial operations are included. These goals are translated to potential project goals. The practitioner decides if these goals are applicable, and, if so, whether they are mandatory or desirable. Mandatory goals are those that are required by the company's policies. Desirable goals are balanced against the cost-to-implement and the impact on the overall project goals.

Environmental. Many corporations have environmental strategies and policies that are designed to go "beyond compliance." These policies can incorporate the principles of pollution prevention, design for the environment (DFE), Green Chemistry, and other voluntary programs into product, process, or activity designs. This worksheet contains potential industrial environmental impacts that many corporations monitor and develop programs to reduce the impact.

Site Constraints. Site constraints are defined as local site policy, geographic, political or community pressures that define limitations or corporate goals for E&H improvements. The geographic location of a manufacturing process can present constraints or extra costs based on the physical location and the sensitivity of the geographic area to impacts caused.

Human Health. Human health impacts that may be associated with the processes or products under consideration are listed in this worksheet. These human health impacts may need to be considered in the decision analysis.

3.2.3.2 Streamline the Analysis

In the Goal Definition and Scoping step, the practitioner defined the "world" of goals and constraints that potentially exist, as dictated by internal corporate policies and goals and external pressures and regulations. Streamlining the goals and constraints connects external goals and constraints (i.e., these goals and constraints that are not generated by the decision under evaluation, but are developed external to the decision) to the specific decision. The goals and constraints defined in the previous section should be reviewed closely to determine their applicability to the specific decision to be made. If they are applicable, are they major cost drivers? Streamlining encourages the practitioner to include in the TCA only the major impacts on the decision, those that have the potential to incur large costs or are important impact categories.

Methods of streamlining may include the following:

- Focusing on specific E&H impacts or issues
- Limiting or eliminating life cycle stages (if it is determined in the previous matrix that this stage is not applicable or has minimum impact or is common to all alternatives)
- Using qualitative data as well as quantitative data
- Using surrogate data (where actual data is not readily available)
- Establishing criteria to be used as "show stoppers" in the **GOAL** statement
- Limiting the constituents studied to those meeting a threshold value

Streamlining allows the practitioner to tailor the goals and constraints to a subset that are directly applicable to the specific decision and narrows the scope of the analysis to the relevant activities that may influence the decision. Because streamlining reflects corporate values, the practitioner must define the streamlined goals and constraints. The method of streamlining and the rationale for the elimination of some goals and constraints should be documented. The streamlining process is a relative process that does not involve direct costing of options, but a more general comparison of attributes that may be more or less important for any particular decision.

3.2.3.3 Identify Potential Risks for Type III, IV and V Costs

When E&H costs, impacts, and benefits are not included in the decision-making process, valuable opportunities can be lost that could benefit both product marketing and company image. Improved product marketing generates revenues. Improved understanding and management of hidden E&H costs and impacts can benefit the "bottom line" in terms of reduced operating costs and, potentially, capital costs, thus meeting stakeholder expectations and providing competitive advantage.

How does this methodology different from traditional investment analysis?

- The sets of cost and benefit items included are broader than in traditional analyses
- Risk and uncertainty are dealt with in a systematic fashion
- The methodology assists in quantifying items that are usually left unquantified (intangibles and externalities)
- Traditional overhead items are assessed and allocated to a specific project or process

The intent of this methodology is to supplement the normal business decision-making process ensuring that E&H costs, benefits, and impacts are well understood and are included as a factor in the overall decision-making process.

The risk identification approach utilized in this tool is presented in Figure 3-5. The critical step in this process is the characterization of each risk scenario. An alternative or project can have several risk scenarios in terms of the cost types and drivers. In this step, the user must determine which scenarios will be carried forward and accounted for in the financial inventory. Those scenarios that are not carried forward may be held for future review, but are not included in the financial inventory task.

3.2.3.4 Conduct Financial Inventory

As discussed earlier, the TCA methodology will use a multi-disciplinary team to define potentially viable alternatives for a particular project or decision. It is anticipated that the Types I and II costs for each alternative will be derived from a company's internal cost accounting system, or may be developed by the project team from prior projects or engineering expertise. Then, the team will work together to shape or build the scenarios or events that could have associated Type III, IV, or V costs. For each scenario (for example, the potential future liability for offsite disposal or the risk of damages related to spills) the team will define the cost drivers for each cost type. Embodied in these formative team discussions will be the identification of probabilities of occurrences and the uncertainties associated with the magnitude and time frame of cost impacts. Each alternative may have several scenarios with potential impacts that require the evaluation of Types III, IV, and/or V costs. In addition, some LCI data may be available to allow for the costing of some outflows as Type V costs. An example of how this approach can be applied is presented in Appendix 3 for a hypothetical case.

Types I and II Costs

Types I and II costs represent direct costs to the project and allocated corporate overhead costs, respectively. Generally, these costs will be determined from a company's internal cost accounting system, or from the economic evaluation and capital project estimation groups. These cost accounting systems are typically very company-specific and have been developed to provide ease of accounting and billing processes. Typically they have not been developed to provide insight into the specific and actual E&H costs incurred. Therefore, interpreting and assigning E&H costs to specific projects and decisions from internal cost accounting systems should be undertaken with care.

It will be critical to include a person knowledgeable in the workings of the company's internal cost accounting systems in the TCA process. In addition, to ensure that E&H costs are appropriately included and accounted for will likely require the expertise of an E&H professional. Below, a few of the critical aspects that should be considered in review of the internal cost data for Types I and II E&H and other cost categories are summarized.

Internal cost accounting systems can be very simple, but can also be very complex with numerous cost categories. The most simple system will typically roll costs up to the plant level with major sub-headings for the largest recurring cost items (e.g., raw materials and energy). More complicated systems will track costs by major categories and sub-categories at a department or divisional level. In recent years, activity-based cost accounting systems have been developed and implemented. The main difference with activity-based systems is that they are designed to identify and track critical processes for manufacturing (or performing work) on a process basis as opposed to an organizational basis. Regardless of the internal cost accounting system in place, care needs to be taken in using these databases to represent the known costs related to E&H, as well as those attributed to a process or product.

Other factors to consider in using data from internal cost accounting systems include the manner in which fixed and variable costs are identified and allocated. This can be an important factor if the decision alternatives include various levels of production, because then the user needs to be sure that the variable costs are handled consistently in the development of the cost profiles. The user should also be aware that some cost systems track actual costs, while others present what appear to be actual costs but may actually be normal or standard costs. The normal or standard costs are often used in manufacturing operations to ease the accounting process and to provide better measures of efficiencies and productivity. Regardless of the internal system, the main point identified here is that the user must have a clear understanding of what these costs represent.

The Types I and II cost spreadsheets in Appendix 2 were developed from industry checklists for typical project and E&H cost categories, as well as with collaborators' input from beta testing and other experiences. In the beta testing, these cost spreadsheets were useful as a checklist to aid in understanding the company's internal cost accounting systems and allowing for adjustments. They are not intended to force a user to find a specific cost for each potential cost driver listed in the spreadsheet. Instead, the spreadsheets are intended to ensure that the user understands whether a particular cost driver is critical to consider in using TCA to evaluate the project or alternative.

If it is decided that a cost driver is important, then the user should make sure that costs are included for the driver in this step. This means that the cost driver must be appropriately accounted for, either by entering a specific cost for the driver, or by including the cost with other charges in a general overhead category. For example, if the project or alternative has a siting component to it, then the user should make sure that due diligence activities are included in the costs for this project/alternative. In many accounting systems, due diligence activities are included in general corporate overhead charges. Therefore, if the user knows that corporate overhead charges include due diligence activities, then a specific due diligence cost does not need to be broken out of overhead costs. The key concept is that the user should know that all, or as many as practical, E&H costs associated with a project or alternative are included in the Types I and II cost sections of the TCA.

Another important consideration for the user is the time frame and type of cost comparison that is desired for the TCA. These two factors will dictate how the costs will be developed and rolled up in the TCA. The time frame is important for several reasons. First, certain projects may require a large upfront investment. The time frame selected will feed into the type of cost comparison desired, for example, annual costs per year (i.e., capital and O&M costs represented together on an annual basis) or costs as incurred. Related to this question will be the choice of discount rates and how long into the future the TCA will cover after the useful life of the equipment is over. In addition, a cashflow analysis may be more useful for some decisions. Thus, the TCA user must review their internal cost systems to see how depreciation and other items will affect the analysis/decision and decide how these items should be evaluated.

This text is not intended to tell the user how to best develop the Type I and II costs, because that will be highly company-specific and related to the decision or alternative being evaluated. However, the point is that these issues need to be recognized and considered in the evaluation of the internal costs, and then a consistent concept should be followed through the development of the Types III, IV, and V costs so that the data are reasonably comparable.

Types III, IV, and V Costs
The development of Type III, IV and V costs will be critically dependent on the decision, project, or alternatives that are under evaluation. The intent here is to allow a user to cost a single baseline case from Type I through Type V costs, or to cost multiple alternatives which can then be compared. Recognizing that is very difficult, and in many cases not currently practical, to develop meaningful cost estimates, the TCA Work Group decided that it would be useful to perform a survey of some of the costing approaches that have been developed. The survey results are presented in Section 3.3, 3.4, and 3.5 and are intended to offer the TCA user a "starting point" that they can expand upon, using company-specific data, published references, and/or research in progress.

An important and controversial area, necessary for summing all cost types, is the choice of the discount rate for the Type V externalities. Each user, group, or company will need to make this decision based on their own assessment of the situation. It is recommended that a different discount rate should be used for the Types I and II costs than for the Type V costs, which are external to the company. Several groups suggest that a 3% discount rate is useful for future externality costs, while many environmental advocates feel strongly that a zero or very low discount rate is appropriate. Another approach can involve escalating the Type V costs more aggressively than the other costs and using a common discount rate for the project. The decision is the user's, although the rate used as the internal discount rate for projects (often referred to as a "hurdle" rate, i.e, the rate of return required on capital invested) should be different from the rate used to discount externalities. Depending upon the decision, project, or alternative being evaluated and the "external" discount rate applied there could be significant differences in the TCA results.

3.2.3.5 Conduct Impact Assessment
The impact assessment is essentially a review of the TCA results. In the initial conception of this process, a total cost (i.e., a total across all cost types) was the ultimate objective. However, as the beta tests developed, it became clear that several summations (e.g., a total cost for Types I, II, and III separate from a total cost for Types I, II, III, and IV) were useful. In reality there are no limitations on the sorting and comparisons that a user can perform with the manual method; the user to evaluate as many alternatives and iterations as desired.

The beta tests and most of the Work Group's efforts in this area are represented in the design and development of the electronic software tool developed based on the concepts presented in this manual. The electronic tool allows for uncertainty analysis for all cost types and through the use of various statistical techniques. Some samples of these options are presented in the case example in Appendix 3. Similarly, the reporting and documentation aspects of the process have been placed entirely in the user's hands. This group has not sought to dictate to the user the type of information that must be documented. However, in the development of the software tool, we have provided for some fairly detailed documentation and reporting of project assumptions, inputs, and results. A sample of these attributes can viewed in the hypothetical case example presented in Appendix 3.

3.3 Type III Costs

Costs that may or may not be incurred at some point in the future are termed contingent, or Type III, costs. Type III costs are often associated with future costs due to unexpected consequences of permitted or intentional releases. Costs included in this TCA method are: compliance obligations, civil and/or criminal fines and penalties, remediation costs, compensation and punitive damages, natural resource damages, off-site potentially responsible party (PRP) costs, and costs associated with industrial process risks. These costs may also be termed "contingent liabilities" or "contingent liability costs." Because these costs may not currently be recognized, they may not receive adequate attention in internal management accounting systems and in decision-making. Contingent costs are best described in probabilistic terms: their expected value, their range, and the probability of their exceeding some dollar amount. In addition, each category has an associated administrative/legal multiplier either incorporated into the values presented, or which will be input by the TCA user.

The Work Group recognized that developing accurate and reliable costs for these future and contingent liabilities is very difficult. Therefore, the Group directed the identification of publicly available cost data to provide the TCA user with starting points for developing Types III, IV, and V costs. Thus, this section describes the results of these data searches and presents the data to begin to quantify Type III costs.

The table below summarizes the data sources selected to represent Type III cost categories. As described in the following sections, a variety of sources were reviewed, and the most appropriate data sources were selected. Each section also provides a discussion of the uncertainties associated with each selected data source and potential influences on probability.

Table 3-1 Summary of Data Sources for Type III Cost Categories

Type III Cost	Data Sources Selected
Compliance obligations	EPA's Basis and Purpose Documents (BPDs), Background Information Documents (BIDs), and Economic Impact Analysis (EIAs) prepared by the USEPA for proposed National Emission Standards for Hazardous Air Pollutants (NE&HAPs)
Civil and criminal fines and penalties	EPA's Integrated Data for Enforcement Analysis (IDEA) database
Remedial costs of contamination	Federal Remediation Technologies Roundtable website (case studies for 141 remedial full-scale and demonstration projects); data on the types of contaminants, remedial technologies, and overall project costs
Compensation and punitive damages	Compilation of individually reported compensation amounts for toxic torts from published literature
Natural resource damage	Compilation of individually reported NRD amounts from published literature
PRP liabilities for off-site contamination	EPA CERCLIS database
Industrial process risk	EPA ARIP database Production downtime (company-specific, i.e., daily cost of production downtime)

3.3.1 Compliance Obligations

Compliance obligations are generally add-on technologies that could include costs associated with newly required air and wastewater pollution control systems, or cost escalation of off-site hazardous waste treatment. The cost databases identified generally also include the administrative costs to document/monitor compliance, but they do not fully address the personnel and human resource implications that may be associated with new regulations.

3.3.1.1 Data Sources Reviewed

This search focused on compliance obligations associated with air and wastewater regulations. A literature search was performed to locate costs that are required to bring a facility into compliance with air and wastewater regulations. The Dialog online service and the Internet were searched. Industrial market reports from Frost & Sullivan and the McIlvaine Company were also reviewed, but these sources provide overall nationwide data air pollution control and wastewater treatment market costs that are not plant-specific.

The data sources identified focus on pollution control regulatory options or requirements in the United States. Nevertheless, there are similarities in technology options for similar industries in Europe and the rest of the world. Therefore, these data could represent a good starting point for applications outside of the United States, provided appropriate adjustments are defined and implemented.

The best sources of data found were Basis and Purpose Documents (BPDs), Background Information Documents (BIDs), and Economic Impact Analysis (EIA) documents prepared by the USEPA for proposed National Emission Standards for Hazardous Air Pollutants (NESHAPs). These documents were downloaded from an Internet site established by the U.S. EPA's Office of Air and Radiation (OAR). BPDs and BIDs for the following nine industries were used to estimate potential compliance costs:

- Aerospace
- Amino and Phenolic Resins
- Pesticides
- Pharmaceuticals
- Polymers and Resins I (Butyl Rubber, Epichlorohydrin Elastomers, Ethylene Propylene Rubber, Hypalon™, Neoprene, Nitrile Butadiene Rubber, Polybutadiene Rubber, Polysulfide Rubber, and Styrene Butadiene Rubber)
- Polymers and Resins IV (ABS, MABS, MBS, Nitrile, PET, Polystyrene, SAN)
- Polyurethane Foam
- Pulp & Paper
- Synthetic Organic Chemicals

There have been many additional studies conducted by EPA to determine the potential future cost of proposed regulations. These studies are regulation-specific and are not summarized here. However, to provide perspective, we present one study, in which the authors investigated the incremental impact of EPA and OSHA regulation on the manufacturing sector as a whole (Robinson, 1995). Calculated as the weighted average of annual impacts for 445 industries, the impact grew from a 1.1% annual reduction in multifactor productivity in 1974-75 to a 2.5% annual reduction in 1985-86. The cumulative impact through 1986 on the manufacturing sector as a whole, computed as the weighted mean of impacts on the 445 industries, was to reduce multifactor productivity by 11.4% from the level it would have achieved absent the regulations.

3.3.1.2 Selected Database

Description
The EPA's Office of Air Quality Planning and Standards division of the Office of Air and Radiation prepared the BIDs, BPDs, and EIAs. In some instances these documents included cost and related information provided by industry and industry associations. Although an air division of the EPA wrote these documents, they also addressed wastewater discharges. They examined manufacturing processes, reviewed the means of controlling emissions, and analyzed the impacts of the proposed regulations.

Determination of Cost Ranges
The two primary components of environmental compliance costs are capital costs and operating and maintenance (O&M) costs. Some documents presented separate capital and O&M costs, while others presented an annualized cost that included capital and O&M costs. Some sources presented capital and O&M costs for a model plant, while others

reported them for the entire industry. Compliance costs are presented as the costs to bring new or existing facilities into compliance with proposed regulations.

To make all of the costs comparable, the following approach was used. All of the data was assembled on a unit plant basis. Sometimes it was necessary to divide the nationwide cost of implementing the emission standards by the total number of process units in the country. Then the capital, annualized, and O&M costs were brought to 1998$ using GDP price factors published by the U.S. Department of Commerce, Bureau of Economic Analysis. Where no year of costing was indicated, two years prior to the publication date of the document was assumed. A 7% discount rate and a 2% inflation rate were applied to O&M costs over an expected equipment life of 15 years. Annualized costs were assumed to have used a discount rate, so only an inflation rate was applied to come up with a final cost.

The resulting costs were graphed and grouped into low, medium, and high cost ranges. A summary of the compliance costs for the nine industries reviewed is presented in Table 3-2. The compliance cost ranges are presented in Table 3-3.

Table 3-2 Unit Plant Compliance Costs for Selected Industries (1998$)
(All figures rounded to the nearest $1000)

Industry	Capital Cost	Total O&M Cost	Total Annualized Cost	Total Compliance Cost
Aerospace			$ (1,420,000)	$ (1,420,000)
Amino and Phenolic Resins	$ 2,592,000	$ 21,042,000		$ 23,634,000
Pesticides	$ 900,000	$ 5,480,000		$ 6,380,000
Pharmaceuticals			$ 242,230,000	$ 242,230,000
Polymers and Resins I	$ 2,411,000	$ 21,014,000		$ 23,425,000
Polymers and Resins IV			$ (24,283,000)	$ (24,283,000)
Polyurethane Foam	$ 350,000	$ 363,000		$ 713,000
Pulp & Paper	$ 10,827,000	$ 12,924,000		$ 23,751,000
Synthetic Organic Chemicals	$ 572,000	$ 1,989,000		$ 2,561,000

	Compliance Cost
Average	$ 32,999,000
Low	$ (24,283,000)
Median	$ 6,380,000
High	$ 242,230,000

Table 3-3 Unit Plant Compliance Cost Ranges (1998$)
(All figures rounded to the nearest $1000)

Cost Range	Number of Facilities	Compliance Cost	
Low	2	$	(12,852,000)
Medium	3	$	3,218,000
High	4	$	78,260,000

Source: Arthur D. Little, Based on USEPA's National Emission Standards for Hazardous Air Pollutant (NE&HAP) Basis and Purpose Documents (BPDs), Background Information Documents (BIDs), and Economic Impact Analysis (EIA) documents for selected industries (1992-1997)

Uncertainties

The primary strength in the data is that it comes from focussed studies of specific industries by the USEPA. Costs were developed from examining specific air and wastewater pollution control processes necessary for a plant to comply with new regulations.

However, uncertainties exist in this data set for several reasons. These documents were published between 1992 and 1998 and often presented cost data in different ways. Some sources presented capital and O&M costs for a model plant, while others reported them for the entire industry. Three sources presented annualized costs that took into account both capital and O&M for a model plant. Three sources did not indicate the year upon which their costs were based.

Another drawback of this data set is that the BPDs and BIDs differed in what cost items were used to determine a final compliance cost. Not all of the sources stated their assumptions, and sometimes it was unclear what factors were included in the costs. Two industries, pharmaceuticals and polymers and resins IV, determined the environmental cost of bringing new sites into compliance, whereas the remainder only determined what costs were needed to bring existing facilities into compliance or the costs necessary to meet the new stricter standards. Four sources indicated that their costs included monitoring, recording and recordkeeping, while it was not mentioned in the other documents. Some sources indicated that they were taking into account product recovery savings or were saving control costs through product substitution. Other documents did not specify if potential cost savings were considered.

3.3.1.3 Influences on Probability of Occurrence

When considering the selection of a low, medium, or high compliance cost for a proposed process or product, as well as the probability of that cost occurring, the following issues should be considered:

- Potential to use common control devices to upgrade existing control devices
- Potential to vent or direct emission streams into current control devices
- Cost savings generated by reducing the loss of product through emissions

- Cost savings by material substitution to avoid end-of-pipe treatment for air and wastewater streams containing hazardous constituents
- Ease of removal or destruction of hazardous chemicals from effluent streams

If none of the above criteria apply, then a higher cost would be more likely. For example, if the first criterion does not apply, and installation of new, more expensive and/or untested control devices would be required, then a higher cost is more likely. If two or three criteria apply, then a medium cost is more likely. If more than three criteria apply, a low cost is more likely. All of these considerations should be balanced, however, with the throughput of the process and the performance level required for the specific process or wastestream. For example, if the process has a low volume exhaust stream and the performance level (e.g., percent reduction requirement) is not very strict, then medium or low control costs would probably be more likely.

Other influences on the probability of future compliance costs could include:

- Current efficiency and state of the art of control technologies
- Current compliance status of industry
- Emergence of new control technologies
- Regulatory climate (e.g., more stringent regulatory climate in the future could mean increased controls required)
- Public opinion (e.g., public opinion could influence voluntary or regulatory initiatives for increased controls)

3.3.2 Civil/Criminal Fines and Penalties

Civil or criminal fines and penalties may result from future noncompliance. Data regarding past fines and penalties faced by various industries were gathered from publicly available sources. But these numbers may not include expenses for projects agreed to as part of a settlement for noncompliance (i.e., in the United States these projects are referred to as Supplemental Environmental Projects (SEP)), legal fees, consulting fees, or internal labor required to prepare defense positions and related documentation. In addition, for some potentially litigious situations considerable legal and technical fees will be encountered even with a successful defense or favorable legal decision. These databases do not provide information on these situations. Data on criminal fines was available from EPA databases, as well. However, criminal fines and penalties were not reviewed for this project. A multiplier for legal/administrative costs associated with fines and penalties is likely to be company-specific and must be added by the TCA user.

3.3.2.1 *Data Sources Reviewed*

Data for fines and penalties incurred by infractions of federal environmental statutes is kept by the U.S. EPA in several databases. These data are accessible either through the Freedom of Information Act (FOIA), or through a modem connection to an EPA mainframe computer system. The data used for this analysis was obtained through a FOIA request to the EPA's Office of Enforcement and Compliance Assurance; data from the mainframe system was also reviewed.

The data received from the EPA were a selection of relevant fields from the Civil Enforcement Docket System (DOCKET) database as of July 22, 1998. This system is a case activity tracking and management system for federal civil, judicial, and administrative EPA enforcement cases. DOCKET is maintained by the USEPA Office of Enforcement and Compliance Assurance and is updated monthly. Information of particular interest to this analysis includes the case name, law(s) violated, pollutant(s), dates filed and concluded, assessed federal penalty, and cost recovery award. The cost recovery award is a sum collected from past damages and is typically found in CERCLA violations. According to a contact at the EPA's Office of Enforcement and Compliance Assurance, 90 percent of the fines and penalties listed in DOCKET are final. In addition, although the fines and penalties can be appealed and/or renegotiated, it is very unusual for that to occur after the fine or penalty is entered into DOCKET.

Another source of information on fines and penalties is the EPA's Integrated Data for Enforcement Analysis (IDEA) system located on a mainframe in Research Triangle Park, North Carolina. This system is a user interface that allows access to information from several databases. A user can write a specific program to extract desired information. Databases included in IDEA and reviewed include the following:

Table 3-4 Databases Included in IDEA

Database	Regulation for Data Collection
AIRS Facility Subsystem (AFS)	Clean Air Act (CAA)
National Compliance Database (NCDB)	Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Toxic Substances Control Act (TSCA), Emergency Planning and Community Right to Know Act (EPCRA)
Permit Compliance System (PCS)	Clean Water Act (CWA), National Pollution Discharge Elimination System (NPDES)
Resource Conservation and Recovery Information System (RCRIS)	Resource Conservation and Recovery Act (RCRA)

The DOCKET database is also incorporated in this system, however, some information on the DOCKET database duplicates the other databases in IDEA. Like DOCKET, the databases listed above contain the case name, pollutant(s), dates filed and closed, penalty amounts, and cost recovered. They also contain SIC codes for the facility. Only the PCS and RCRIS databases indicate if an action is a state or federally lead action.

After reviewing both IDEA and DOCKET, the latter was used to generate fine and penalty cost ranges, since searches conducted with the IDEA database frequently produced duplicate data that would have skewed the analysis. Further analysis incorporating a facility's SIC code can be done with the IDEA system, if categorization by SIC code would prove useful in TCA Type III costing.

3.3.2.2 *Selected Database*

Description
As described above, the DOCKET database contains fines and penalties for federal civil, judicial, and administrative EPA enforcement cases.

Determination of Cost Ranges
The data from DOCKET was sorted by federal statute, then by the date the case was concluded. Penalties and cost recovery data from January 1, 1995 to July 22, 1998 were compiled. This period was selected to understand recent trends in penalties and to limit the amount of data to be managed. In addition, there is only a 5% difference between 1995 dollars and 1998 dollars. Due to the small difference in the dollar values, and due to the amount of data, the figures were not adjusted for inflation. A total of 4,320 administrative and 346 judicial penalties were levied during this period for all federal statutes. The average, median, and high values are shown in Table 3-5. Only non-zero values were included in the analysis. The low values are not shown, since they can be as low as $1.

The data were then graphed by federal statute and divided into three parts to obtain an average for low, medium, and high cost ranges. Almost all of the graphs displayed a straight line over most of cost the range, but ended with an exponential curve upward for the higher costs. For these graphs, the straight-lined portion was evenly divided into a low and medium cost range, while the exponential portion was considered to be the high cost range. The data within each range was averaged to give an average cost for each range. Results of this analysis are shown in Table 3-6.

Table 3-5 Summary of Penalty Data from DOCKET Database (Jan. 1, 1995 - July 22, 1998)
(All figures rounded to the nearest $1000)

	Adminstrative Fines				Civil Judicial Fines			
Statute (a)	**Number of Cases**	**Average**	**Median**	**Maximum**	**Number of Cases**	**Average**	**Median**	**Maximum**
CAA	486	$ 21,000	$ 10,000	$ 300,000	157	$ 486,000	$ 150,000	$ 11,000,000
CWA	767	$ 19,000	$ 10,000	$ 150,000	111	$ 669,000	$ 201,000	$ 14,040,000
EPCRA	885	$ 18,000	$ 7,000	$ 210,000	3	$ 31,000	$ 13,000	$ 74,000
FIFRA	456	$ 12,000	$ 3,000	$ 876,000	6	$ 8,000	$ 2,000	$ 39,000
RCRA	904	$ 31,000	$ 1,000	$ 1,020,000	44	$ 795,000	$ 163,000	$ 8,000,000
SDWA	160	$ 7,000	$ 3,000	$ 125,000	18	$ 247,000	$ 20,000	$ 2,500,000
TSCA	662	$ 65,000	$ 14,000	$ 4,000,000	7	$ 50,000	$ 33,000	$ 142,000

Table 3-6 Cost Ranges for Penalties and Cost Recoveries of Federal Statutes (Jan. 1, 1995 - July 22, 1998)

(All figures rounded to the nearest $1000)

Range of Administrative Fines						
Statute (a)	**Number of Cases**	**Low Range**	**Number of Cases**	**Medium Range**	**Number of Cases**	**High Range**
CAA	221	$ 3,000	221	$ 22,000	44	$ 101,000
CWA	420	$ 4,000	280	$ 26,000	67	$ 85,000
EPCRA	427	$ 2,000	427	$ 25,000	31	$ 135,000
FIFRA	213	$ 2,000	213	$ 6,000	30	$ 126,000
RCRA	400	$ 1,000	400	$ 18,000	104	$ 198,000
SDWA	72	$ 1,000	72	$ 6,000	16	$ 36,000
TSCA	310	$ 5,000	310	$ 43,000	42	$ 679,000
Range of Civil Judicial Fines						
Statute (a)	**Number of Cases**	**Low Range**	**Number of Cases**	**Medium Range**	**Number of Cases**	**High Range**
CAA	72	$ 61,000	72	$ 359,000	13	$ 3,538,000
CWA	50	$ 83,000	50	$ 462,000	11	$ 4,268,000
EPCRA	1	$ 5,000	1	$ 13,000	1	$ 74,000
FIFRA	2	$ 1,000	3	$ 3,000	1	$ 39,000
RCRA	16	$ 27,000	16	$ 189,000	12	$ 2,626,000
SDWA	9	$ 9,000	5	$ 98,000	4	$ 356,000
TSCA	2	$ 10,000	2	$ 27,000	3	$ 93,000
Range of Combined Administrative and Civil Judicial Fines						
Statute (a)	**Number of Cases**	**Low Range**	**Number of Cases**	**Medium Range**	**Number of Cases**	**High Range**
CAA	293	$ 64,000	293	$ 381,000	57	$ 3,639,000
CWA	470	$ 87,000	330	$ 488,000	78	$ 4,353,000
EPCRA	428	$ 7,000	428	$ 38,000	32	$ 209,000
FIFRA	215	$ 3,000	216	$ 9,000	31	$ 165,000
RCRA	416	$ 28,000	416	$ 207,000	116	$ 2,824,000
SDWA	81	$ 10,000	77	$ 104,000	20	$ 392,000
TSCA	312	$ 15,000	312	$ 70,000	45	$ 772,000
Notes:	(a) - Multiple law violations (e.g. RCRA and SDWA for the same case) were counted with the first statute listed in the DOCKET database.					
Source: Arthur D Little, Based on USEPA DOCKET (July 22, 1998)						

Uncertainties

The data consist of actual fines levied against facilities that violated a federal statute. A variety of industries across the U.S. are represented.

However, the data presented does not allow the user to sort by SIC code or by EPA Region. In addition, pollutants that were released are not listed for every case. Adjustment for inflation was not taken into account, since the penalties were incurred since 1995.

3.3.2.3 *Influences on Probability of Occurrence*
When considering the selection of a low, medium, or high fine/penalty cost for a proposed process or product, as well as the probability of that cost occurring, the following issues should be considered:

- The extent that spill control measures will be in place (either through inspections, containment, or process controls)
- The history and reputation of the plant or company
- The local culture and visibility of the operation to non-governmental organizations
- How well the administrative requirements of monitoring, recording and recordkeeping will be maintained
- The toxicity of the potential contaminants
- The chance for a large release

In general, as the chemical toxicity and release potential increase, so will the potential penalty costs.

Other potential influences on the probability of future fines and/or penalties are:

- The potential for migration of chemicals off-site
- Past release data from the company
- The regulatory climate

3.3.3 Remedial Costs
Future remedial (site cleanup) costs could be associated with process-based releases, transportation-based releases, and waste handling, storage, and disposal practices proposed for the new process or product. In general, potential remediation liability items may include site investigations, remediation of specific areas of soil contamination or waste areas, and remediation of ground water.

3.3.3.1 *Data Sources Reviewed*
To estimate potential site remedial costs three approaches can be used:

A bottom-up approach that uses unit costs and site-specific data
A top-down approach that uses aggregate site remediation costs based on precedent
A decision analysis approach that accounts for multiple uncertain outcomes and results in an expected value or range of reasonable expected outcomes; may use a combination of bottom-up or top down approaches

For this analysis, given the level of uncertainty associated with future potential remedial costs, a top-down approach is used.

A literature search was conducted to locate remedial costs for sites with contaminated soil and groundwater. The Dow Jones Interactive Publications Library, the Dialog online service, and the Internet were searched. The best source of remedial cost data was a series of remedial case studies listed at the Federal Remediation Technologies Roundtable (FRTR) website. The FRTR is an association consisting of the personnel from the EPA, U.S. Department of Defense, U.S. Department of Energy, and U.S. Department of Interior. The EPA's *Cleaning Up the Nation's Waste Sites: Markets and Technology Trends* (April 1997) was also reviewed, but only provided average site costs based on the overall markets, not specific site data, as follows.

Table 3-7 EPA's Estimated Average Site Costs

Site	**Estimated Average Site Cost** ($)
Superfund – EPA lead	10,000,000
Superfund – PRP lead	8,500,000
RCRA	14,900,000
UST	125,000
DOD	3,400,000

Another Type III cost is potential future off-site PRP liabilities, which are also recovery costs for Superfund sites; off-site PRP liabilities are considered in Section 3.3.6. This section addresses only remedial costs, which are estimates for cleaning up a site located on a facility's property. The PRP liabilities cost data in Section 3.3.6 are used to estimate off-site liability costs.

3.3.3.2 *Selected Database*

Description

The source used to estimate potential remedial costs was located on the Internet at the FRTR website. This site listed several aspects of the case including the type and levels of contamination, vendor and government contact names, and a site description. Data on the types of contaminants, remedial technologies, periods of operation, and remedial costs were entered into a spreadsheet for analysis.

A total of 56 soil/sediment and 38 ground water remediation sites were selected to generate a range of costs for site remediation. Only full-scale remedial projects that had contaminants and technologies likely to appear at an industrial site were included. The majority (87%) of the soil remediation technologies included bioremediation, incineration, soil-vapor extraction, or thermal desorption. Most of the groundwater remedies consist of groundwater extraction and treatment with granular activated carbon (GAC), air stripping, UV oxidation, or chemical addition.

Determination of Cost Ranges

Since the costs were reported as far back as 1982, the costs were adjusted to 1998 dollars using GDP price factors published by the U.S. Department of Commerce, Bureau of Economic Analysis. For the soil/sediment remediation sites, the capital and O&M costs were assumed to occur in the same year, since most of these operations are completed within a one-year period. For ground water remediation sites, the capital costs were assumed to occur in the first year of operation, unless the remediation occurred in

December, then the next year was used for the inflation adjustment. O&M costs were assumed to occur in the last year reported for the site in the case study.

The results of the data were plotted to determine a range of costs. The data were separated into low, medium, and high ranges. The two graphs displayed a straight line over most of the cost range, but ended with an exponential curve upward for the higher costs. The straight-lined portion was evenly divided into a low and medium cost range, while the exponential portion was considered to be the high cost range. The data within each range was averaged to give an average cost for each range. The average, low, medium, and high costs for soil/sediment and ground water remediation are shown in Table 3-8.

These costs are only for the remediation and associated activities. Not included are costs for remedial investigations, and general legal and administrative fees. Design costs were not often mentioned as being included. These additional costs must be added to the clean-up values to attain a final remedial figure. Costs of $100,000, $250,000 and $500,000 were added respectively to the low, medium and high costs, based on professional judgment. A legal and administrative cost of 5% and a design engineering cost of 10% were added (also based on professional judgment) to arrive at a final remedial cost. The low, medium, and high cost ranges are shown in Table 3-9. These costs do not include legal defense costs.

Table 3-8 Average, Low, Medium, and High Soil/Sediment and Ground Water Remedial Costs (1998$)
(All figures rounded to the nearest $1000)

	Soil/Sediment Remedial Cost	Ground Water Remedial Cost
Average	$ 20,861,000	$ 8,366,000
Low	$ 114,000	$ 246,000
Median	$ 2,602,000	$ 2,820,000
High	$ 192,395,000	$ 53,847,000

Table 3-9 Remedial Cost Ranges for Soil/Sediment and Ground Water Sites (1998$)
(All figures rounded to the nearest $1000)

Remedial Intensity	Soil/Sediment Remediation					
	Number of Cases	Clean-up Cost	Legal & Admin Cost	Design Engineering Cost		
Low	22	$ 810,000	$ 41,000	$ 81,000		
Medium	22	$ 5,168,000	$ 258,000	$ 517,000		
High	12	$ 86,391,000	$ 4,320,000	$ 8,639,000		
Remedial Intensity	Ground Water Remediation					
	Number of Cases	Clean-up Cost	Legal & Admin Cost	Design Engineering Cost		
Low	15	$ 1,432,000	$ 72,000	$ 143,000		
Medium	15	$ 4,370,000	$ 219,000	$ 437,000		
High	8	$ 28,861,000	$ 1,443,000	$ 2,886,000		
Remedial Intensity		Soil/Sediment and Ground Water Remedial Cost			RI Cost	Total Average Remedial Cost
		Clean-up Cost	Legal & Admin Cost	Design Engineering Cost		
Low		$ 2,242,000	$ 113,000	$ 224,000	$100,000	**$ 2,679,000**
Medium		$ 9,538,000	$ 477,000	$ 954,000	$250,000	**$ 11,219,000**
High		$ 115,252,000	$ 5,763,000	$ 11,525,000	$500,000	**$ 133,040,000**
Source: Arthur D. Little, Based on Case Studies from the Federal Remediation Technologies Roundtable website (March 1999)						

Uncertainties

The remedial costs are taken from actual remediation sites from around the U.S. using conventional technologies currently applied to site remediation. The case studies include a range of contaminants from a variety of settings from 1982 to 1998. Although it is uncertain that these remediation technologies are applicable to international situations, there are similar remedial technology options in Europe and the rest of the world. Therefore, these data could represent a good starting point for applications outside of the United States, provided appropriate adjustments are defined and implemented.

Even though the data is extensive, certain limitations in the available data should be noted. Many of the ground water remediations were ongoing at the time the data was reported, so the final remedial cost is not yet known for these sites. The data also includes only the remedial and associated pre- and post-treatment costs. The inflation adjustment for the ground water O&M costs were assumed to occur in the last year reported in the case study, not as they would have been incurred during the programs. Costs for remedial investigations, legal and administration fees, and design costs were estimated and added to inflation-adjusted clean-up cost to determine a final remedial cost.

3.3.3.3 Influences On Probability of Occurrence

When considering the selection of a low, medium, or high remediation cost for a proposed process or product, as well as the probability of that cost occurring, the following issues should be considered:

- Toxicity/hazard of plant wastes
- Proximity of sensitive environmental receptors
- Regulatory climate
- History of community/third party involvement
- Future site use potential other than industrial

For example, if none or one of these criteria are applicable to the proposed process or product, then a low remediation cost might apply and it may be associated with a low probability of occurrence. If several of these criteria apply, then a medium remedial cost is more likely. Finally, a high remedial cost may be more probable if, for example, a plant waste is highly toxic, the plant is close to sensitive environmental receptors, and there is a history of community involvement surrounding the plant location.

3.3.4 Compensation and Punitive Damages

Future liabilities due to compensation and punitive damages may be associated with toxic tort cases for community or worker exposures, and may also be associated with:

- Future claims due to loss of property value
- Future claims due to loss of economic uses of a property

A multiplier for legal/administrative costs associated with the potential settlement/award dollar values presented in this section is likely to be company-specific and must be added by the TCA user.

3.3.4.1 Data Sources Reviewed

A single database which contains toxic tort claims or settlements was not identified. Therefore, searches were conducted of published literature databases, newswire databases, the Internet, federal government document databases, and state and federal government web sites to find detailed cost information for toxic tort claims and settlements. One published literature database searched was LEXIS, which contains a number of legal publications, such as Mealy's Litigation Reports. Another valuable resource was the Jury Verdict Research Series (LRP Publications). This publication maintains a nationwide database of plaintiff and defense verdicts and settlements resulting from personal injury claims. Jury Verdict Research Series is supplied with abstracts of personal injury verdicts from court clerks, plaintiff and defense attorneys, law clerks, legal reporters, media sources, and students.

3.3.4.2 Selected Database

Description
As described above, a comprehensive literature review was conducted to find dollar amounts of jury awards or settlements. The data were compiled, including information on the disease claimed, the scenario of exposure, and whether it was a community or worker exposure. The compiled data may be found in Table 3-10.

Determination of Cost Ranges
The data were compiled and plotted on graphs. Dollar values are the awards or settlement amount per person. Therefore, if the number of individuals potentially affected will also need to be estimated, based on potentially exposed community populations and/or potentially exposed workers. Low, medium, and high ranges were determined from a scatter plot of the awards and settlement amounts identified in the searches. The averages for the low, medium, and high ranges are presented in Table 3-11.

Table 3-10 Summary of Toxic Tort Data

	Number of Cases	Range of Costs ($)	Median ($)	Mean ($)
Community Torts	14	3,500 - 555,000	27,000	100,136
Occupational Torts	23	30,000 - 9,652,381	2,000,000	2,461,851

Table 3-11 Toxic Tort Cost Ranges

Community Torts

	Number of Cases	Range of Costs ($)	Average ($) (rounded to 1,000s)
Low	7	3,500 - 55,000	15,000
Medium	5	110,000 - 146,000	111,000
High	2	185,500 - 555,000	370,000

Occupational Torts

	Number of Cases	Range of Costs ($)	Average ($) (rounded to 1,000s)
Low	8	30,000 - 270,000	115,000
Medium	6	700,000 - 2,000,000	1,277,000
High	6	2,300,000 - 9,652,381	4,948,000

Two cases of property contamination were not included in the ranges, since the number of individuals suing was not reported. These two cases are presented here, because it is important to note that property contamination, in addition to personal injury/toxic tort suits, can result in large awards.

- Residents of two mobile home parts charged that gasoline at a gas station had leaked and contaminated their water supply with benzene and other toxic substances. The jury awarded $9.5 million for medical monitoring, and also found Conoco liable for punitives which were to be determined in a separate phase. However, the parties settled prior to the verdict being returned. Although the settlement amount was confidential, a leaked report indicated a settlement of $36 million with the residents (The National Law Journal, February 23, 1998).
- An award of $210 million in punitive damages and $7.7 in punitive damages for PCB migration to plaintiffs' properties in a negligence, trespass and nuisance case (Environmental Compliance and Litigation Strategy, September, 1997).

Uncertainties
Uncertainties associated with this data set include the fact that settlements that occur out of court are confidential, and are not reported in the literature. In addition, claims may be for extremely large sums of money, but the amount awarded by a jury may be smaller (or larger). Also, initial awards based on a jury decision can be reduced later through an appeal process.

3.3.4.3 Influences on Probability of Occurrence
A variety of factors are associated with whether or not a toxic tort suit will be brought in the future, the magnitude of the cost, and the probability of its success, for example:

- The prior history of the facility
- The litigious climate of the state in which the facility is found
- The toxicity or hazards and extent of chemicals released from the facility
- The potential for exposure
- Level of exposure
- Resulting illness is associated with the exposure
- Perceived risk
- The existence of prior toxic tort cases
- The willingness of law firms to initiate toxic tort claims

Exposure is a function of receptor locations and distance from the site, existence of off-site contamination, and/or plant emissions or releases. For workers, exposure is based on past worker activities and plant operations. Illness is a function of the toxicity and/or the strength of the association of the chemical with a disease. Perceived risk is a function of community involvement, prior cases, and/or general public knowledge of the chemical/disease connection.

The Jury Verdict Research Series publishes a "Personal Injury Valuation Handbook" which describes plaintiff recovery probabilities for various claims. Only original, compensatory jury verdicts rendered to individual plaintiffs for claims of physical, mental, or emotional injury or trauma are included in the analysis. As an example, the following probabilities are listed (Issue 25, 1998) for product liability cases involving industrial, construction, commercial, and farm products:

- Asbestos/Asbestos-containing products: 76% plaintiff recovery probability
  - Verdict Median: $400,000
  - Verdict Range: $5,000 - $22,400,000
  - Verdict Mean: $1,178,829
- Chemicals: 68% plaintiff recovery probability
  - Verdict Median: $559,640
  - Verdict Range: $1,000 - $9,173,245
  - Verdict Mean: $1,256,641

These data may also be used in the TCA method, if product liability is of concern.

3.3.5 Natural Resource Damages

Under the authority of CERCLA (Superfund), responsible parties are liable for the costs of restoring injuries to natural resources, such as wildlife and ground water. Natural resource damage (NRD) claims may also be brought independently of a particular Superfund hazardous waste site, with federal agency leads from the U.S. Fish and Wildlife Service (FWS) or National Oceanographic and Atmospheric Administration (NOAA). Federal agencies, state governments, and tribal authorities have been designated natural resource trustees and are authorized to make claims against responsible parties for natural resource damages.

There are a variety of methods to assess economic damages, but NRD monetary compensations (damages) generally include costs for:

- Damage assessment
- Planning
- Restoration costs (the condition that would have existed had the release not occurred
- Costs associated with the loss of the resource and/or the benefits or services derived from the resource from the date of the injury until the full restoration of the resource and/or the benefits or services

Thus, site-specific cleanups are separately funded activities. The trustees can seek damages only for injuries that remain after the cleanup has been completed.

An "abbreviated type B" procedure is often used to quantify damages. The steps are:

- Determine the injuries (damage assessment)
- Quantify their value (using various analyses)
- Determine the damages

Other economic NRD assessment methods could include: fines, replacement values, replacement costs, market values, lost expenditures, and willingness to pay (travel cost, contingent valuation, property value). For ground water resource damages, cost estimation methods may include: cost of alternative water supply, changes in property value, and direct measurement of the demand for drinking water (API, 1987).

The detailed calculation of compensation amounts described in NOAA and FWS guidance documents was not utilized in this analysis. This is because the TCA methodology must be able to be applied in a wide variety of as-yet-undetermined industrial incidents and NRD amounts are quite variable from site to site. These variations are based on the environmental setting, the type and amount of damage, and on the agencies involved in the costing. There is also a "Natural Resource Damage Assessment Model" available from the Department of Interior which was not used in this methodology, although it could be used for a particular and well-defined spill event. To value potential NRD costs we used NRD amounts from historical precedents, as gathered from available literature and other information.

Because most NRD costs do not include administrative/legal costs, a multiplier for legal/administrative costs associated with the estimated NRD settlement/award dollar values presented in this section is likely to be company-specific and must be added by the TCA user.

3.3.5.1 Data Sources Reviewed

Searches were conducted of published literature databases, newswire databases, the Internet, federal government document databases, and state and federal government web sites, including NOAA and FWS. In addition, when NRD cases were known to be in progress or were settled, but the dollar amounts were not available, personal contacts with government agencies, including NOAA and FWS, were made. The U.S. Government Accounting Office (GAO) summarized all available NRD information up to April 1995, and then updated that information in 1996 (GAO, 1996). According to the GAO, as of April 1995, relatively few claims had been settled and their amount was small compared with the cost of cleaning up sites, but some recent claims had been much larger, increasing concerns among industries and the U.S. Congress.

To date, the FWS reports that it has not been necessary to pursue natural resource damage assessment litigation to a judicial decision, and many of these cases have been settled out-of-court, through negotiation.

3.3.5.2 Selected Database

Description

All available historical cost data for NRD settlements or estimated amounts was gathered from the references cited above. The majority of the data was derived from the GAO reports, along with literature and newswire reviews, and personal contacts with individuals in trustee and government agencies.

Determination of Cost Ranges

The FWS reports that about 20 sites have been identified as potentially exceeding $50 million. GAO recently showed that about half of all cases are settled with no cash payment, and over 35% are settled for less than $5 million.

There is a high likelihood that additional claims will occur in the U.S.; based on data presented in 1996, there are about 67 claims settled and/or pending. Ninety-eight settlements had been reached as of April 1995. As many as 20 sites have NRD claims exceeding $50MM each; another 40 sites have claims between $5MM and $50MM each.

Summaries of the costs and the averages of each cost range are presented in Tables 3-12 and 3-13.

Table 3-12 Summary Description of NRD Costs

Type of NRD Case	Number of Cases	Average	Median	Maximum
Ground Water	5	$ 21,000	$ 10,000	$ 300,000
Other	74	$ 3,951,928	$ 145,000	$ 54,900,000

Table 3-13 Ranges of NRD Costs

	Ground Water		Other	
	Number of Cases	Average of Cost Range	Number of Cases	Average of Cost Range
Low Average	3	$ 550,000	32	$ 38,000
Medium Average	1	$ 37,000,000	22	$ 250,000
High Average	1	$ 120,000,000	12	$ 9,200,000

Uncertainties

We have researched readily available data regarding the values of past NRD settlements. Additional data may be available on proposed or estimated NRD costs, which may be obtainable only through contacts with individuals in each trustee agency.

There is considerable uncertainty associated with the development of NRD costs. Controversy exists in scientific and government circles about the correct way to cost natural resource damages, and there are several different methods and models.

It should be noted that the NRD costs may or may not include:

- Penalties
- Property purchase
- Wetlands restoration
- Litigation costs
- Compensation costs

In addition, the settlement may have been associated with past contamination from several parties, thus costs would have been allocated among several parties, decreasing an individual company's liability. The possibility of ground water NRD costs is highly site-specific, because the demand for an underground drinking water source is site-specific.

3.3.5.3 Influences on the Probability of Occurrence

Based on the number of settlements and NRDA studies discovered in the literature, and the fact that a government agency must initiate the research necessary to being and NRDA, it is certainly not a given that an NRDA would result in a future scenario of an environmental incident. If a spill or other damage to the environment did occur, and a federal agency or other party conducted a study to assess NRD, some of the factors that could contribute to the probability of occurrence or the magnitude of the NRD cost could include:

- Proximity to streams, rivers, lakes, estuaries, marshes, bays, or wetlands
- Proximity to sole source ground water aquifers
- Proximity to protected or unique habitats
- Proximity to water bodies used for commercial fishing
- Regulatory climate of the state or states in which the incident occurred
- Past company relationships with the community
- Past company relationships with the regulators
- Volume of material released to the environment
- Toxicity of material released to the environment
- Fate and transport of material released to the environment

Large NRD settlements often involve major aquatic systems with widespread unremediated sediments, at several thousand times allowable limits, that will not dilute within measurable time periods. Sites where future NRD claims or settlements may have a medium magnitude could be coastal areas with smaller impact areas. For inland sites or sites with smaller potential for environmental damage, the low average of reported NRD claims could be appropriate.

3.3.6 Off-Site PRP Liabilities

Companies may face liability as a potentially responsible party (PRP) under CERCLA, resulting from the disposal of wastes from their facilities at off-site disposal locations, although an effective waste management program, where wastes are disposed in approved facilities, would limit this type of liability. A scenario for off-site PRP liabilities should include the following assumptions:

- Waste is disposed in off-site disposal sites
- Documentation exists that the off-site location received wastes from the company
- If other PRPs exist, liabilities would be allocated
- For off-site disposal sites which are permitted incinerators rather than landfills, need not assume a potential for future PRP settlements

These costs do not include on-site remedial costs, as described in Section 3.3.3.

3.3.6.1 Data Sources Reviewed

Data for PRP liabilities are compiled in U.S. EPA databases. These data are accessible either through the Internet, through the Freedom of Information Act, or through a modem connection to an EPA mainframe computer system. The data used for this analysis was obtained through a request to the EPA's Office of Enforcement and Compliance Assurance; however, databases from the Internet and the mainframe were also reviewed.

Data on specific sites and their PRPs are also available through the Right-To-Know Network. This is a good source to identify information on specific sites or PRPs, but is not useful for examining nationwide trends in PRP liabilities.

The PRP cost data received from the U.S. EPA were from a subset of the Civil Enforcement Docket System (DOCKET) database as of July 22, 1998. As described in Section 3.3.2, this system is a case activity tracking and management system for federal civil judicial and administrative EPA enforcement cases, maintained by the EPA's Office of Enforcement and Compliance Assurance. DOCKET is used to generate PRP cost ranges, since it was also used to generate cost ranges for Civil/Criminal Fines and Penalties (Section 3.3.2).

3.3.6.2 Selected Database

Determination of Cost Ranges

The data from DOCKET was sorted by federal statute, then by the date the case was concluded. PRP cost data from January 1, 1995 to July 22, 1998 were compiled. This period was selected to understand recent trends in PRP penalties and to limit the amount of data to be managed. In addition, there is only a 5% difference between 1995 dollars and 1998 dollars. Due to the small difference in the dollar values, and due to the amount of data, the figures were not adjusted for inflation. A total of 249 administrative and 380 judicial PRP penalties were levied during this period for all federal statutes. The average, median, and high values are shown in Table 3-14. Only non-zero values were included in the analysis. The low values are not shown, since they can be as little as $1.

The data were then graphed by federal statute and divided into three parts to obtain an average for low, medium, and high cost ranges. The graphs displayed a straight line over most of cost the range, but ended with an exponential curve upward for the higher costs. The straight-lined portion was evenly divided into a low and medium cost range, while the exponential portion was considered to be the high cost range. The data within each range was averaged to give an average cost for each range. Results of this analysis are shown in Table 3-15.

Table 3-14 Summary of CERCLA PRP Data from DOCKET Database (Jan 1, 1995 - July 22, 1998)

(All figures rounded to the nearest $1000)

	Adminstrative Fines/Cost Recovery				Judicial Fines/Cost Recovery			
Statute (a)	**Number**	**Average**	**Median**	**Maximum**	**Number**	**Average**	**Median**	**Maximum**
CERCLA	249	$ 178,000	$ 14,000	$ 5,000,000	380	$ 2,982,000	$505,000	$108,904,000

Notes: (a) - Multiple law violations (e.g. RCRA and SDWA for the same case) were counted with the first statute listed in the DOCKET database.

Table 3-15 Range of PRP Fines and Cost Recovery Data from DOCKET Database (Jan 1, 1995 - July 22, 1998)

(All figures rounded to the nearest $1000)

Statute (a)	Number of Cases	Low Range	Number of Cases	Medium Range	Number of Cases	High Range
Administrative	113	$ 3,000	113	$ 107,000	23	$ 1,386,000
Civil Judicial	182	$ 179,000	182	$ 1,995,000	16	$ 46,085,000
Total	**295**	**$ 182,000**	**295**	**$ 2,102,000**	**39**	**$ 47,471,000**

Notes: (a) - Multiple law violations (e.g. RCRA and SDWA for the same case) were counted with the first statute listed in the DOCKET database.

Uncertainties

The data consist of actual PRP fines and cost recoveries levied against facilities that violated a federal statute. A variety of industries across the country are represented.

The data presented does not allow the user to sort by SIC code or by EPA Region. In addition, pollutants that were released are not listed for every case. Adjustment for inflation was not taken into account, since the penalties occurred since 1995. However, this difference is not expected to significantly affect the analysis.

3.3.6.3 Influences on Probability of Occurrence

The following factors should be considered in determining the PRP cost range and the probability of occurrence for a scenario in which a facility is a responsible party at a CERCLA site.

- The number of responsible parties at the site
- The volume of waste disposed at this site relative to other parties
- The toxicity of the contaminants

For example, if a facility is one of many who have disposed at a site and their volume of waste (if known) is relatively low, then a low cost range is likely. As the number of responsible parties decreases, a facility's volume of waste relative to other parties increases, and as the toxicity of the contaminants increases, then a medium cost range might be more likely. In some instances, a facility will be fully responsible for all of contamination. In this case, the toxicity and volume of the contamination will determine if the high range should be selected.

3.3.7 Industrial Process Risk

Industrial process risk could include the costs associated with accidents, such as fires, property loss, and production downtime. Costs of fires and property loss data are available from published sources, however, it is likely that production downtime will be process- and company-specific.

3.3.7.1 Data Sources Reviewed

To identify potential sources of cost data on process accidents, we searched the Internet and/or directly contacted the federal government agencies in North America and Europe responsible for collecting accident statistics. The following organizations were contacted:

- U.S. Environmental Protection Agency, Chemical Emergency Preparedness and Prevention Office,
- U.S. Fire Administration, National Fire Data Center
- Environment Canada, Environmental Emergencies Branch
- Major Industrial Accidents Council of Canada
- European Commission, Joint Research Centre

A summary of the review conducted is provided in Table 3-16. The database selected to provide estimates of the cost of process accidents is the Accidental Release Information Program (ARIP), administered by the Chemical Emergencies Prevention and Preparedness Office, United States Environmental Protection Agency (US EPA). The primary reasons for its selection are summarized in Table 3-16.

An additional tabulation of accident costs is provided in Table 3-17. It provides reported costs for material loss and business interruption based on insurance payouts to the oil, gas, and petrochemical industries. This information was published by the Major Industrial Accidents Council of Canada for looking at the cost-benefits of implementing process safety management in Canada (MIACC, 1996). The tabulated values should be considered as averages and indicate the range of potential material damage and downtime following a major process accident.

Table 3-16 Review of Process Accident Cost Data Sources

Organization/Agency	Data Source	Brief Description of Information Source	Summary of Review/Findings
US Environmental Protection Agency, Chemical Emergency Preparedness and Prevention Office	Accident Release Information Program (ARIP)	Database contains information on accidents from fixed facilities that have potential for off-site impacts. Cost of the accident is one of the required fields to be reported. EPA uses incident data in the Emergency Response Notification System (ERNS) to select facilities to send questionnaire to.	ARIP represents the primary publicly available sources on chemical accidents in the United States. It was selected as the primary source of accident cost data due to its availability, future potential (accidents will be entered due to regulatory requirements but at a lesser rate - see below) and other information it retains about the accident, e.g., cause, material, etc. The weakness of the database are that many incidents lack cost data and/or direct correlation with quantity spilled, and due to changing regulatory requirements, the number of incidents now being entered into the database are limited to nine per year (giving a smaller sample size).
US Fire Administration, National Fire Data Center	National Fire Incident Reporting System (NFIRS)	A national fire database containing detailed information on individual fires and casualties. It contains data on the loss associated with the fire.	NFIRS contains data about the fire incident and the estimated cost of the fire loss based on the responding fire department's estimate. Hazardous material incidents are also reported in the database but the loss data refers to the damage caused by the fire. This database was not selected since there are other known sources of published sources for information on fire losses.
Environment Canada, Environmental Emergencies Branch	National Analysis of Trends in Emergencies System (NATES)	A national spill incident database in Canada maintained by Environment Canada. Spills reported since 1973 are included in the database based on spill data received from the provinces. The two cost-related fields are fines and clean-up costs.	NATES contains some information on clean-up costs (less than 2% of the spill incidents had information) and less data on fines. The database has other information about the spill incident such as cause, source, etc. and is the most comprehensive database on spills in Canada. This database was not analyzed for this study.

Table 3-16 (continued) Review of Process Accident Cost Data Sources

Organization/Agency	Data Source	Brief Description of Information Source	Summary of Review/Findings
Major Industrial Accidents Council of Canada (MIACC)	Document entitled "Canada Advantages"	Background document that addressed the benefits of implementing process safety management against the costs of accidents (examined in terms of insurance payouts for business interruption and material damage loss).	MIACC does not maintain a database for accidents. Some of the information in the background document provides a useful reference to the average total insurance payout per accident (in millions of US$ 1994) between 1988 to 1992: • Canada – 6.8; • United States – 37.6; and • Rest of world – 18. Information was not provided on the type of incident involved (i.e., fire, explosion, spill) or the size of incident. But the results indicate that large potential loss can be associated with accidents depending on the consequences involved. These costs are based on insurance payouts to the oil, gas, and petrochemical industry (MIACC, 1996).
European Commission, Joint Research Centre	Major Accident Reporting System (MARS)	The European Commission's Major Accident Reporting System (MARS) database is based on the requirements of the "Seveso Directive" and dedicated to collect data on major industrial accidents involving dangerous substances from the Member States of the European Union.	A review of the technical guideline document for the MARS indicated that cost information is available in the database. The total costs associated with the accident, if available, are given in the local currency and in ECU. Based on the description provided in the technical guideline (European Commission, 1998), the cost information consists of: 1) Material Losses – the actual value of physical damage to buildings, plant, materials or other property (including agricultural animals and crops) directly attributable to the accident, but not the costs of restoration works, nor incidental trading losses. 2) Response, clean up, restoration – the actual or projected costs of emergency service operations, cleaning up contamination and subsequent efforts. The costs of rebuilding or other restoration work should be reported, unless they were reported as material losses in cases of partial damage (see above). 3) Establishment Losses - Losses which occurred inside or outside the establishment and fully burdened the operator or the insurance company of the operator, e.g., the cost of material lost, or the cost of clean-up inside and outside the establishment if this was paid by the operator. 4) Off-site Losses - Losses which occurred outside the establishment and burdened not the operator but the local population, government, etc. 5) The actual database was not examined during this stage of the study but an initial inquiry with the Joint Research Centre indicated that MARS has approximately 50 incidents with some cost information (out of about 350 incidents in MARS).

Table 3-17 Summary of Reported Accident Costs Published by MIACC

CANADA (Millions of US$ 1994)						
Year	Material Damage			Business Interruption		
	No.	$ Amt.	Average	No.	$ Amt.	Average
1981	15	12.3	0.8	4	23.8	6.0
1982	20	28.8	1.4	5	76.7	15.3
1983	11	9.7	0.9	2	23.2	11.6
1984	11	104.4	9.5	3	233.1	77.7
1985	9	9.0	1.0	6	20.0	3.3
1986	5	16.0	3.2	1	17.9	17.9
1987	10	50.3	5.0	3	94.5	31.5
1988	7	4.5	0.6	2	2.0	1.0
1989	8	51.5	6.4	6	50.6	8.4
1990	7	8.6	1.2	6	36.9	6.2
1991	5	4.7	0.9	10	18.5	1.9
1992	5	35.5	7.1	2	1.2	0.6

UNITED STATES (Millions of US$)						
Year	Material Damage			Business Interruption		
	No.	$ Amt.	Average	No.	$ Amt.	Average
1981	26	166.3	6.4	6	35.7	6.0
1982	30	108.9	3.6	11	76.4	6.9
1983	79	259.2	3.3	16	53.1	3.3
1984	32	243.4	7.6	5	23.5	4.7
1985	27	218.2	8.1	5	40.8	8.2
1986	16	42.8	2.7	4	25.6	6.4
1987	14	404.5	28.9	3	265.8	88.6
1988	26	655.8	25.2	3	16.2	5.4
1989	58	1068.9	18.4	29	1230.8	42.4
1990	46	702.5	15.3	17	335.9	19.8
1991	43	321.1	7.5	10	197.6	19.8
1992	13	146.2	11.2	6	138.9	23.2

Source: MIACC (1996) based on data from Swiss Reinsurance Company, Zurich, Switzerland

3.3.7.2 Selected Database

Description

The ARIP database, initiated and administered by the U.S. EPA, is used to collect information on accident causes based on a questionnaire sent to selected facilities. The EPA is authorized to collect this information under numerous regulatory acts. Facilities in the United States are required to report non-routine releases of specific materials, when the amount released exceeds a reportable quantity, to one of the following agencies:

- U.S. Coast Guard
- National Response Center
- Regional EPA offices

The EPA enters these reports into a database called the Emergency Response Notification System (ERNS). The ERNS is used by the EPA to select facilities to send a questionnaire to. The EPA sends the questionnaire to facilities that have off-site consequences or environmental damage. The types of off-site consequences of concern include:

- Casualty
- Evacuation
- Shelter-in-place
- Other precautions that may result due to the incident

Environmental damage that must be reported includes:

- Wildlife kills
- Significant vegetation damage
- Soil contamination
- Ground and surface water contamination

The requested information on cost includes:

- Facility costs – clean-up costs, outside contractor cost, hours diverted to clean-up or lost to shutdown, loss of production
- General public costs – damage to natural resources, public and private properties.

An overview of the evolution of ARIP will assist with understanding changes that impact on the number and type of incident data in the database. In 1987, ARIP started collecting information on accidents. In July 1991, changes were made to streamline the data gathering process and to verify information provided in the ERNS database. In July 1993, the selection criteria for facilities surveyed changed from quantity of material released to off-site impacts and environmental damage. Since September 1997, EPA has narrowed its focus to concentrate on the significant incidents and the number of facilities that can be surveyed has been limited to nine incidents per year (due to the Paper Work Reduction Act). This will restrict the future size of the database.

Determination of Cost Ranges

A review of the ARIP database indicated that about 20% of the total incidents had information on the cost of accidents. There were very few incidents with information on general public costs; for facilities that reported information on cost, it was primarily facility cost. Table 3-18 shows the summary data for reported incidents. An analysis of the range of accident costs led to the ranges presented in Table 3-19.

Note that the low end cut-off of $10,000 was based on our judgement of an insignificant cost to a facility compared to other potential costs. The majority of incidents are in the low cost range and this is reflected in the reported median value of $35,000. The cost values presented are based on the cost at the year of the incident and are not corrected to a present cost value.

Table 3-18 Summary of Facility Accident Costs from ARIP Database
(All figures rounded to the nearest $1000)

Statistic	Costs (USD)	Spilled Quantity (lb)
Average	$246,771	26,501
Median	$35,000	814
Maximum	$15,000,000	1,779,198
# incidents with cost=>$10,000	513	

Table 3-19 Cost Ranges for Facility Accident Costs
(All figures rounded to the nearest $1000)

Range	Cost Range (USD)	Number of Incidents	Average Cost for Range (USD)
Low	$10,000- $100,000	389	$31,433
Medium	$100,001 - $1,000,000	97	$268,025
High	$1,000,001+	27	$2,717,683

Uncertainties

The ARIP database is easily accessible and easy to use, and has potential for further analysis of cost by type of facility, incident (e.g., a fire or spill), material, quantity spilled, cause of accident, and different parameters describing accidents.

Some of the weaknesses associated with the ARIP database include:

- The facility cost is an aggregate number (and a breakdown is not provided) with the potential for an apples-to-oranges comparison
- There are no details on the length of downtime
- The number of incidents and the severity of the incident in ARIP have changed over the lifetime of the database due to changing facility selection criteria.
- No correlation of cost with quantity released (based on all incidents)
- Not likely to include any legal or enforcement cost included since facilities are usually asked to fill out the questionnaire within 6 to 10 months of the reported incident

- Data on injuries/fatalities is not necessarily captured

3.3.7.3 Influences on Probability of Occurrence and Consequences of a Facility Process Accident

The expected cost of a process accident is difficult to predict and it depends on a number of factors that can influence the severity of consequences following the incident (this type of analysis is commonly referred to as consequence analysis):

- The type of material released and its inherent hazard (i.e., flammable, explosive, or toxic)
- The rate of release following loss of containment
- The conditions at the time of the accident that may affect the type of resulting hazard (e.g., immediate or delayed ignition of a propane release can lead to jet flames, flash fires, vapor cloud explosion – each hazard has different impacts and costs)
- The severity of damage to susceptible receptors (e.g., physical plant, workers, public, near-by property, etc.) which is influenced by the proximity of the receptor to the release point, the vulnerability of the receptor to the hazard, wind speed/direction and atmospheric stability, size of the hazard zones, etc.

Note that not all receptors will be affected to the same degree by a hazardous event and there can be varying degrees of consequence give the same level of severity of hazard at a receptor.

These factors deal with the consequence and the receptor side of industrial process risk. Another important component of industrial process risk is the frequency or probability that an incident occurs. An easy way to look at factors that effect the probability of an incident occurring at a fixed facility is to look at the elements of process safety management (designed for prevention) and for any factors that could lead to weaknesses or failures in these elements. Some of the key elements of process safety management include:

- Process safety information (e.g., limits of process parameters, process chemistry, safety systems, etc.)
- Operating procedures
- Operator training
- Mechanical integrity effected by inspection and maintenance programs for critical process equipment (e.g., interlock-trip systems, etc.)
- Management of change
- Pre-startup review
- Hot work permit

Deficiencies in these areas are indicators that the likelihood of an incident are increased compared against other similar operating facilities that have a good process safety management system and safety culture.

3.4 Type IV Costs

Type IV costs are defined as "internal intangible" costs. These are costs that are difficult to measure, and are not usually considered in budgeting or strategic planning. However, these costs end up affecting the bottom line, and thus ought to be considered in any TCA. The Type IV costs included in this TCA methodology are: staff issues, market share, license to operate, and relationships with investors, lenders, communities, and regulators.

Type IV costs have greater uncertainty than Types I, II, and III costs, and there is considerable confusion about their definition and quantification. We conducted a survey of publicly available literature to identify sources that attempt to quantify these costs. We have included all of the data collected, regardless of the methodology used, and we did not critically evaluate each study. As in all research studies, each methodology may be questioned and has associated uncertainties. The data identified provides the TCA user with a starting point, which can be supplemented with company-specific data. This section describes the results of these data searches and presents the data to begin to quantify Type IV costs.

Each Type IV cost has an associated probability of occurrence, which will be company-specific. The probability of a Type IV cost occurring could be associated with a company's overall reputation, past history of environmental incidents, and the quality of the company's relationships with investors, lenders, communities, and regulators. Other influences on the probability of occurrence of Type IV costs could include:

- The likelihood of an environmental incident could be based on the existence of an effective emergency management plan
- The past relationships with the community, with the news media, and with regulators
- The probability of a workplace fatality, injury, or illness occurring is influenced by many factors, including the existence of a worker safety program and the past history of an operating facility. In addition, the more toxic a substance being used, the more likely that an accidental exposure could result in illness or fatality.
- The probability that a company would be rewarded with better credit ratings, and that it has a good environmental record, is likely based on the efficacy of the company's emergency management plans, the effectiveness of its community and media relations, and its regulator relationships.

Examples of Scenarios

Scenarios which could affect a firm's reputation and general corporate environmental image include catastrophic events or negative news reports. As described below, a negative effect on stock prices is likely to occur with either of these events.

Table 3-20 summarizes the potential data sources for Type IV costs. A description of each Type IV cost may be found in the following sections. Each section includes: definition and sources reviewed, examples of scenarios to which the Type IV cost could be applied, the influences on the probability of the costs occurring, and the uncertainties associated with the selected approach.

Table 3-20 Summary Table for Type IV Costs

Type IV Cost	Data Sources
Staff (productivity/morale; turnover; union negotiating time)	1) Published literature on costs of injuries in specific industries (could include direct costs to employer, cost of lost productivity, cost of recruiting and training) 2) Published literature on multipliers of salary (e.g., costs to employers of mortality/illness in the workplace)
Market Share (value chain perception, public perception, consumer perception)	1) Published literature on market value of environmental reputation and "green company" policies 2) Published literature on the loss of market share following an environmental incident 3) Published literature on the market share effect of negative news reports
License to Operate	Takes into account relationships with communities, regulators, and suppliers.
Relationships	
Investors	1) Published literature on the effects on share value of environmental reputation and "green company" policies 2) Published literature on decreases in stock prices following environmental incidents 3) Published literature on the effect of negative new reports on share price
Lenders	Data on the effect of environmental incidents on credit ratings
Communities	Cost and benefits of public relations programs. Overlaps with License to Operate
Regulators	Costs of new regulations. Overlaps with License to Operate

3.4.1 Type IV Costs - Staff

Definition and Sources Reviewed

The costs that are related to recruiting and maintaining quality personnel and staff are more than just salaries and compensation. Workers' productivity and morale are affected by company policies and by the company's E&H record. Turnover levels can have costs associated with lost production time and retraining new employees. High turnover rates can also have negative effects on other employees and can result in lower morale and reduced worker productivity. Conversely, and probably more difficult to cost, there can also be benefits to establishing lower turnover rates, although lower turnover rates are likely associated with many factors, including good employee morale.

One way of measuring these indirect costs associated with worker productivity and morale, which are not normally linked internally to any particular process or product, is by assessing the additional costs of injuries, illnesses, or fatalities in specific industries. In addition, some researchers have proposed multipliers of salary, which quantify the premium paid by a company above and beyond salary and compensation when an injury, illness, or fatality occurs in the workplace.

A literature search was conducted, however, journal references were usually specific to a particular industry, such as construction or railroad workers. Therefore, the selected data source is *Accident Facts* by the National Safety Council (1997), which compiles industry-specific statistics for fatal and nonfatal injuries and illnesses in the workplace, rates by industry of lost workdays, and overall costs to industry.

In 1996, there were 4 unintentional-injury deaths per 100,000 workers, and approximately 3,000 disabling injuries per 100,000 workers. The National Safety Council's estimates of the total costs of occupational deaths and injuries were $121 billion in 1996, which includes wage and productivity losses of $60.2 billion, medical costs of $19 billion, administrative expenses of $25.6 billion, employers costs of $11.3 billion (time of workers other than those directly injured), damage to motor vehicles of $1.6 billion, and fire losses of $3.3 billion (National Safety Council, 1997). The estimated cost per worker, which indicates the value of goods or services each worker must produce to offset the cost of work injuries, is $960; this is not the average cost of a work injury, which is $26,000. The average cost per death is $790,000. The days lost due to injuries in 1996 was estimated as 80,000,000.

The National Safety Council continues their analysis by type of injury and by industry. The most common type of injury results from contacts with objects or equipment or from overexertions. Exposure to harmful substances accounts for 5.1 percent of the nonfatal occupational injuries, while fire and explosions accounts for 0.2 percent; these percentages are further categorized by industry division (e.g., agriculture, mining), and for manufacturing 5.4 percent of the nonfatal occupational injuries are due to exposure to harmful substances and 0.2 percent associated with fire and explosions.

The injury incidence rates per 100 full-time workers are also categorized by industry. Some representative numbers from 1995 are presented below.

Table 3-21 Industry-Specific Injury Incidence and Lost Workday Rates (1995)

Industry	Total Cases	Total Lost Workday Cases	Cases Without Lost Workdays
Manufacturing (all)	11.6	5.3	6.3
Lumber and wood products	14.9	7.0	7.9
Paper and allied products	8.5	4.2	4.3
Chemicals and allied products	5.5	2.7	2.8
Industrial inorganic chemicals	3.9	1.9	2.0
Plastics materials and synthetics	5.3	2.5	2.8
Industrial organic chemicals	3.4	1.7	1.7
Agricultural chemicals	5.8	2.8	3.0
Miscellaneous	8.0	3.5	4.5

chemical products			
Drugs	5.4	2.7	2.7

Source: Bureau of Labor Statistics, data from about 250,000 establishments in the private sector, summarized in National Safety Council, 1997.

Below, incidence rates per 100,000 workers are also presented for 1996, and include lost workdays. One approach for TCA would be to use the lost workday numbers and multiply it by the company-specific cost per day of lost productivity.

Table 3-22 Industry-Specific Injury Incidence and Lost Workday Rates (1996)

Industry	Total Cases	Lost Workday Cases	Lost Workdays[1]
Manufacturing (all)	14.9	5.48	118
Lumber and wood products	5	2.31	63
Paper and allied products	5.73	2.65	68
Chemicals and allied products	2.5	1.11	27
Industrial inorganic chemicals	2.14	0.93	22
Plastics materials and synthetics	1.89	0.85	23
Industrial organic chemicals	2.26	0.96	25
Agricultural chemicals	5.47	2.1	56
Miscellaneous chemical products	4.08	1.92	42
Drugs	4.66	2.38	45

Lost workdays include both days away from work and days of restricted work activity.
Source: National Safety Council, 1997

Another possible approach is the multiplier approach. However, because the range of indirect:direct costs for workplace fatalities, injuries, or illnesses varies widely in the literature, this approach is not recommended. For example, one reference states that the indirect expense of injury ranges from 2 to 20 times the direct expense for construction accidents. Excluding third-party lawsuits, the indirects versus the directs were found to average 2 to 1. Including third-party lawsuits, a factor of 20 to 1 can be reached (Construction Industry Institute, 1993). Another article reviews the literature on indirect accident costs, and quotes ratios of indirect:direct costs of 1:1 to 20:1, and another reference is quoted that has indirect:direct ratios ranging from 1:1 to 101:1. Most references found that reasonable ratios were about 4:1 and 5:1. These ratios are difficult to apply across all industries, since they may vary from industry to industry and by injury (Ferry, 1980).

A scenario of workplace injury or fatality is not difficult to imagine. If an explosion or malfunction in the industrial process were the scenario, the user of the TCA tool could select the overall dollar values presented which would include all types of potential workplace injuries or fatalities) and apply either $26,000 for a workplace injury or $790,000 for a workplace fatality, then multiply it by the number of workers affected and the probability of occurrence. Alternatively, industry- or injury-specific numbers could be applied. These are the costs associated with workplace injury or illness that are currently not accounted for.

Uncertainties

The uncertainties associated with the data from the National Safety Council include:

- The numbers presented may not fully include retraining costs
- There are categories labeled "all other" where it is impossible to identify the causes of the injuries
- Categories of industries may overlap

3.4.2 Type IV Costs - Market Share

Definition and Sources Reviewed

The market share of a company may be affected by the company's overall reputation, its environmental reputation, its environmental record, past environmental incidents, or news reports. Market share reflects consumer preference and assumes that the consumer has some knowledge of these aspects of a company's operations. In our limited review of the literature, we identified several qualitative studies, but no study was identified that objectively quantified and correlated market share impacts and financial costs with a company's environmental reputation, environmental record, past environmental incidents, or news reports. Our literature searches and recent experiences indicate that fairly substantial efforts are underway in certain sectors of the financial community to more objectively correlate financial ratios and financial returns with various levels of environmental performance within certain industries. Therefore, future efforts may establish a quantitative relationship, but currently the literature are more accurately represented as hypotheses that still need to be proved.

Environmental Reputation

A company's reputation is a key influence on consumer preferences. Studies have been conducted which examine reputational losses associated with product recalls and criminal fraud, but none were identified that quantitatively analyzed the relationship between market share and a company's environmental reputation. However, some studies are available on the effect of a company's environmental reputation on relationships with investors, as discussed in the Section 3.4.4.1. Again, from our review of the literature, it appears that certain sectors of the financial community are beginning to seek this type of understanding. Indications are that they are in the early stages of these efforts.

Environmental Record

Another factor which may influence potential costs and benefits associated with market share is the overall environmental record of a company, including "green company" policies. A reputation for leadership in environmental affairs could increase sales among customers who are sensitive to environmental issues. The publication of "green" handbooks and ratings systems allows consumers to make choices based on a company's environmental record (Russo and Fouts, 1997). The actual market share effect of these policies is not quantified in the literature, and in many ways will be difficult to separate from the more general parameter of environmental reputation.

Environmental Incidents

There are qualitative accounts of the market share effects of public perception following environmental incidents, for example, for Exxon following the Valdez oil spill (Tierney, 1998; New York Times, April 2, 1989; Lukaszewski and Gmeiner, 1993). Several authors conclude that Exxon's impression management efforts in the first few days following the oil spill were probably at least partially responsible for reducing the negative consequences Exxon experienced and for containing the damage to its corporate image. A campaign to return Exxon credit cards did not have any market share effect on Exxon. And, as discussed in Section 3.4.4.1, the incident did not have a great effect on relationships with investors. Although the experience clearly had some effect on Exxon's relationships with consumers and in the overall marketplace, these studies do not appear to be conclusive nor in consensus on the overall cost to relationships related to this accident.

If an environmental incident does occur, case studies show that being prepared, including planning for successful media relations, and effectively executing the plan when a crisis occurs, is necessary, and must be accomplished with the support of top management. Another basic requirement is that management tell the truth (Gottshalk, 1993). These types of costs for preparation are really Types I and II costs.

Scenarios in which a company's market share could be affected could include all of the factors potentially affecting a company's environmental reputation, as described above. For example, a large environmental incident could affect national market share, while a smaller, local, incident could affect local markets. Of course, product recalls are the most likely incidents to cause a decrease in market share. Another example, although the financial benefit has not been quantified, is that if a product is advertised to stress its "green" qualities, e.g., a pollution prevention aspect of its production and/or a decrease in end waste, then it is conceivable that a positive consumer response could result.

Uncertainties

The greatest uncertainty with the Type IV market share cost category is that there are no quantitative predictions of the effects of company reputation, record, or environmental incidents on market share. The user of this TCA methodology will need to provide a company-specific estimate of the magnitude of this Type IV cost. For example, if a scenario states that a large environmental incident occurs, then perhaps a 1% decrease in market share will result; this estimate is based on the mostly anecdotal reports of a lack of consumer response after the Exxon Valdez oil spill. It is recommended that this estimate be developed during the brainstorming portion of the TCA methodology, and through performing some additional research. In addition, it will be important for the TCA team to test internal assumptions regarding the current status of the parameters identified above in the "Influences on Probability." This is because events leading up to and causing these types of incidents are probably most often associated with unforeseen circumstances. Even well-managed companies can experience these types of costs and situations.

3.4.3 Type IV Costs - License to Operate

The concept of license to operate is clearly critical to industry and any business. Relative to a Type IV cost for this parameter, we are not referring to the direct costs to develop a greenfield plant or the costs related to permitting an expansion. These are Type I & II cost types. For example the direct costs of maintaining good relations with the regulators and the community are Type I & II costs. These Type IV costs are those intangible costs or benefits related to issues such as delays in receiving permits and the related costs due to loss of days of production/sales or the benefits that are derived from receiving timely reviews and approvals.

In our experiences there is consensus that these costs and benefits are real. However, there is not consensus on how to best represent these costs in a TCA. From our experiences there are a few concepts that may be helpful. These concepts can be applied to estimate costs or benefits. The first method consists of objectively characterizing your relationships with the community, regulators and other parties that may have some comment on your ability to operate. This characterization is best if there are objective situations in the past that can be associated with either cost savings or expenses, for example, if an emergency permit modification was necessary to meet an increased demand for a product or a tight construction schedule.

Once the relationship has been characterized, the next step is to connect the relationship to the alternative that is being evaluated. This can be done by assessing the sales that could be achieved on a daily basis, or the increase/decrease in costs that may be experienced due to missing construction windows (e.g., in northern climates, construction costs in winter can be much more expensive than those experienced in spring and summer). The exact nature and magnitude of these type of costs will be dependent on the alternative that is being evaluated in the TCA.

Another method that can be used to estimate these types of costs has a more negative connotation. However, this method can be used to represent benefits as well as costs if the concept of cost avoidance is employed. This method is to use the costs that are associated with fines from regulators for either delayed construction or for unpermitted sources. In the United States, the air pollution control programs are where the principal authority is placed to allow or deny construction and operation of most industrial sources. Within most state regulatory programs, a fine structure is in place for non-compliance and frequently these are identified in terms of non-compliant days. In the federal Clean Air Act, authority is provided for fines of up to $25,000 per day. However, experience indicates that this fine is applied only in extreme cases. Our experience from many states and consent orders is that $1,000 per day of non-compliance is more typical. Therefore, a cost or benefit can be derived for this Type IV cost category by estimating the number of days that are saved or lost relative to the license to operate and applying this typical daily fine or another cost multiplier.

Yet another method to capture these types of costs is a refinement on the first method. Since many companies have a long history with permitting and operational issues at plant sites, an historical review of a company's indirect or overhead expenses can be performed (using regression analysis if desired) and related to the permitting efforts at the different time periods. The changes in these cost profiles or the outliers could be used to represent these intangible costs that are experienced by companies.

3.4.4 Type IV Costs - Relationships

The costs of relationships are not often considered by corporations. Several authors point out that these costs may be significant, and should not be ignored. Relationships with investors, lenders, communities, and regulators are important components feeding into corporate profits. Relationships may be affected by a catastrophic event or by the general "green" image of a company. Relationships may also be affected by news media reports. The following sections describe the articles reviewed. Some of the articles provide cost estimates or percentages associated with negative events, such as a catastrophic event or a negative news media report. When quantitative values are available, they are summarized in the text and highlighted in the tables.

3.4.4.1 Relationships with Investors

Definition and Sources Reviewed

Relationships with investors may be measured by the effects of a firm's reputation on stock prices, by the response of stock market to general corporate environmental image (and/or social responsiveness), which is often a difficult characteristic to measure, by the response of the stock market to catastrophic events (what are termed event studies), or by the response of the stock market to negative news reports. Unanticipated events or new information may lead capital markets to revise their expectations about a firm's profitability. Example scenarios, influences on probability, and uncertainties are presented at the end of this section.

3.4.4.1.1 Effects of Environmental Reputation and "Green Company" Policies

A favorable environmental reputation may be linked to corporate financial value. "Environmental reputation" can mean different things to different people. In general, a reputation for efficient and sustainable use of natural resources, the firm's history with regard to spills and other incidents, and a firm's effectiveness of communication with third parties are key items. Corporate social responsibility is another factor associated with a firm's reputation. There is currently no clear consensus on the relationship between corporate social responsibility and financial performance.

The following bullets briefly summarize the effects on stock prices (positive, negative, or no association), as analyzed in the studies reviewed:

Positive Environmental Reputation/High Environmental-Social Scores/Green Company Policies

1. 5% increase in stock prices (environmental improvements)
2. 2.66% increase in stock prices (upgrading environmental scores)
3. 1.05% increase in stock prices (signing of CERES principles)
4. 23% increase in stock prices (high social performance tier compared to low social performance tier)
5. 3% increase in stock prices (difference between low vs. high number of Superfund sites)
6. 10% increase in stock prices (difference between low vs. high number of oil spills)

7. 8.1% increase in stock prices (difference between low vs. high number of toxic chemicals)
8. Positive association between 14 firms' social responsiveness indices and stock prices – no $ values (overall social responsiveness reputation)

Negative Environmental Reputation/High Environmental Costs/Lack of Green Policies

9. Decrease in shareholder wealth - no $ values (high environmental costs)
10. Decrease in total market valuation of $100 million (exceedance of government environmental standards)
11. Negative correlation between pollution abatement expenditures and economic performance – no $ values (high pollution abatement costs)
12. Decrease of 0.3%, or $4 million (release of TRI list)
13. Negative association between number of Superfund sites, number of toxic releases, and number of environmental penalties and share price – no # values (overall environmental status)
14. A –1% abnormal loss (announcement of poor pollution rating from British Columbia Ministry of Environment)

No Association with Environmental Reputation/High Environmental Costs/Lack of Green Policies

15. No association between the number of environmental penalties and fines levied against a company and the company's reputation
16. In studies of social responsiveness, of 21 studies reviewed, there was no association between firm social responsiveness and stock prices in 7 firms
17. Insignificant capital market response to a sample of 98 negative environmental events

The studies are described in the following table.

Table 3-23 Studies on Effects of Environmental Reputation and "Green Company" Policies

Study	Study Results
Positive Assocations	
1. ICF Kaiser study, cited in WBC, 1999	Environmental improvements might lead to a substantial reduction in the perceived risk of a firm, with possibly a **5% increase** in stock prices. More than 300 firms were evaluated and systematic risk is related to a number of financial and environmental variables, using multiple regression analysis.
2. Yamashita, Sen and Roberts, cited in WBC, 1999	Study finds a positive relationship between higher environmental scores and higher stock returns over the long run. Upgrading the environmental score could result in a **2.66% increase** in the 10 year average of beta-adjusted returns
3. White, 1996b	This paper examines the link between corporate environmental responsibility – measured by environmental reputation indices—and shareholder wealth. For firms that have adopted the CERES Principles, investors earn risk adjusted returns significantly greater than either the overall market or portfolios composed of less environmentally-responsible firms. Upon signature of the CERES Principles, shareholders from 5 out the 6 companies studied experienced a **1.05% increase** in the value of their holdings the day after the signing event.
4. Camejo, 1992, cited in Cohen et al., 1995	Rated 1,000 companies on 36 different social and environmental criteria, sorted companies into three social performance tiers, compared performance for a five-year period. The 200 companies with the highest social performance scores produced a 100% return vs. a 92% return by the 600 middle companies and a 76.6% return for the 200 bottom tier companies, a 23% difference in economic performance.
5, 6, and 7. Cohen et al., 1995, Investor Responsibility Research Center	Examined the relationships between environmental and financial performance using S&P 500 companies. Industry portfolios were constructed and the financial returns of the "high pollution" portfolios were compared to the "low pollution" portfolios adjusted for firm size, since firm size contributes to the ability of a firm to absorb the financial consequences of environmental risks and because larger firms are more likely to be exposed to greater environment risks. The general results were that, in many cases, low pollution portfolios achieved better returns than high pollution ones. • For number of Superfund sites, the firms with a low number of sites outperformed those with a large number by about **3%** • For number of oil spills, low oil spill portfolios earned a –4.2 percent compared to a –14.2 percent for the high spill portfolio, a difference of **10%**: Return on assets and return on equity are generally lower for the high oil spill portfolio • Risk adjusted returns were 32.1 percent for the low toxic portfolio vs. 23.7 percent for the high toxic portfolio, a difference of **8.1%** • For number of environmental lawsuits, firms with a relatively large number were found to earn a lower level of return on assets and return on equity, but no difference in stock market returns Investors who choose the environmental leaders in an industry-balanced portfolio were found to do as well, and sometimes better than those choosing less environmentally sound firms in each industry.
8. Davidson and Worrell, 1990	In a study of corporate social responsibility, twenty-one published studies were examined. Fourteen reported a positive association between corporate social responsibility and stock prices, while seven reported no real link.

Table 3-23 Studies on Effects of Environmental Reputation and "Green Company" Policies (continued)

Study	Study Results
Negative Association	
9. Holman, et al., 1985	Disclosure of high environmental cost requirements has an adverse impact on shareholder wealth or firm value. A regression analysis only, no quantitative dollar amounts provided. Found a significant positive result between total risk and a "Regulatory Compliance Capital Expenditure Index" variable.
10. Cormier, et al., 1992	The greater the level of pollution produced by a firm compared with government standards, the lower its stock market evaluation. Although a marginal statistical significance was found, the difference in market valuation between a firm that barely matches government norms, and one that is well within government norms is approximately **$100,000,000**. Thus, a firm's pollution performance is interpreted by market participants as providing information about its environmental liabilities.
11. Freedman and Jaggi, 1982	Study examines whether information concerning pollution abatement activities, required by the SEC, is really necessary for investors and stockholders. Analyzes the association of a pollution disclosure index with measures of economic performance using correlation tests. No association between the extensiveness of pollution disclosures and economic performance. Largest firms found a negative correlation between pollution disclosures and economic performance, possibly reflecting high pollution abatement expenditures.
12. Hamilton, 1995, summarized in Cohen et al., 1995	Examined the stock market reaction to EPA's toxic release inventory emissions data. Market value of publicly traded firms dropped by about **3/10 of 1 percent, or $4 million**. The larger the number of chemicals produced or handled at a facility, the larger the loss in market value – for each additional chemical, a loss of $236,000.
13. Johnson, et al., 1996	Examines the association between environmental performance and the 1988-90 market valuation (using equity and bond valuation analyses, with models and correlation statistics – no quantitative values reported) of 275 S&P 500 manufacturing firms. The four types of environmental compliance measures examined included hazardous waste cleanup responsibilities, legal releases of toxic chemicals, accidental oil and chemical spills, and penalties for non-compliance with federal environmental legislation. Results: 1. Equity values are affected by all except accidental spills, and are impacted by obligations arising from both past and current environmental performance. Average spill may be too small to impact market value. 2. Documented a negative association between share price and the number of Superfund sites at which it has been named a PRP, between share price and the level of a firm's toxic releases, and between share price and the number of environmental penalties received by the firm. Documented a positive association between firm value and the number of RCRA sites, due to RCRA's focus on abatement and prevention of future contamination. 3. Knowledge of the general toxicity of a firm's operations, irrespective of its current regulatory compliance status, is relevant to an assessment of the firm's future environmental obligations.
14. Lanoie et al., 1997	Examined the impact of lists published by the Ministry of Environment of British Columbia, indicating firms not complying with an environmental standard or permit, and firms that are of concern to the Ministry. Appearing on the list has no effect on the firms' equity value, using a 3-day event window However, for firms appearing more than once on the list, a –1% abnormal loss is found on the day following the announcement.
No Association	
15. Karpoff et al., 1998	The results indicate that firms violating environmental laws (measured by fines, damages, or remediation costs) suffer statistically significant losses in the market value of firm equity, however this loss is <u>not</u> related to reputational effects.
16. Davidson and Worrell, 1990 (cited above)	In a study of corporate social responsibility, twenty-one published studies were examined. There was no association between firm social responsiveness and stock prices in 7 firms.
17. Jones and Rubin, 1999	Studied events which produce negative responses, but do not affect the quality of products or break implicit labor or supply contracts. Found overall insignificant capital market response to a sample of 98 negative environmental events from electric power companies or oil firms with listed stocks (from Wall St. Journal 1970 to 1992)

3.4.4.1 2 Response of Stock Market to Environmental Incidents

Studies appear in the finance literature of the ability of the market to incorporate new information into stock prices. Past studies of environmental incidents have generally confirmed that financial markets respond efficiently when information concerning these events is released (White, 1996). In the case of the Exxon Valdez oil spill, several studies conclude that effects occurred for Exxon only; the impact of the spill on the volatility of other oil firms' share prices was not significant. In general, the studies support the conclusion that market reactions to unforeseen events is short-lived.

The following bullets briefly summarize the effects on stock prices, as analyzed in the studies reviewed:

1. Cumulative abnormal return of –19.04% over 255 trading days (Exxon Valdez)
2. Negative abnormal return of –1.69% (Exxon Valdez, and for other firms with high exposure to the Trans-Alaska Pipeline)
3. No significant pattern after initial negative reaction to major airline crashes - the immediate negative reaction to the crash is significant for only one full trading day after the event occurs – no $ values
4. Stock price fell approximately $1 billion or 27.9% (Union Carbide Bhopal) - firms with more extensive environmental disclosures experienced less negative stock market reactions

The studies reviewed are described in the following table.

Table 3-24 Studies on Response of Stock Market to Environmental Incidents

Study	Study Results
1. White, 1996a	The author examines the impact of the 1989 Exxon Valdez oil spill on investment returns to shareholders in two groups of firms: the oil industry and a sample of unrelated firms with environmental reputation rankings. The market model was estimated for each security in the sample over a 255 trading day period ending two trading days before the event data. Exxon's shareholders experienced an immediate, sustained and significant negative reaction to the spill; cumulative abnormal return was **negative 19.04**. Also, within the industry the effects of the spill were strongly negative, but were corrected at the end of the 120-day study period. Companies with reputations for environmentally responsible behavior earned significantly positive returns in the aftermath of the spill.
2. Mansur, et al., 1991	Study on the equity return levels of companies and the Exxon Valdez oil spill. Reviewed 14 major oil companies; effects estimated using a multivariate regression model. The effect of the spill on the equity return levels of large oil companies depended on the speed with which the market reacts to the news event, and whether the market was able to discriminate among oil companies based on its exposure to the Trans-Alaska Pipeline (The Alyeska Pipeline). Results showed: (1) There was a negative abnormal return (**1.69%**) confined only to Exxon. The market responded in an efficient manner to new information. (2) The high exposure group incurred greater negative abnormal returns than the non-exposed and less exposed groups. Stockholders of the high exposure groups realized abnormal losses equal to those of Exxon shareholders. No significant abnormal changes for firms marginally affected by the event indicates that the spill did not have an industry-wide impact.

Table 3-24 Studies on Response of Stock Market to Environmental Incidents (continued)

Study	Study Results
3. Barrett et al., 1987	Analyzes the response of stock prices to unanticipated events – fatal commercial airline crashes. The shares of affected airlines respond negatively to news of the crash, but the adjustment to the new information is immediate. This is contrasted with gradual price adjustment in response to anticipated events such as, news of stock splits, cash dividend changes, earnings and merger plans, where the reaction is complete by the time the pending announcement occurs. The conclusion was no significant pattern emerges after the initial negative reaction to major crashes. Also, the immediate negative reaction to the crash is significant for only one full trading day after the event occurs. Similar result observed if use the ratio of deaths to the book value of the firm's assets at time of crash.
4. Blacconiere and Patten, 1994	Examined the stock market reaction after the Bhopal chemical leak. Results were that firms with more extensive environmental disclosures experienced less negative stock market reactions. News of Union Carbide's Bhopal chemical leak caused an overall negative market reaction for a sample 47 chemical firms. The effect on Carbide's stock prices was immediate and pronounced. Within 5 trading days following the leak, the market value of Union Carbide's common stock price fell approximately \$1 billion or 27.9% (from \$3,443 million to \$2,483 million). Intra-industry market reactions to announcements were expected to affect future regulatory costs. Reaction was more negative for firms with larger ratios of chemical segment revenues to total revenues. Other examples in article: Tylenol incident: significant negative intra-industry reaction was observed for Johnson and Johnson within a few days following the incident, the reaction was insignificant for other firms in the industry/ Three Mile Island: A significant negative intra-industry reaction occurred and likely driven by investors concerned with the regulation of nuclear energy generation.

3.4.4.1.3 Response of the Stock Market to News Reports

Media reporting of a firm's environmental reputation or of environmental incidents is also important. Several authors (Shane and Spicer, 1983; Klassen and McLaughlin, 1995) investigate the association between media reports and security prices. Their results indicate that media reports directly influence economic performance, proving that good environmental performance, along with strong public relations efforts concerning good corporate environmental performance, will benefit the shareholders.

The studies identified with quantitative results, as referenced below, found:

1. A positive news effect of +0.58% on stock prices and a negative return of –1.48%
2. A positive news effect of +0.63% on stock prices and a negative news effect of –0.82%
3. Qualitative study concluded that an increase in firms' market value occurs when there is news of superior environmental performance, and a decrease when citizens' complaints occur
4. A negative news effect of –1.58% for news stating allegations of environmental violations, and a negative news effect of –1.92% for news stated that the firm was charged with or sued for a violation
5. A negative news effect of –1.2% in market value
6. A negative news effect of –1.65 to 2% in market value
7. A negative news effect of –3.0% to –3.3% in average abnormal mean-adjusted returns

The following table summarizes the studies reviewed.

Table 3-25 Studies on Response of the Stock Market to News Reports

Study	Study Results
1. Klassen and McLaughlin, 1993, summarized in Cohen et al., 1995	The magnitude of the positive news effects is relatively small, +0.58% abnormal returns. This compares to a negative return of –1.48% abnormal returns for negative news.
2. Klassen and McLaughlin, 1996, summarized in Innovest, 1999	Study to determine the effect of environmentally-related new on stock prices. The event period was defined as 3 days following the announcement. The average cumulative abnormal return for 140 companies for positive events was +0.63%, and was +0.82% when contemporaneous financial and management announcements were excluded. For negative events for 22 companies, the cumulative abnormal return was –0.82%, and was –1.50% when contemporaneous events were excluded. This translates to an average valuation of an environmental crisis of -$390 million.
3. Dasgupta et al., 1997	Although there is generally acknowledged poor enforcement of environmental regulations in the countries studied, capital markets react positively (increase in firms' market value) to news of superior environmental performance, and negatively (decrease in firms' market value) to citizens' complaints. Quantitative results available for a large number of firms in Argentina, Chile, Mexico, and Philippines.
4. Karpoff et al., 1998	Firms violating environmental laws (measured by fines, damages, or remediation costs), as reported in the news media, suffer statistically significant losses in the market value of firm equity. Using a sample of 283 cases, press announcements containing allegations of a violation were associated with an average –1.58% abnormal stock return. When the announcement contains information that the firm has been charged with, or sued for, a violation, the average abnormal stock return was –1.92%. Share value losses were relatively high for violations that lead to product recalls or assignment of environmental liabilities, and were higher, on average, for actions brought by state and local authorities than for actions brought by EPA or DOJ. This conclusion reinforces the value of maintaining good relationships with state and local authorities (see section on Type IV Relationships with Regulators).
5. Muoghalu et al., 1990, cited in Lanoie et al., 1997	Examined the impact of environmental enforcement measures. Sample consisted of 128 lawsuits and 74 case settlements reported in the news between 1977 and 1986. Average statistically significant loss of 1.2% in stock value, translating to an average loss of $33 million in equity value.
6. Lanoie and Laplante, 1994, cited in Lanoie et al., 1997	Analyzed news of 9 lawsuits and 13 settlements in Canada from 1982 to 1991. Observed abnormal losses between 1.65% and 2%.
7. Shane and Spicer, 1983	Study investigates whether security price movements are associated with externally produced information about companies' pollution control performances; the externally produced information used was from eight major studies conducted by the Council on Economic Priorities (CEP) of environmental performance in four industries. Results indicate that the CEP firms experienced relatively large negative returns (between –3.0 and –3.3%) on the two days immediately prior to newspaper reports on the release of the CEP findings. Returns for those companies with low pollution control performance ratings were more negative than companies with high rankings. Measured security price behavior as average abnormal mean-adjusted returns.

Uncertainties

There are a wide range of percentage changes in stock prices provided, and the selection of the appropriate value is not obvious. The appropriate value may vary from company to company and from scenario to scenario. Another uncertainty is that although the studies were conducted with specific influences in mind, such as a negative news event, other influences on the percentage point changes other than the factor under study could have been occurring at the time of the study.

3.4.4.2 Relationships with Lenders

Definition and Sources Reviewed

A company's relationships with its lenders has definite cost implications – the cost of credit is likely to hit a company's bottom line. Published literature and the internet were researched to compile information on costs to companies associated with lender relationships. The World Business Council for Sustainable Development discusses the evidence that better rates of credit are being offered to borrowers with demonstrably good environmental records. In one case, a leading international engineering company obtained funding for a revolving credit facility at a lower rate than the standard rate "in part because of its financial performance" (World Business Council, 1996).

As a note of caution, the user needs to be careful not to double count the costs or benefits for these categories (e.g., take credit for increased market value of equity and reduced cost of credit for a project) unless they can clearly be separated. Also, these costs or benefits may not be applicable for many of the projects that are reviewed in the TCA. For example, even if a project alternative may have a very positive impact on cashflow and probability, it may not be large relative to the numerous other issues that effect credit ratings. Nevertheless, since these are intangible costs, the user could use the spread between top corporate investment grade bonds and more riskier bonds to approximate the cost or benefit from a project. For example, if Moody's AAA rated bond pays 5.5% and a B rated bond pays 6.5%, then this spread could be applied as a cost factor to represent the cost or benefit for a particular project or alternative. It is important to note that these costs may be partially included in the Types I and II costs as part of the financing costs. Thus, the user needs to be careful that they understand what it is they are attempting to cost. In this situation, it may very well be that the cost we are simulating is not the direct cost of capital for the current project, but the impact on credit this project will have on financing future projects.

Scenarios could occur in which a company's overall environmental record is known to the public, or in which a large environmental incident occurred. Depending on the scenario, a company is either penalized for having a poor environmental record or rewarded for having a good environmental record. In these scenarios, the cost of credit would either increase several points or decrease several points (based on the cases presented above). The actual total dollar cost to the company will need to be company-specific.

Uncertainties

The major uncertainty associated with this Type IV cost category is that changes in credit ratings are very difficult to predict. A change in credit rating could have many sources, only one of which could be a company's environmental record.

3.4.4.3 Relationships with Communities

Definition and Sources Reviewed

Relationships with communities are important because they are associated with a company's license to operate and with profitable operations. Costs may be associated with community relations programs; these costs will be company-specific. According to one article, political skills are a valuable resource (which the authors call an "intangible asset") that can be used to "neutralize, promote, or otherwise manage external constituencies" (Russo and Fouts, 1997).

Increased dialogue between industry and the public about accident prevention and, ultimately, risk reduction, has been the recent result of several EPA regulations, such as the "Right-to-Know" and "Risk Management Plan" regulations. This dialogue, although it is likely to generate questions and discussions in the community about safety, emergency response readiness, and more, could improve communication, and thus, the relationships that companies have with the surrounding communities.

Uncertainties
This Type IV relationship cost has not been quantified. The user of the TCA method will need to estimate a percentage increase or decrease associated with good or poor community relationships, which may be based on its past experience with the community, or a predicted relationship in a new location.

3.4.4.4. Relationships with Regulators

Definition and Sources Reviewed
Relationships with regulators can affect the costs paid by a company. For example, when permits are required, a positive relationship with state regulators will allow for a smoother, and perhaps speedier, receipt of a permit. An organization's political acumen, defined as the ability to influence public policies in ways that confer a competitive advantage, is an intangible asset that has been neglected in the past (Russo and Fouts, 1997).

Arguments regarding the impact of regulations on firm value and productivity are: (1) environmental regulations negatively impact firm value by limiting the choices available to management and (2) environmental regulations can increase firm value by stimulation of innovation (Johnson, et al., 1996, Porter, 1995, Harvard Business Review). It is not generally agreed that superior environmental performance can enhance business performance, but this opinion is becoming more prevalent within industry. One paper holds that two factors contribute to this guarded optimism: 1) environmental standards today afford companies substantial flexibility in determining how to meet requirements, and 2) new regulations are focusing heavily on substances with essential functions in production, creating opportunities for manufacturers to reduce materials use and for suppliers to develop effective substitutes (Bonifant et al., 1995).

In one study, the financial effects of EPA investigations were analyzed (Bosch et al., 1996). Firms were divided into "winners" and "losers" of EPA investigations, and losers were further subdivided into firms that cooperated with EPA and those that did not. There was a weak negative market response to the announcement of EPA actions, with a cumulative abnormal return of –1.04% to the stockholders. The loss of cooperating firms was only 59.2% of those not cooperating. There was no market response to positive EPA announcements.

Uncertainties
As with other studies of stock prices, there could have been influences on the stock price other than the factor under study. In addition, quantitative data were only available from one study.

3.5 Type V Costs

Type V costs (intangible external) are the most difficult costs to quantify. Type V costs may include the social costs associated with pollution discharges to air, surface water, ground water/deep wells, and land. Type V costs will also include overall natural habitat impacts, value chain impacts, and product health impacts. The Type V costs were identified by surveying published literature, news reports, and the internet, and by interacting with the US EPA and international regulatory agencies. The approaches proposed in this methodology have not been widely used, and should be considered a first step in the development of accurate values for Type V external costs.

The approaches investigated for quantification of Type V costs are summarized in the following table.

Table 3-26 Summary Table for Type V Costs

Type V Cost	Data Sources
Pollutant Discharges to Air	1) Costs per ton of greenhouse gas emitted 2) Costs per case of disease or mortality, due to air emissions 3) Published literature on the social costs of global warming
Pollutant Discharges to Surface Water	1) Cost of lost fishing habitats and fisheries resources, using published literature 2) Cost of market transfers of water for environmental protection
Pollutant Discharges to Ground Water/Deep Well	1) Costs of freshwater use (region-specific) 2) Costs to desalinate
Pollutant Discharges to Land	1) Published literature on willingness-to-pay scales, related to recreational land use or conservation of land 2) Costs/benefits of preserving undeveloped land
Natural habitat impacts: local community, wetlands, wildlife reserves	1) Published data on the costs of restoring wetlands, habitats, or species 2) Valuation of societal benefits of wetlands 3) Published literature on willingness-to-pay scales, related to preservation of natural habitat or to protection of a particular species.
Value Chain Impacts	Category not costed in this TCA method draft.
Product Health Impacts	Category not costed in this TCA method draft.

3.5.1 Pollutant Discharges to Air

Externalities are costs or benefits that are outside or "external" to the market price of a product. These costs can be considered environmental externalities and include effects on air quality and the loss of natural resources. Table 3-27 provides environmental cost estimates for a number of air pollutants and for damages to natural resources.

The values in the table for pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM_{10}), and sulfur dioxide (SO_2) are derived from a study ordered by the Minnesota legislature in 1993. The study was conducted by the Minnesota

Public Utilities Commission (PUC) to quantify environmental costs associated with the generation of electricity. After a number of appeals, the PUC adopted final environmental externality costs in July 1997 (see notes (a) and (c) in the table).

Table 3-27 Type V Air Pollution Costs

Contaminant/ Factor	Cost Range	Cost Range (1998$)	Basis for Calculation	Reference
CO	$0.21 - $2.27 (1995$/ton)	$0.22 - $2.38	Damage Cost Approach based on a Willingness-to-Pay to avoid adverse human health effects, agricultural effects, and materials damage.	(a)
CO (UK)	$17 (1993$/ton)	$19	Secondary benefits of emissions reductions.	(b) Table 6-13,
CO (Norway)	$1-$14 (1991$/ton)	$1 - $16	(See note with Nitrogen Oxides)	p. 217
CO2	$0-$3.10 (1995$/ton)	$0 - $3.25	Damage Cost Approach based on a Willingness-to-Pay to avoid adverse human health effects, agricultural effects, and materials damage.	(a)
Hg	$1,429 - $4,359 (1995$/lb)	$1,498 - $4,568	Willingness-to-pay to protect recreational fishing values in Minnesota (interim value that was not finalized)	(c)
NOx	$18-$978 (1995$/ton)	$19 - $1,025	Damage Cost Approach based on a Willingness-to-Pay to avoid adverse human health effects, agricultural effects, and materials damage.	(a)
NOx (UK)	$136 (1993$/ton)	$149	Secondary benefits of emissions reductions. These	(b)
NOx (Europe)	$539 (1993$/ton)	$592	figures represent social costs in addition to overall	Table 6-13,
NOx (Norway)	$1,760-$34,540 (1991$/ton)	$2,038 - $39,997	climate changes from burning less fossil fuels. These can include such areas as air quality improvements,	p. 217
NOx	$2,200 (1989$/ton)	$2,772	reduction in traffic congestion and accidents, and the reduced risk of oil spills and tanker accidents.	
NO_x	$11 - $110 (1993$/ton)	$12 - $121		
Pb	$402 - $3,875 (1995$/ton)	$421 - $4,061	Damage Cost Approach based on a Willingness-to-Pay to avoid adverse human health effects, agricultural effects, and materials damage.	(a)
PM (UK)	$23,466 (1993$/ton)	$25,985	Secondary benefits of emissions reductions. These	(b)
PM (Europe)	$23,466 (1993$/ton)	$25,985	figures represent social costs in addition to overall	Table 6-13,
PM (Norway)	$2,310 - $29,700 (1993$/ton)	$2,536	climate changes from burning less fossil fuels. These can include such areas as air quality improvements,	p. 217
PM	$2,970 (1989$/ton)	$3,742	reduction in traffic congestion and accidents, and the reduced risk of oil spills and tanker accidents.	
PM	$440 - $11,900 (1993$/ton)	$483 - $13,066		
PM_{10}	$562-$6,423 (1995$/ton)	$589 - $6,731	Damage Cost Approach based on a Willingness-to-Pay to avoid adverse human health effects, agricultural effects, and materials damage.	(a)
SO_2	$10-189 (1995$/ton)	$10 - $192	Damage Cost Approach based on a Willingness-to-Pay to avoid adverse human health effects, agricultural effects, and materials damage.	(a)
SO_2 (UK)	$404 (1993$/ton)	$444	Secondary benefits of emissions reductions. These	(b)
SO_2 (Europe)	$701 (1993$/ton)	$770	figures represent social costs in addition to overall	Table 6-13,
SO_2 (Norway)	$550-$8,360 (1991$/ton)	$637 - $9,681	climate changes from burning less fossil fuels. These can include such areas as air quality improvements,	p. 217
SO_2	$330 - $1,980 (1993$/ton)	$362 - $2,174	reduction in traffic congestion and accidents, and the reduced risk of oil spills and tanker accidents.	
SO_2	$5,280 ($1989/ton)	$6,652		
VOCs	$396 - $2,640 (1993$/ton)	$405 - $2,899	Secondary benefits of emissions reductions. (See note above)	(b) Table 6-13, p. 217

Table 3-27 Type V Air Pollution Costs (continued)

Copntaminant/ Factor	Cost Range	Cost Range (1998$)	Basis for Calculation	Reference
Impingment and Entrainment of aqutic life in the intake of cooling water piping	$0 - $725,000 (1992$/cfs)	$0 - $817,075	Range of damages to commercial and recreational fishing from thermal power plants along the Hudson River with once-through cooling systems. The range is from three estimates in 1992$ ($0, $136,000, and $725,000).	(d) Vol. I, Table 16-12, p. 567
Water Thermal Discharge	$21 - $102 (1992$/cfs)	$24 - $115	Range of weighted averages of damages to aquatic life in the Hudson River, Lake Erie, and Lake Ontario	(d) Vol. I, Table 17-6, p. 593
Coastal drylands land loss from sea level rise	$4,000 (1995$/acre)	$4,192	Land preservation costs	(b) p. 191
Coastal wetlands land loss from sea level rise (coastal wetlands)	$10,000 - $30,000 (1995$/acre)	$10,480 - $31,440	Land preservation costs	(b) p. 191
Deforestation	$45 - $150 (1992$ per year per acre)	$51 - $169	Value of US forested areas above raw land value	(b) p. 193
	$0.81 - $8.09 (1995$/acre)	$0.85 - $8.49	Damage valuation. Low value is for low income countries, high value is for high income countries. (Converted from square kilometers)	(b) p. 192
Carbon Sequestration Cost	($14)(1994$/ton of carbon) - $205 (1992$/ton of carbon)	($15) - $231	Range of Costs for Forest Plantation, Forest Management, and Agroforestry. ($14) represents a cost savings of $14.	(b) Table 9.35, p. 353
Cancer Impacts	(1992$/ton)		Values for extra cancer cases incurred based on case study emissions. Assumes $1.7 million for each cancer case (includes health care costs and lost wages). For an affected population within 50 km of the site.	(e) Table 8-9,
- Arsenic	$476-$13,260	$536 - $14,944		p. 363
- Beryllium	$272-$10,710	$307 - $12,070		
- Cadmium	$204-$7,990	$230 - $9,005		
- Chromium	$1,326-$52,700	$1,494 - $59,393		
- Dioxin	$3,950,000,000-$83,300,000,000	$4,451,650,000 - $93,879,100,000		
- Formaldehyde	$2-$221	$2 - $249		
- Furans	$989,000,000-$11,900,000,000	$1,114,603,000 - $13,411,300,000		
- Nickel	$27-$1,054	$30 - $1,188		
- PCBs	$226,000,000-$5,210,000,000	$254,702,000 - $5,871,670,000		
- Polycyclic Organic Matter	$3,570-$153,000	$4,023 - $172,431		

Sources:
- Cost description is from Part 2 of 2 of the Northern States Power Company's Settlement (Docket No. E-999/CI-93-583), Executive Summary, Nov. 29, 1994.

The externality values had undergone several revisions before finalization.

Final externality values were downloaded from the Minnesotans for an Energy-Efficient Economy website in March 1999.
- Bruce, J.P., Lee, H., and Haites, E.F., eds. Climate Change 1995: Economic and Social Dimensions of Climate Change. Contribution of Working Group III
to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press (1996)
- Initial Brief of the Environmental Coalition on Substantive Issues. Section II.D. (Docket No. E-999/CI-93-583), January 12, 1996
- New York State Environmental Externalities Cost Study (NYSEECS), Oceana Publications (1995)
- NYSEECS - Adapted from Rea, D., Rowe, R.D., Murdoch, J. and Lula, R. Valuation of Other Externalities: Air Toxics, Water Consumption, Wastewater, and

Land Use. Prepared by RCG/Hagler, Bailly, Inc., Boulder, CO for New England Power Service Company, Westborough, MA

As a basis for its study, the PUC used a damage-cost approach to estimate externality costs based on an individual's willingness to pay to avoid the negative external effects of pollution. For example, if an additional unit of an air pollutant causes a person $10 worth of extra cleaning, health and other less tangible costs, such as the discomfort of a headache, then that person would be willing to pay up to $10 to avoid an increase in the pollutant. Using the damage-cost methodology, the PUC study linked emissions to effects on health, agricultural yields, and the value placed on avoiding or reducing these effects. The approach also attempted to incorporate the benefits of current regulations that reduce potentially damaging contaminants.

The fact that this study focused specifically on the state of Minnesota may limit its broader application. For example, to improve the accuracy of the data, the study estimated damages for local geographic areas and accounted for the effects of state-specific regulations designed to curb pollutants such as the Minnesota Acid Deposition Control Act. Also, in order to design a comprehensive, accurate study of the affected area that could estimate damage at the zip code level, the study focused on local factors such as differences in population, resources, and pollution concentrations. The Minnesota study also took into account models designed to simulate how air emissions disperse throughout specific geographic areas and agricultural models that account for county-specific yield trends, product values, and price linkages.

The survey conducted for this work revealed that externality cost estimates have also been developed for pollutants such as CO (for the UK and Norway), nitrogen oxides (NO_x), Particulate matter (PM), sulfur dioxide (SO_2), and volatile organic compounds (VOCs). These costs were reportedly developed (with the source (b) referenced) by placing a value on the secondary benefits of emission reductions and air quality improvements. These social costs include improvements to air quality, reduced traffic-related externalities like accidents and traffic congestion, the reduced risk of oil spills, and conservation of the world's biodiversity through a reduction in deforestation that all result from burning less fossil fuels.

The secondary benefits mentioned in Table 3-27 originated from a 1995 report by the Intergovernmental Panel on Climate Change. The report highlighted a number of different studies on the social costs of climate change and the benefits associated with controlling greenhouse emissions. A possible problem with using data from the report is that it selected results from various studies in order to provide a number of estimates for different regions. This compilation of different studies made a comparison of the estimates difficult, since social costs vary greatly from region to region and are based on region-specific air quality standards, ecosystems, and populations. In contrast to the global character of greenhouse damage estimates, secondary benefits are connected to the level of greenhouse gas abatement that occurs on a regional basis.

Table 3-27 also includes a cost range for damages to aquatic life caused by thermal discharges from power plants along the Hudson River, Lake Erie, and Lake Ontario.

These data were gathered to satisfy an order of the New York Public Service Commission (PSC) requiring electric utilities to develop estimates of external environmental costs associated with the generation of electricity. These costs are referenced by the letter (d) in the table. The cost range set for these damages represents an estimate of the annual impacts of three thermal power plants along the Hudson River.

Damages presented are based on dollars per cubic feet second for power plants with once-through cooling systems and incorporate the river's unique ecosystem. Therefore, they are not necessarily directly transferable to other plants on other bodies of water. Similarly, the range of damages to aquatic life in Lake Erie and Lake Ontario was taken from four case studies that appear to be highly variable depending on the thermal generation source and location. Also, since damage estimates are based on 1980s data, as mitigation measures and equipment improve, future damage estimates may prove to be overstated.

The last group of cost data that is represented in Table 3-27 also came from the New York Public Service Commission's Environment Externalities Cost Study. The data referenced in the table as from source (e) represent cost estimates associated with cancer cases caused by power plant emissions. Values are based on dollars per ton of emissions for contaminants such as arsenic, chromium, dioxin, and PCBs. The data assume $1.7 million for each case of cancer, including expenses such as health care costs and lost wages and covers an affected population within 50 km of a power plant. The cost estimate attempts to assess the added individual cancer risk through inhalation and ingestion for each toxic chemical emitted to the air. The added risk data is then multiplied by size of the population at each location to determine the additional potential cancer cases caused by the pollutants. Of course these estimates carry a certain amount of uncertainty based on the medical community's limited knowledge of how cancer attacks the body. Specifically, little is still known about the length of time between exposure and onset of disease and about what specific types of cancer result from each chemical.

3.5.2 Pollutant Discharges to Surface Water

A willingness-to-pay methodology for predicting natural resource damages due to surface water discharges is the first proposed method to value this Type V cost. This method, also termed contingent valuation, assumes that individuals' behavioral responses to reductions in resource services can be simulated in a survey questionnaire, that is, values for resources can be estimated by soliciting individuals' expressed preferences for them. This method assumes that expressed preferences are consistent with the behavior individuals would reveal in a market, if it existed (API, 1989). Economic valuation criteria ask the basic question: How much is the reduction in utility for an injury to a natural resource worth to an individual? Any estimates of willingness-to-pay values are affected by a variety of factors, in particular the distribution of income of the respondents.

Contingent valuation is important in valuing non-use components of social value (existence value). It is also useful in situations in which the direct and indirect uses of resources, for both consumptive and nonconsumptive purposes are severely restricted, as in preservation of a wildlife habitat in a remote location. Criticisms of the contingent valuation method include: (1) the reported willingness to pay is greater than actual willingness to pay; (2) hypothetical nature of the questions; (3) produces inconsistent results ($ value was the same for 2,000 ducks as for 200,000 ducks); (4) responses seem unrealistically large; (5) respondents' pre-existing biases; (6) lack of an appropriate multiplier (e.g., all households in the U.S.); (7) cost and difficulty of a good contingent valuation study (Mundy and McLean, 1998).

The willingness to pay for clean surface water is likely to be location-specific, and thus may be difficult to apply in this TCA methodology. However, one study found that in the Northeast, the willingness to pay for fishing increased with fishing experience. The average willingness to pay (with negative responses incorporated) ranged from $10.09 to $11.49 per year, while those who fished for more than a year were willing to pay more than 3 times these amounts, from $36.56 to $39.52 (Cameron and Englin, 1997). Another study found that elimination of toxic contamination from New York lakes and ponds would generate an annual benefit of about $63 per capita, per fishing season (Montgomery and Needleman, 1997).

A second proposed approach to providing a dollar value for this Type V cost is the cost of market transfers of water for environmental protection. One source states that from 1990 to 1997 more than $37 million was spent to lease 2 million acre-feet of water and $23.8 million was spent to purchase 132,000 acre-feet for environmental protection, primarily by state and federal agencies, mostly to augment flows on major rivers. Lease prices identified in 1991 ranged from $2/acre-foot to $7/acre-foot and purchase prices ranged from $9/acre-foot to $14/acre-foot. However, purchase and lease prices are highly region-specific. In the west, from 1990-1997, the average purchase price for the region was $397/acre-foot and the lease price $30/acre-foot. The highest average purchase price was in the Rocky Mountain region with the average purchase price of $553/acre-foot, while the average in the Southwest was $420/acre-foot. Lease prices ranged from $0.08/acre-foot to $214/acre-foot (EDV&CBN, 1998).

3.5.3 Pollutant Discharges to Ground Water/Deep Well

In order to estimate the external Type V costs for water use, a surrogate approach could be used. For example, the volume of water used by a process could be represented with the cost of a reverse osmosis system for brackish or salt water. Essentially, the surrogate for the externality would be the cost for replacement of the presumably clean water. From cost information developed by a vendor of reverse osmosis systems for salt and brackish water, the capital cost for a medium size system is approximately $5,000 per gallon per minute of clean water produced. Operation and maintenance costs ranges for a brackish system are $0.50 to $1.50 per 1000 gallons, and are $1.60 to $2.00 per 1000 gallons for a saltwater system. Therefore, if one knows the flow rate or consumption value for water, then a surrogate Type V externality cost could be estimated in this manner.

3.5.4 Pollutant Discharges to Land

One way to measure the social impacts of pollutant discharges to land is to measure the public's willingness to pay for access to recreational land. The American Recreation Coalition (ARC) conducts research to study public policy issues that will shape future recreational opportunities, such as the public's willingness to pay to use or visit federal lands (American Recreation Coalition, 1999). Those Americans who have used public lands in the past year (1998), equal to 32% of the public, are willing to pay an average of $9.20 in additional fees when they use federal lands. At the same time, approximately one in seven (15%) Americans who have used public lands in the past 12 months are not willing to pay any extra for visiting and using public lands. The size of this group is down 5 percentage points from the 20% level seen in prior years.

Another approach would be to assess the benefits of maintaining undeveloped land. There are many studies which quantify these benefits, for example, studies that quantify the value of open space, however, we have not attempted to summarize that literature in this TCA manual. It is noted that the trend toward spending tax dollars to protect public lands is increasing, as summarized by the Land Trust Alliance: "Voters overwhelmingly approved ballot measures to protect open space on Nov. 3, 1998, voting in eight of 10 state initiatives and a vast majority of county and municipal open space measures…the Land Trust Alliance has compiled the results of 148 ballot questions on open space funding, of which 124 (84 percent) were approved by the public…"

3.5.5 Natural Habitat Impacts

This section consists of a presentation of the potential approaches to valuing potential natural habitat impacts, and a compilation of our literature survey.

The costs of damages to natural habitats can be measured in a variety of ways, and there is considerable scientific and regulatory debate over the methodology and the applicability of these approaches. Possible approaches include:

- Wetland ecological assessment methods
- Compilation of published literature on willingness-to-pay scales (contingent valuation), related to preservation of natural habitat or to protection of a particular species
- Compilation of published data on the costs of restoring wetlands, habitats, or species
- Valuation of societal benefits of wetlands

Additionally, published literature is available on the costs of eutrophication, but these costs are not included in this initial TCA tool.

Both of the first two approaches listed, wetland ecological assessment methods and the contingent valuation approach, are methods that must be applied on a site-specific basis, for a particular wetland or for a particular spill or other damage, and thus would not apply to the Type V costing for the TCA tool. However, these approaches will be briefly outlined, in order to provide a full description of potential evaluation methods.

A variety of wetland ecological assessment methods are available, but must be applied in a site-specific manner. None of the available wetland valuation methods comprehensively account for all of the ecological and societal functions of a wetland. Because functions such as providing fish, shellfish, and wildlife habitat, flood control, storm damage prevention, and pollution prevention vary widely among different wetland types and locations, a combination of ecological assessment and economic valuation methods are needed to determine the value of a particular wetland. For example, the flood control and storm damage prevention functions of a wetland are likely to be far more valuable to property owners in an urban setting - more vulnerable to flooding due to storm water runoff - than at a rural locality where ample flood storage capacity has been preserved across the less densely populated landscape.

Contingent valuation is described above in Section 3.5.2. A key problem with using the contingent valuation method to evaluate Type V natural habitat impact costs is that it is clearly site-specific. Any study on willingness-to-pay measures the demand for the services of a particular site, not total or general recreational demand. The model must be directly linked to the resource being damaged.

Therefore, the natural habitat impact Type V costs for the TCA model will incorporate only the last two approaches outlined above, which compile quantitative results from past studies on the costs of restoring wetlands and other habitats, and the societal value of wetlands and other habitats.

It should be noted that there are a large number of studies on valuing natural habitats for specific locations around the world (see, for example, the Environmental Valuation Reference Inventory for Ecological Functions compiled by the Government of Quebec, Ministry of the Environment, at www.evri.ec.gc.ca/EVRI). We have included here only a few examples of the literature in this field.

3.5.5.1 Costs of Restoring Wetlands, Habitats, or Species
The benefits of wetlands exist in their function as fish and shellfish habitat, for recreation, resource preservation, and erosion control. To comprehensively assign an economic value, per unit area, to a particular wetland type or habitat, the following, key ecological and societal functions of wetlands should be considered:

- Ground water recharge and discharge
- Floodflow alteration and flood/storm damage prevention
- Provision and protection of freshwater supply
- Sediment stabilization and sediment/toxicant retention
- Nutrient removal/transformation and production export
- Fish and shellfish habitat and breeding areas
- Wildlife habitat, food sources, and breeding areas
- Enhancement of aquatic and terrestrial biodiversity
- Aesthetic, natural heritage, and recreational value to society

The economic value of a particular wetland habitat and its resident or migratory biota can be estimated indirectly, by integrating these wetland ecological assessment methods and natural resource damages/valuation metrics for site-specific evaluations of the:

- fish, shellfish, and wildlife support capacity of the wetland
- commercial value of the shellfish and/or fish population supported
- commercial value of wildlife supported (e.g., furbearers, game)

- aesthetic and recreational value of the habitat
- prescribed value, per individual, of non-commercial fish and wildlife species
- losses of endangered species (of prescribed value) and/or their habitat
- interim loss of natural resources and services from the time of the incident until full recovery of the resources, and
- the rehabilitation, restoration, and/or replacement costs for a damaged/lost wetland

Published case studies of the economic valuation of one or more wetland functions are briefly described below.

Restoration or replacement costs for damaged or lost wetlands are a typical element of a NRDA performed after a spill of oil or hazardous materials or some other physical damage to a wetland habitat. One or more approaches, such as WET 2.0, provide qualitative evaluation within the context of the CWA Section 404(b)1 guidelines. NRDA/HEA can be used to characterize the affected wetland and serve as a basis for the design of its restoration and/or replacement with a compensatory wetland habitat. While these site-specific wetland restoration costs can be calculated based on the costs of the required survey, design, earthworks, hydrologic engineering, soil replacement, and replanting of wetland vegetation, it is more difficult to assign an economic value to the full range of ecological functions lost from destroyed or impaired wetlands.

3.5.5.2 Valuation of Societal Benefits of Wetlands

Several studies are presented in this section, to illustrate approaches to valuing the societal benefits of wetlands. Our literature survey identified a considerable body of literature on this subject. However, because the valuations are highly location-specific, we have only presented a few examples to provide the TCA user with some background on this subject.

Thibodeau and Ostro (1981) estimated the economic benefits to society from protecting riparian wetlands within the Charles River watershed of the metropolitan Boston area (Table 3-28). They evaluated the benefits of wetland protection in terms of flood control, increases in nearby land value, pollution reduction, water supply, and recreation and aesthetics. Flood control functions of the wetlands were estimated at about $2,000 per acre, and the authors noted that "an asset which yields $2,000 per acre in perpetuity has a present value of more than $33,000." Since these estimates were for 1981 dollars, this should be considered as a low estimate of the flood control value of a riparian wetland in an urban setting. An increased property value of about $150 per acre of adjacent wetland also was estimated to derive from the aesthetic benefit of increased privacy enjoyed by wetland abutters. Pollution reduction functions of an acre of marsh were estimated based on equivalent costs to obtain the same water quality improvements from an engineered water treatment plant, but without also estimating the benefit from the toxic pollutant adsorptive capacity of the marsh. An acre of marsh was found to substitute for a treatment plant cost of $85 and an annual operation and maintenance cost of $1,475; the total of the plant cost and the capitalized annual cost was estimated at $16,960. The water supply value of an acre of wetland, calculated as the cost savings of using wetland-supported well water instead of purchasing municipal water, was about $6,044 per year, or $100,730 per acre when capitalized at 6 percent. The recreational value of the wetlands, capitalized at 8.75%, was estimated to have a present value of $56,100 per acre (in 1981 dollars).

Overall, the authors concluded that the economic value of Charles River wetland ranged from $153,535 to $190,009 per acre in 1981. However, this is likely an underestimate, because it did not account for other valuable wetland functions, such as the support of commercial and recreational fisheries, e.g., shellfish and finfish, or its value as wildlife habitat. Since the Charles River includes estuarine reaches that serve as breeding and nursery areas for commercially important fish and shellfish populations, a more complete study would have evaluated these fishery support functions and values.

Table 3-28 Summary of the Benefits of One Acre of Charles River Wetland (Boston, MA)

Function	1980 dollars Low Estimate of Value	High Estimate of Value	1998 dollars (b) Low Estimate of Value	High Estimate of Value
Increases in Land Value				
Flood Prevention	$ 33,370	$ 33,370	$ 62,302	$ 62,302
Local Amenity	$ 150	$ 480	$ 280	$ 896
Pollution Reduction				
Nutrients and BOD	$ 16,960	$ 16,960	$ 31,664	$ 31,664
Toxic Substances (c)				
Water Supply	$ 100,730	$ 100,730	$ 188,063	$ 188,063
Recreation and Aesthetics				
Recreation	$ 2,145	$ 38,469	$ 4,005	$ 71,822
	$ 153,355	**$ 190,009**	**$ 286,314**	**$ 354,747**

Notes:

a) Values depend on urban or rural settings. Urban settings have values at the high end of the range. Rural settings have lower values.
b) Values adjusted to 1998 dollars using GDP Price Deflator, US Dept. of Commerce, Bureau of Economic Analysis
c) Long term effects or permanence of heavy metals and pesticides in the wetlands was not known at time of this publication, therefore, the value of adsorptive capacity was not quantified.

Source: "An Economic Analysis of Wetland Protection," Francis R. Thibodeau and Bart D. Ostro. Journal of Environmental Management (1981) 12, 19-30

The valuation of riverside wetlands in the "Donau-Auen" National Park in Austria, performed by Kosz (1996), focused narrowly on a few costs and benefits of several project alternatives as part of an environmental impact assessment (EIA). Kosz valued the aesthetic and recreational benefits of the wetlands to local and regional inhabitants by determining the public's willingness to pay entry/user fees for a proposed national park that would consist of the preserved wetlands. The EIA also included a cost estimate for the perpetual ground water protection and management efforts that would be needed, to mitigate the loss of this wetland-mediated ecological function/service, in the event that a hydroelectric dam were built that would destroy these riparian wetlands. No other wetland ecological functions of value to society, such as flood control and storm damage prevention, reduction of surface water pollution, provision of water supply, or provision of fish and wildlife habitat, were included in this valuation component of the EIA. Kosz estimated the mitigation costs for two different national park alternatives, in terms of "the present value of investment, operating, and maintenance costs of securing water quality," as follows:

- 611 million ATS for Project III, that would destroy 1,800 hectares of wetlands
- 1.44 billion ATS for Project IV, that would destroy 8,800 hectares of wetlands

The inferred value of this ground water protection function of the riparian wetlands, thus, ranges from about 164,000 to 340,000 ATS per hectare. Due to the other valuable functions of wetlands, this evaluation of the benefits provided by the Donau-Auen wetlands is likely to understate their full economic value to society.

Bell (1997) placed economic value on the contribution of wetlands in supporting recreational finfish fishing in the southeastern U.S. Commercial fishing effort was not included. The amount of fish catch potentially affected is represented by a production, or yield, function. Data input into the production function included: recreational fisheries production data for estuarine-dependent finfish from coastal states from Virginia to Texas; the average weight of each fish species; the total number of fishing trips by state. The model uses consumer surplus or willingness to pay to impute value to salf marsh. Incremental changes in the wetlands will correspond to incremental changes in recreational catch and incremental changes in recreational demand. Using a discount rate of 8.125%, the estimated value of one incremental acre of wetlands is $6,471 on the East cost of Florida and $981 on the west coast of Florida (1984 dollars). The wide range of estimates is because the average willingness-to-pay is 50% higher on the East Florida Coast, and saltwater marsh is 4.5 times on the West coast than on the East coast.

The approach selected will be up to the user of the TCA tool, and will depend on the scenario being considered and the parameter to be measured. For example, if the scenario states that a release to surface water occurs, and the area is a wetland, the cost of wetland restoration would be an appropriate selection. In another example, if the scenario considers the building of a facility near a wetland or selecting another site to ensure conservation of a wetland, the societal value of wetlands would be an appropriate choice.

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Appendix 1 LCA Background

1.0 History of LCA

Life cycle assessment had its beginnings in the 1960s. Concerns over the limitations of raw materials and energy resources sparked interest in finding ways to cumulatively account for energy use and to forecast future resource supplies and use. Later in the 1960s, global modeling studies published in *The Limits to Growth*[1] and *A Blueprint forf Survival* (Club of Rome) resulted in predicting the effects of the world's changing population on the demand for finite raw materials and energy resources. During this period about a dozen studies were performed to estimate costs and environmental implications of alternative energy sources.

The process of quantifying the resource use and environmental releases of products became known as Resource and Environmental Profile Analysis (REPA), as practiced in the United States. In Europe, it was called an Ecobalance. During the early 1970s, the interest in LCA was driven by the energy shortages as a systems-oriented tool for tracking energy flows in industrial systems. However, as the oil crisis faded, so did interest in LCA. From 1975 to the early 1980s, environmental concerns shifted to issues of hazardous waste management. During this time, European interest grew with the establishment of an Environmental Directive (DG X1) by the European Commission. European LCA practitioners developed approaches parallel to those used in the US. Besides working to standardize pollution regulations throughout Europe, DG X1 issued the Liquid Food Container Directive in 1985, which directed member companies to monitor the energy and raw material consumption and solid waste generation of liquid food containers.

LCA, by its very nature, is data intensive, thus resulting in a costly assessment methodology when conducted manually. From the 1980s to the early 1990s, LCAs were conducted on a "special case" basis, with costs of an analysis ranging up to $250,000 for a single, complicated process. The two largest obstacles to the use of LCA as a day-to-day decision support tool were the cost and the fact that, performed manually, the LCA represented a static "moment-in-time" analysis of the product line. Scenario analyses or "what if" evaluations were cost-prohibitive and generally not performed.

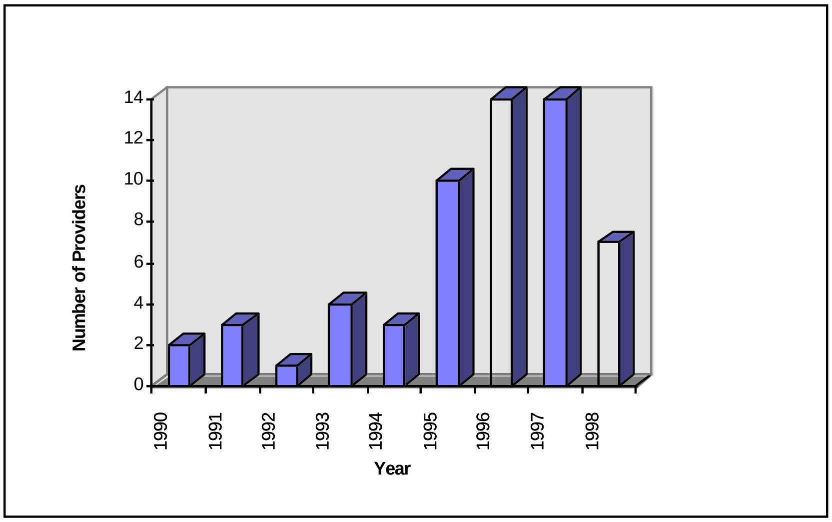
The labor intensity associated with data collection and data quality and availability have been recognized as significant obstacles for the use of LCA in day-to-day decision making. To address these issues, software tools to automate LCAs were introduced in 1990. At the beginning only a few tools were available. They could be characterized as being easy to use, but offered limited functionality. Many of the tools originated from Germany and Switzerland, where the terms "Ökobilanz" (Ecobalance) and "ökologische Buchhaltung" (ecological accounting) were used for the ecological evaluation of both products (LCA) and companies (ecobalance). Since 1995 the market has faced an impressive expansion and differentiation and a second generation of tools was released, keeping pace with the dynamic development of the methodology. These second-

[1] *The Limits to Growth: a Report for the Club of Rome's Project on the Predicament of Mankind,* D. H. Meadows, et al., Universe Books, New York, 1972, p. 205.

generation LCA programs also contain extensive electronic databases of LCA data, collected by industrial sector (i.e., pulp and paper, chemicals, transportation) from raw material extraction to manufacture of the product of interest. These databases have reduced the labor intensity of data collection.

Figure A.1 shows the number of providers who have developed automated LCA software systems that are commercially available. Note that the 1998 curve represents *the firstf three months of 1998 only.* Since May 1995, the cumulative market volume of LCA licenses sold increased more than 95 percent, compared to the total licenses sold between 1990 and 1995. This demonstrates the renewed interest in LCA, particularly since the previous obstacles of cost, labor intensity and the availability of data has been, in part, dealt with.

Figure A.1 History of Market Entry of LCA Software Programs



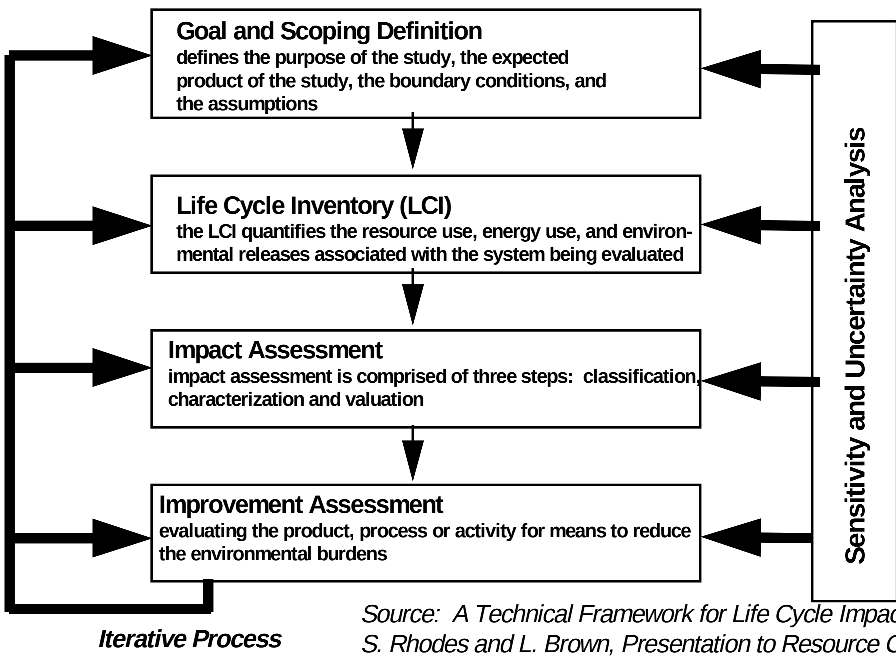
Source:- LCA-Software-Guide-1997:- Market-Overview - Software-Portraits,-C.-P.-Siegenthaler,-S.-Linder,-and-F.-Pagliara,-öbu,-Schriftenreihe-13/1997.-

2.0 Overview of the LCA Methodology

In the U.S., the Society for Environmental Chemistry and Toxicology (SETAC) and in Europe, the Society for Promotion of Life Cycle Assessment Development (SPOLD), are working to develop standard approaches for conducting LCAs. In both Europe and the U.S., the approaches are similar, reflecting the international coordination of this subject area. This section is devoted to providing an abbreviated description of LCA in its current state of development.

As mentioned previously, LCA is composed of four stages: goal definition and scoping, life cycle inventory, impact assessment, and improvement analysis (Figure A.2). The following provides a description of each of these areas.

Figure A.2 Technical Framework for LCA



Source: A Technical Framework for Life Cycle Impact Assessment, S. Rhodes and L. Brown, Presentation to Resource Canada Workshop, November, 1997.

The ***goal definition and scoping*** stage of LCA defines the purpose, the expected outputs, the boundary conditions and the assumptions for the study. The goal definition consists of stating, succinctly, the purpose for the defined activity. Typically, LCA studies are performed in response to specific questions. The nature of the questions determines the goals and scope of the study.

LCA studies are comparative by nature. Usually someone is seeking information to use in making a decision. A company may be deciding whether to fund or promote a new process, a new product, or a different type of package for the product. Determining what choices are available helps determine what the purpose and scope of the LCA should be. Complex choices can lead to more in-depth analysis and may require a full LCA. Simpler choices can perhaps be made with the information provided by an LCI of the competing systems.

Once the general goals and purpose of the LCA study are understood, the boundaries of the study must be determined. It is common practice to define the life cycle of the product, process, or activity being studied as a system.[2] All operations that contribute to the life cycle of the product, process, or activity fall within the system boundaries. The environment is the surrounding for the system. Inputs to the system are natural resources, including energy resources. Outputs of the system are ultimately a collection of releases

[2] Ian Boustead, *Eco-balance Methodology for Commodity Thermoplastics*, The European Center for Plastics in the Environment (PWMI), Brussels, December, 1992.

to the environment (air, water and land). If the system represents the manufacture and use of a product, then outputs include the post-consumer use or discarded product. Scoping defines the boundaries, assumptions, and limitations of a specific LCA. Practitioners must decide at the outset the system to be studied and its relationship to the defined goal of the LCA. This will provide better understanding of the types of data to be collected and the impact areas to be assessed. Resources may limit LCAs, and the scope of the LCA must be bounded. Scoping should be done before an LCA is conducted to ensure that:

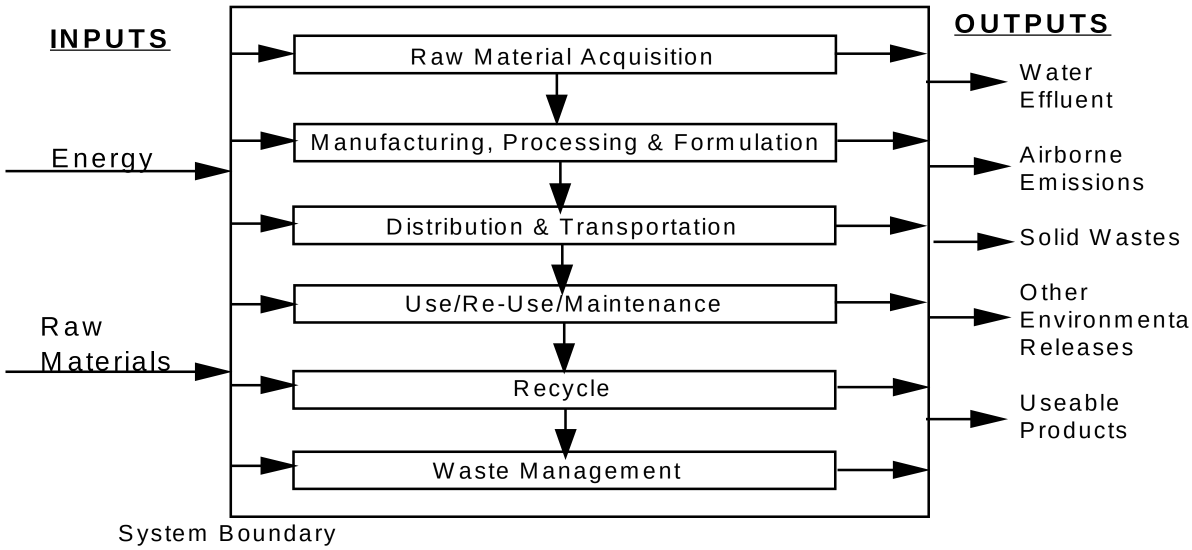
- ➥ the breadth and depth of the analysis are consistent with the defined goals of the LCA
- ➥ all boundaries, methodologies, data categories, and assumptions are clearly stated, comprehensive and visible

Scoping and goal definition play an integral role in shaping the outcome of any LCA. It is unlikely that any two LCAs have exactly the same goal and scope, and be conducted under the same set of conditions. Therefore, it is also unlikely that any two LCAs produce exactly the same results.

Life cycle inventory (LCI) is the second stage of an LCA analysis. The LCI quantifies the raw materials used, energy use, and environmental releases associated with the system being evaluated. For a product life cycle, the analysis involves all steps in the life cycle of each component of the product being studied (illustrated in Figure A.3). This includes the acquisition of raw materials from the earth, the acquisition of energy resources from the earth, processing of raw materials into usable components, manufacturing products and intermediates, transportation of materials to each processing step, use of the product and final disposition (which may include recycling, reuse, incineration or landfill).[3]

[3] *Environmental Life-Cycle Assessment*, Mary Ann Curran, McGraw-Hill, ISBN 0-07-015063-X, 1996, p 2.2

Figure A.3 Input/Output Analysis for Industrial Operation



Source: "A Technical Framework for Life-Cycle Assessments", SETAC, 1993.

EPA and SETAC guidance documents present the following activities in preparing a LCI:

- ➥ Define the purpose of the inventory analysis
- ➥ Define the boundaries of the system to be studied
- ➥ Develop a data questionnaire to collect the appropriate data
- ➥ Gather data
- ➥ Develop stand-alone "subsystem" data
- ➥ Construct a computational model for normalizing and aggregating the data
- ➥ Present results
- ➥ Conduct a peer review to validate the results
- ➥ Interpret the results
- ➥ Communicate the results

A complete LCI provides an overview of the life cycle inputs (e.g., materials and energy) and outputs (e.g., air emissions, water effluents, solid waste, hazardous waste and co-products) associated with a system. The results of an inventory analysis may be used to identify areas to achieve improvement, as baseline information for conducting an impact assessment, or some combination of the two.

LCI has been practiced in the U.S. and in Europe for more than 20 years and the basic methodology is widely accepted and used. Most environmental studies performed to date have been LCIs. This stage of LCA is critical because the LCI results are needed to perform any type of quantitative impact assessment. If the impact assessment is not performed, the LCI results can be used directly to perform improvement assessments based on energy and emission results, but not directly on effects on human health or the environment.

Impact assessments (IA), the third stage of a LCA, represents a focus area where there is little consensus by LCA practitioners for a technically-sound methodology. The life cycle impact assessment chain differentiates between three levels of environmental impacts leading to damages. For instance, in the production of glass packaging, SO_2 is produced as an output. These emissions, in addition to all other inputs and outputs, are characterized by the LCI, which relates the pounds of SO_2 generated per glass container produced. The intermediate effects correspond to the increased acidity of adjacent bodies of water, caused by SO_2 contamination. The ultimate impacts correspond to the number of fish killed and the loss of biodiversity resulting from this increased acidity.

Conceptually, impact assessment consists of three stages: classification; characterization; and valuation.[4] [5] [6]

- *classification:* the process of assignment and initial aggregation of LCI data into relatively homogeneous impact groups
- *characterization:* the process of identifying impacts of concern and selecting actual or surrogate characteristics to describe impacts. It is a goal of characterization methodologies to develop conversion models that are used to translate LCI and supplemental data to impact descriptors, called environmental and human health stressors
- *valuation:* the assignment of relative values or weights to different impacts. This allows integration across all impact categories. When valuation is completed, the decision-makers can directly compare the overall potential impacts of each product. Although a desirable goal, the valuation step is highly subjective. The assignment of relative weights to various potential impacts is inherently value-laden and there is no currently accepted scientific method for accurately completing the valuation step of impact assessment.

Classification. Classification is the process of assigning and aggregating results from the inventory into relatively homogeneous impact categories. Impact categories are chosen to represent the issues of interest for a specific study. SETAC lists four general impact categories:[21]

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[4] SETAC, *A Conceptual Framework for Life-Cycle Impact Assessment,* SETAC Workshop (Feb. 1-7, 1992) report, The Society of Environmental Toxicology and Chemistry, Pensacola, FL., 1993
[5] Canadian Standards Association, Standard Z760-94, Life-Cycle Assessment, Etobioke, Ontario, Canada, 1994.
[6] *Life-Cycle Assessment,* Environmental Protection Agency, Report to the EPA by Research Triangle Park Institute, 1994.

- ➥ environmental or ecosystem quality
- ➥ quality of human life (including health)
- ➥ natural resource utilization
- ➥ social welfare

There is no agreement at this time on a standard approach to conduct an IA of social welfare issues.

Table A.1 shows a listing of the primary *ecological stressors* identified from literature sources as outputs from LCI studies, which include pollutant discharges to all media (i.e., air, water and soil). The "stressor concept" is described in the box below.

Each of these stressors is classified into a relatively homogeneous group of ecosystem impacts. In addition to the classification of the stressors that create ecosystem impacts, there is also the need to include the principles of sustainability of industrial operations. Table A.2 shows a list of measurement criteria proposed for natural resources depleted or accreted and criteria for emissions loading. The user of this manual is cautioned that the generation of classification indicators is a highly dynamic area, with little consensus by any country or the global LCA community as to the completeness or the significance of these indicators.

The Stressor Concept

The stressor concept has provided a useful means of talking about the relationship between life cycle inventory items and subsequent impacts. A stressor is defined as any physical, chemical, or biological entity that can induce an impact, and may be characterized by the following attributes:

- ➥ Type: chemical physical, or biological
- ➥ Intensity: concentration, magnitude, abundance/density
- ➥ Duration: acute (short term) versus chronic (long-term)
- ➥ Frequency: single event versus recurring or multiple exposures
- ➥ Timing: time of occurrence relative to environmental and human health parameters
- ➥ Scale: spatial extent and heterogeneity in intensity

The stressor concept is imbedded (implicitly) in life cycle impact assessment. In this context, a stressor can be an inventory item that leads to a primary impact(s). For example, a stressor could be identified as the quantity of SO_2 emissions to the air from a given product or process system. This SO_2 can be linked to primary impacts such as acid precipitation. Acid precipitation is an impact of SO_2 emissions as well as a stressor, because it can be linked to secondary impacts such as acidification of water bodies, tree damage, building materials corrosion, and the leaching of metals from soils.

Table A.1 Ecological Stressors: The Apparent Causes of Environmental Impacts

Ecological Stressors		
Acid (air)	Dissolved solids	Nitrogen oxides
Acid (water)	Ethylene oxide	Odorous sulfur
Aldehyde	Fluorides	Oil
Aluminum	Herbicides	Other organics
Ammonia	Hydrocarbons	Particulates
Arsenic	Hydrogen fluoride	Pesticides
Biochemical oxygen demand (BOD)	Iron	Phenol
Carbon dioxide	Kerosene	Phosphates
Carbon monoxide	Lead	Phosphorus
Chemical oxygen demand (COD)	Mercury	Sulfides
Chlorine	Metal ion (water)	Sulfuric acid
Chromium	Methane	Sulfur oxides
Cyanide	Nickel	Suspended solids
	Nitrogen (water)	

Source: *Environmental Life-Cycle Assessment,* Mary Ann Curran, McGraw-Hill, ISBN 0-07-015063-X, 1996, p 2.29

Table A.2 Compilation of Ecological Indicators and Measurement Criteria for LCA

Ecosystem Impacts			
Net Resources Depleted/Accreted		**Indicators for Emissions Loading**	
Indicator	**Unit of Measure**	**Indicator**	**Unit of Measure**
Water	equivalent cubic meters	Greenhouse gases	tons of CO_2 equivalents
Wood	equivalent cubic meters	Acidification	tons of SO_2 equivalents
Fossil fuels	tons of oil equivalent	Ground level ozone	tons of O_3 equivalents
Non-fuel oil and gas	tons of oil equivalent	Stratospheric ozone depletion	tons of CFC-11 equivalents
Metals (specific)	tons of metal equivalents	Trace hazardous chemical (air)	
Minerals (specific)	tons of mineral equivalents	- PM 2.5-10 (respiratory/ pulmonary)	equivalent tons
Marine	TBD	- <PM 2.5 (respiratory/ pulmonary)	equivalent tons
Land area		- Aromatics TRI (oncogenic)	equivalent tons
- Terrestrial habitat	equivalent hectares	- Heavy metals TRI (oncogenic)	equivalent tons
- Wetland habitat	equivalent hectares	Noise	decibels
- Aquatic habitat	equivalent hectares	Eutrophying chemicals	tons of PO_4 equivalent
- Soil	equivalent hectares	Total organic carbon (TOC) or BOD	tons of oxidizable C equivalents
		Total suspended solids (TSS)	TBD
		Trace hazardous chemical (water)	
		- Heavy metals TRI (acute ecotoxicity)	equivalent tons
		- Non-metals TRI (acute ecotoxicity)	equivalent tons
		Thermal	equivalent BTUs
		Non-treatable hazardous waste	equivalent tons

Source: *"A Technical Framework for Life-Cycle Impact Assessment and Its Potential Application in Measuring the Degree of Sustainability of Industrial Systems",* S. Rhodes and L. Brown, Presentation to Resource Canada Workshop, November 1997.

For the major classification of human health, potential impact categories are defined in Table A.3

Table A.3 Human Health Impacts from Exposure to Environmental and Human Health Stressors

Human Health Impact Categories
➥ Human carcinogen (class A)
➥ Irritant (eye, lung, skin, GI tract), corrosive
➥ Respiratory system effects
➥ Central nervous system effects
➥ Allergenicity, sensitization
➥ Methemoglobinemia, blood disease
➥ Odors
➥ Cardiovascular system effects
➥ Reproductive system effects
➥ Behavioral effects
➥ Bone or renal effects

Characterization. The second step of the impact assessment is characterization, which is assessing the magnitude of potential impacts on the chosen major categories (human health or ecosystem quality) for each of the subcategories selected.

For instance, carbon monoxide, carbon dioxide, chlorine, and methane are all classified under the category of greenhouse gas and global warming. Each chemical has a potential impact on ecosystem quality through this subcategory. Models for the potential impact of each substance are used to equate the quantities of each pollutant to units of potential global warming.

Various models have been reviewed by SETAC for purposes of assessing the contribution of each emissions. The goal of each of these models is to assess the magnitude of environmental harm from the product systems being studied. For example, if one manufacturing system produces 15 pounds of airborne particulates and another system produces 30 pounds, some mechanism is desired to assess whether it is a matter for concern. Some proposed characterization models are[7]:

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[7] *Environmental Life-Cycle Assessment*, Mary Ann Curran, McGraw-Hill, ISBN 0-07-015063-X, 1996, pp 2.30-2.31.

- *Loading.* These models assess inventory chemical data on quantity alone, with the assumption that less quantity produces less potential impact
- *Equivalency.* These models use derived equivalency factors to aggregate inventory data with the assumption that aggregated equivalency factors measure potential impacts
- *Inherent chemical properties.* These models pool inventory data based on chemical properties, toxicity, persistence and bioaccumulation with the assumption that these criteria would normalize the inventory data to provide measure of potential impacts
- *Generic exposure and effects.* These models estimate potential impact based on generic environmental and human health information
- *Site-specific exposure and effects.* These models determine the actual impacts of products systems based on site-specific fate, transport and impact information for the relevant area or site.

Valuation. Valuation, the assignment of relative values or weights to different impacts, is the least developed area of an impact assessment. Valuation attempts to establish equivalency factors for different environmental impacts. For example, which degrades the environment more – a ton of SO_x or a ton of volatile organic compounds? And how does one compare the environmental degradation equivalency between air pollutants and water pollution? The following lists possible bases for equivalency factors.[8]

- Cancer potency index
- Molecular weight or other molar basis
- Reference does values (Rfd)
- Hydrogen-ion or acid equivalents
- Carbon equivalents
- Oxygen equivalents
- Halogen-ion equivalents
- Acute toxicity values (LD_{50})
- Sensory irritation index (RD_{50})
- Chemical “potentials” (e.g., ozone depleting potentials, global warming)
- Environmental or ecotoxicity data (e.g., genetic toxicity values, Ames’ mutagenicity test)chromosomal aberration, aquatic toxicity values)
- Other physical or chemical data (e.g., partition coefficients)
- Quantitative risk assessment

[8] *Environmental Life-Cycle Assessments,* Mary Ann Curran, McGraw-Hill, ISBN 0-07-015063-X, 1996, p. 2.32.

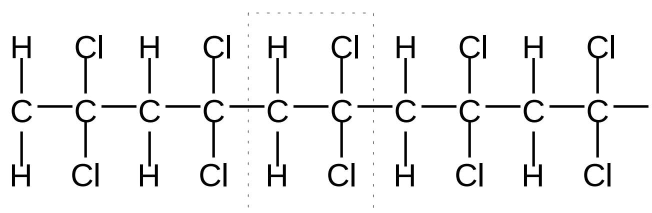
None of these techniques are considered to be routinely acceptable.

Improvement Analysis. The improvement analysis component of the LCA is a systematic evaluation of the needs and opportunities to reduce the E&H burdens associated with energy and raw material use and waste emissions throughout the life cycle of a product, process, or activity. This analysis may include both quantitative and qualitative measures of improvements.

3.0 A Case Study[9]

The production of polyvinylidene chloride (PVdC) is used to illustrate the LCA methodology. PVdC is a semi-crystalline thermoplastic with the structural formula shown in Figure A.4. The most valuable property of PVdC is its very low permeability to gases, water vapor, aromas, and fats under both wet and dry conditions. It is widely used as a barrier layer in many packaging applications, especially in the food and drink industry.

Figure A.4 Structural Formula for Polyvinylidene Chloride



The polymer is commonly produced as a co-polymer with monomers such as vinyl chloride, methyl acrylate, methyl methacrylate and acrylonitrile. In general, the higher the vinylidene chloride content of the co-polymer, the higher the barrier properties. The polymer is produced as an aqueous dispersion, as a solid resin for use in solvents, as a lacquer and as an extrudable granulate. Aqueous dispersions are used to coat paper, board, polyethylene terephthalate (PET) films and bottles and oriented polypropylene (OPP) films. Lacquers are employed as heat sealable barrier coatings on cellophane and other plastic films, while the extrudable resin can be converted into barrier films or coextruded with other polymers into barrier films or sheets.

The principal operations employed in the production of PVdC are shown in Figure A.5. This schematic represents the major steps in the production of PVdC from raw material extraction to manufacture.

PVdC in Use. PVdC is most commonly used as a barrier layer applied to packaging films made from other polymers. This application is quite different from the use of most other polymers that are fabricated into the final component. As a consequence, the contribution that PVdC makes to the overall environmental burden in any application is

[9] Association of Plastics Manufacturers of Europe, *"Eco-profiles of the European Plastics Industry, Report 7: PVdC (Polyvinylidene Chloride),* Brussels, December 1994.

significantly less than these other polymers because of the relatively small quantities used in the final application.

Figure A.5 Schematic Flow Diagram of the Principal Operations used in the Production of PVdC

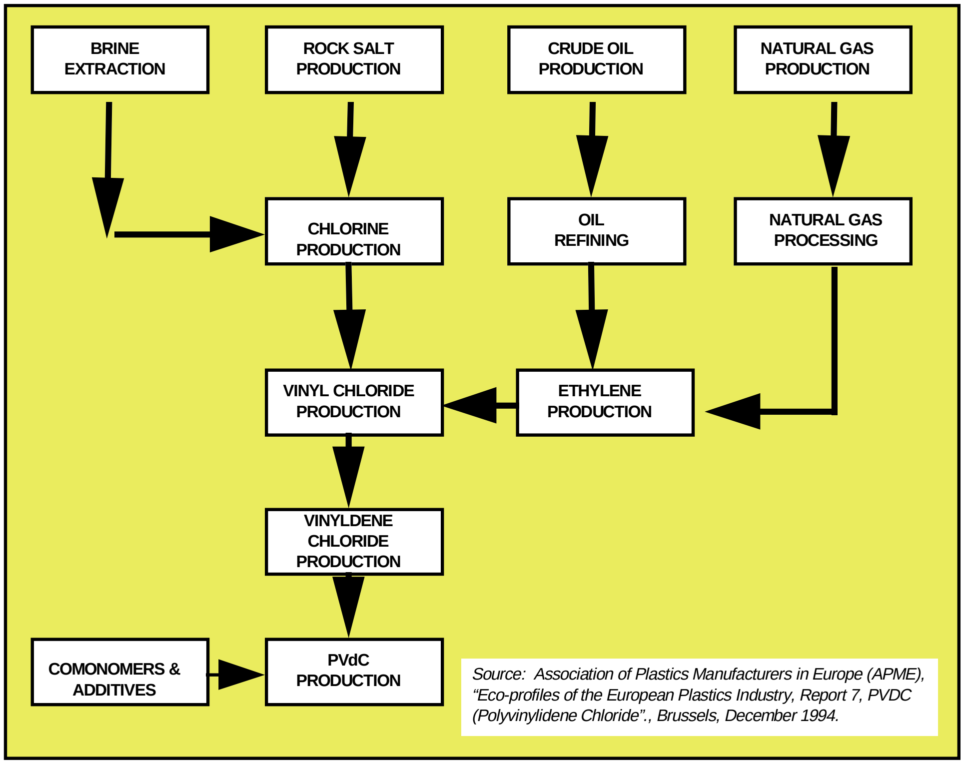


Table A.4 contains the LCI data that compares two scenarios for barrier film production. Case 1 contains data resulting from the use of 1 kg of PVdC coated on PP film to produce the specified permeability. Case 2 presents data resulting from the production of an uncoated PP film that has the same permeability as the film produced in Case 1. LCI data for the two base materials, PVdC and PP, are included in the columns labeled Basis.

Case 1 – PVdC Coated PP Film. Oriented polypropylene film, which is typically 20 to 50 µm thick, can be coated with PVdC to a thickness of between 1.8 and 3.3 µm, although the thickness usually applied is in the range of 2.0 to 2.5 µm. In mass terms, an oriented PP film would typically have a coating of 0.13 kg of PVdC per 1 kg of PP. The effect of this can be seen in Table A.4, where the column labelled Case 1 shows the inputs and outputs associated with the manufacture of 1 kg of coated film with the permeability specification.

The small incremental changes arising from the use of PVdC in this barrier application are best put into perspective by considering the properties that it imparts to the film. The permeability to oxygen of coated PP film depends upon the thickness of the PVdC coating, but in typical thicknesses currently applied commercially (2.0 to 2.5 µm), the permeability of the film to oxygen is reduced by a factor of about 50.

Table A.4 LCI for Polyvinylidene Chloride (PVdC), Polypropylene (PP), PVdC coated Film and the Uncoated PP Film Needed to Produce the Same Barrier Properties as the Coated Film

Raw Material Inputs		Units	Basis 1 1 Kg of PVdC	Basis 2 1 Kg of PP	Case 1 1 Kg PVdC coated PP film	Case 2 PP film with same properties as coated film
Fuels	Coal	MJ	13.72	1.66	3.05	83.00
	Oil	MJ	12.67	16.87	16.39	843.50
	Gas	MJ	24.02	11.90	13.29	595.00
	Hydro	MJ	0.94	0.82	0.82	40.50
	Nuclear	MJ	18.77	3.04	3.04	50.00
	Lignite	MJ	0.24	0.08	0.08	3.00
	Total fuels	MJ	70.36	32.30	36.68	1615.00
Feedstocks	Coal	MJ	0.01	0.01	0.01	0.25
	Oil	MJ	14.14	37.91	35.18	1895.00
	Gas	MJ	11.62	9.82	10.03	491.00
	Total feedstock	MJ	25.77	47.74	45.21	2386.75
Total fuel plus feedstock		MJ	96.13	80.04	81.89	4001.75
Raw materials	Iron ore	mg	1200	300	404	15000
	Limestone	mg	645000	200	74381	10000
	Water	mg	30000000	3100000	6194690	155000000
	Bauxite	mg	780	400	1251	20000
	Sodium chloride	mg	1350000	5000	159735	250000
	Sand	mg	3500	30	429	15000
Outputs		**Units**	**Basis 1 1 Kg of PVdC**	**Basis 2 1 Kg of PP**	**Case 1 1 Kg PVdC coated PP film**	**Case 2 PP film with same properties as coated film**
Air emissions	Dust	mg	10000	2000	2920	100000
	Carbon monoxide	mg	8600	700	1609	35000
	Carbon dioxide	mg	3550000	5000	159735	250000
	Sulfur oxides	mg	49000	11000	15372	550000
	Nitrogen oxides	mg	33000	10000	12646	500000
	Hydrogen chloride	mg	430	40	85	2000

Table A.4 LCI for Polyvinylidene Chloride (PVdC), Polypropylene (PP), PVdC coated Film and the Uncoated PP Film Needed to Produce the Same Barrier Properties as the Coated Film

	Hydrocarbons	mg	33000	13000	15301	650000
	Other organics	mg	8500	0	978	0
	Chlorinated organics	mg	25	0	3	0
	Chlorine	mg	2	0	0	0
	Metals	mg	10	5	6	250
Water emissions	COD	mg	3000	400	699	20000
	BOD	mg	70	60	61	3000
	Acid as H+	mg	220	90	105	4500
	Metals	mg	140	300	282	15000
	Calcium ions	mg	200000	0	23000	0
Outputs		**Units**	**Basis 1** **1 Kg of PVdC**	**Basis 2** **1 Kg of PP**	**Case 1** **1 Kg PVdC coated PP film**	**Case 2** **PP film with same properties as coated film**
Water emissions	Chloride ions	mg	454000	800	52938	40000
(continued)	Dissolved organics	mg	3000	30	372	1500
	Suspended solids	mg	63000	200	7425	10000
	Detergent/oil	mg	50	40	41	2000
	Phenol	mg	8	0	1	0
	Dissolved solids	mg	1000	200	292	10000
	Hydrocarbons	mg	230	300	292	15000
	Phosphate	mg	20	0	2	0
	Sulfate ions	mg	18000	0	2071	0
	Sodium ions	mg	3200	0	368	0
	Other nitrogen	mg	3	10	9	500
Solid waste	Mixed industrial	mg	3000	4000	3885	200000
	Mineral waste	mg	760000	14000	99823	700000
	Slags & ash	mg	153000	5000	22027	250000
	Regulated chemicals	mg	1000	30	142	1500
	Unregulated chemicals	mg	135000	8000	22611	400000

Source: Association of Plastics Manufacturers of Europe, "Eco-profiles of the European Plastics Industry, Report 7: PVdC (Polyvinylidene Chloride), Brussels, December 1994.

Case 2 – PP Film Uncoated. An uncoated PP film would need to have its thickness increased by a factor of 50 to produce an equivalent effect. As can be seen from the LCI data for Case 2, not only are the environmental burdens associated with such a film much larger than the corresponding coated film, but the thickness of the product is such that it would be unsuitable for many, if not most, packaging applications.

It should be noted that the illustrative calculations given above only consider the materials contribution of PP and PVdC; it does not consider the energy required to produce and coat the film. If these additional factors are added into the calculation, the overall inputs and outputs will be higher than those shown in Table A.4 and the relative contribution of PVdC to the overall totals will be smaller.

Interpreting the Results. When interpreting the table of LCI data, it is important to bear in mind the following points:

- The values presented in Table A.4 refer to the cumulative results when all of the production sequences are traced back to the extraction of raw materials from the earth. There are, therefore, some parameters over which the PVdC manufacturer has no control. For example, a significant contributor to mineral waste will be the coal industry that supplies the production of electricity in many countries. As a consequence of consuming public electricity, a proportion of this waste will be attributable to the production of the polymer.

- The values of some of the parameters will be a reflection of the country in which some plants are sited. For example, plants in countries that generate electricity from coal will exhibit a higher emission of sulfur oxides than plants that do not use coal in electricity generation.

- The magnitude of many of the parameters often owes much to the degree of monitoring of the parameter. This is especially true for air and water emissions. For example, a company that has a detailed program for monitoring all air emissions may well appear worse that a comparable company that does not monitor air emissions in any great detail and must estimate their magnitudes.

- Fuel requirements, energy requirements, solid waste output, emissions to air and emissions to water all refer to the total load for all processes, starting with extracting raw materials from the earth. Although the table headings refer to these sequences of operations by naming the final operation in the sequence, the results should, under no circumstances, be interpreted as referring only the final operations in a production sequence; they refer to the cumulative effect of the whole production sequence.

- Solid waste generation from industrial processes has been categorized under five headings. Mineral waste refers to waste earth and rock generated in mining operations. In this LCI, the principal source of mineral waste is in coal production. Frequently, mineral waste is replaced in a mine working once the valuable minerals have been removed and so represents a measure of the rock moved rather than the generation of permanent waste.

- Slags and ash refer to the solid waste produced by industrial boilers and furnaces. Slag and ash are usually inert and, because it contains no organic matter that can decay with time, it is frequently used in civil engineering operations such as road building. Chemical waste has been divided into two categories, referred to in Table A.4 as inert chemical waste and regulated waste. The distinction between these two categories is that inert chemical waste can be sent to landfill sites without further treatment. Regulated waste represents the category of chemical waste that has to be sent to special storage sites because it is either corrosive or toxic. The final category referred to in Table A.4 as industrial waste is a catch-all classification so that if the waste does not appear to fit into any of the other categories, it will appear here. Usually this consists of wastes such as discarded packaging and housekeeping waste.

- No direct reference is made in the LCI data to mercury emissions, as they generally fall below the level of accuracy of the tables. Mercury emissions arise from chlorine produced by mercury cells. In 1990, the average mercury emission into air for the West European chlor-alkali industry was 2.7 mg/kg of chlorine produced. This represented a decrease of 18 percent from the 1989 value of 3.3 mg/kg chlorine. It is anticipated that these figures will be further reduced since a few mercury cells with above-average emissions are being closed or converted to membrane technology. The corresponding weight average for emissions into water were 0.6 mg/kg chlorine in 1990 compared with 0.8 mg/kg chlorine in 1989.

- The averages quoted for any product refer to the mean for all of the chemical plants examined (Dow, Solvay and Zeneca), weighted by that proportion of the production from the plant that is used in the production of PVdC.

In this case study, an impact assessment and an improvement analysis were not conducted. The results are obvious. In order to achieve the same permeability results, the uncoated PP film would be too thick to use in most applications and, therefore, would not meet the product performance specifications.

Appendix 2 Manual Method Spreadsheets

OVERVIEW

Eco-Efficiency	Y/N
1. Materials use: a. Are materials planned for use in this project the most renewable, to the extent possible? b. Are recycled materials used, where possible, to reduce the use of newly-manufactured materials? c. Is the overall amount of all materials used reduced to the most economically and practical extent possible? 2. Material toxicity: given a choice, were the least toxic materials (both to the environment and human health exposure) selected? 3. Water use: a. Is the usage of water reduced to the lowest volume possible? b. Is the output water used from this project recycled? c. Is recycled water used to the extent possible? 4. Energy use: has the energy consumption per unit of output been reduced to the lowest extent possible? 5. End-of-life considerations: have end-of-product life considerations been considered? a. Recycle b. Reuse c. Recondition/refurbish d. Remanufacture e. Responsibly dispose (state method) f. Retrofit with upgrades	
Environmental 1. Will there be any increase in air emissions, any new source of air emissions or any increase in episodic emission potential? 2. Will there be any increase in materials discharged to the process or clean sewer systems? 3. Are there any plans to dispose of wastewater by underground injection? 4. Are there any or will there be any wastes generated, stored, treated, or disposed of at the project that that would be classified special? 5. Is there presently any soil or groundwater contamination at the project site? 6. Does the project increase the potential to contaminate soil or groundwater? 7. Will underground storage tanks be used for this project?	

OVERVIEW (continued)

Safety and Health	Y/N
1. Will flammable, toxic, corrosive, reactive or otherwise hazardous substances be transported, stored, processed or produced at the project site? 2. Are extremes of pressure (500 psig) or temperature (400°C) present anywhere in the new facility? 3. Will this project use any new process technology? 4. Will this project adversely affect reliability of existing facility? 5. Are any process intermediates isolated that are not included on the governing chemical control law (TSCA in US) inventory listing for the location?	
Product Safety 1. Are any new products manufactured or will any existing products be directed toward a new market? 2. Will distribution schemes cause new or additional public exposures to this product? 3. Will this project introduce new contaminants, increase existing hazardous contaminant level or otherwise increase the hazardous nature of the products?	
Reviewer:____________________________ Date:____________________________	

Project:				
Locations:				
Environmental Checklist				
Environmental -- General	**YES**	**NO**	**Other**	**Comments**
1. Does the geographic location of the project present any potential interstate or international air pollution liabilities?				
2. Does the geographic location of the project present any potential interstate or international water (surface or groundwater) pollution liabilities?				
3. Is process technology design derived from either proven commercial-scale facilities or six months or more of successful pilot-scale operations?				
4. Is there a high degree of confidence that the predicted composition and quantities of air and water pollutants and residues generated from operation of the project have not emitted any chemical more toxic than those documented and have not understated any quantities by more than 50%?				
5. Are there any residuals from either environmental discharges or disposed wastes resulting from operation of the completed project believed to be a potential subject of future governmental rule-making that could cause future unfavorable economics or publicity for the project, location, or corporation?				
6. Will the design and operation of the project be consistent with the location's waste and release reduction programs?				
7. Has the design inventory of hazardous and toxic chemicals been minimized to the extent practical?				
8. Will the facility be staffed, or have readily available, personnel fully aware of the environmental consequences of operation problems and trained to implement timely and proper response actions?				

Environmental -- Air Emissions	YES	NO	Other	Comment
1. Have all significant air emissions (point, fugitive and secondary) been identified and described with respect to quantity, composition and their ultimate treatment? (Consider start-up/shutdown and abnormal operating conditions)				
2. Do proposed air emissions contain any material classified as hazardous under Federal, State or local regulations (pay special attention to Hazardous Air Pollutants [HAPs] identified under Clean Air Act Amendments)				
3. Does the project design satisfy the design objectives for both routine (continuous & intermittent) emissions and episodic air emissions? (Pay special attention to known and suspected carcinogens and acutely toxic emissions)				
4. Will proposed air emissions require Prevention of Significant Deterioration (PSD) review and/or New Source Review?				
5. Do any proposed air emission sources require new air control systems or upgrading of existing systems?				
6. Are the air pollution control systems designed to meeting application governmental technological levels and corporate requirements?				
7. Are there any air pollution control systems that have not been reviewed to assure conformation with Federal, State or local regulations?				
Environmental -- Surface/Groundwater Protection				
1. Have all significant water discharges been identified and described with respect to quantity, composition and their ultimate treatment and/or disposal? (Consider start-up/shutdown and abnormal operating conditions)				
2. Do proposed wastewater discharges contain any substances on EPA's priority pollutant list?				

Environmental -- Surface/Groundwater Protection (continued)	YES	NO	Other	Comments
3. Will wastewater discharges be restricted by water quality limits of the receiving stream or by the capacity of a Publicly-Owned Treatment Works (POTW)?				
4. Does the operation handle any compounds have EPA Reportable Quantities (RQ's)?				
5. Are adequate leak/spill prevention and detection measures provided?				
6. Will secondary containment be provided for all new and modified oil and chemical handling or storage areas?				
7. Are modifications to an existing or an entirely new Spill Prevention, Control and Countermeasures (SPCC) Plan required?				
8. Will underground storage tanks be used for this project?				
9. Are there any plans to dispose of wastewater by underground injection?				
10. Do any proposed wastewater discharges require new control systems or upgrading of existing systems?				
11. Are the water pollution control systems, underground storage tanks and injection wells designed to meet applicable governmental technological and corporate requirements?				
12. Are there any containment, storage, treatment or disposal design plans that have not been reviewed to assure conformance with Federal, State or local regulations?				

Environmental -- Waste Management	Yes	No	Other	Comment
1. Have all significant special wastes been identified and described with respect to quantity, composition and their ultimate treatment and/or disposal? (Consider start-up/shutdown conditions and abnormal operating conditions)				
Have all special waste conservation/ minimization alternatives been reviewed and used where feasible?				

Environmental -- Waste Management (continued)	Yes	No	Other	Comment
3. Are the off-site locations that are managing special wastes approved in accordance with corporate policy?				
4. Has land application of special wastes been minimized to the extent possible				
5. Are any proposed wastes classified as hazardous under Federal, State or local regulations?				
6. Will the project necessitate the storage, treatment or disposal of hazardous waste, either on-site or off-site?				
7. Are the hazardous waste storage, treatment and disposal systems designed to meet applicable governmental technological levels and corporate requirements?				
8. Are there any storage, treatment or disposal design plans that have not been reviewed to assure conformance with Federal, State or local regulations?				

Environmental -- Compliance/Permits	Yes	No	Other	Comments
1. If the project is associated with an existing facility, has the facility experienced any incidents of non-compliance with air, wastewater, stormwater, solid/hazardous waste permits or regulations, or received any pollution-related citizen complaints in the past 12 months that may affect the project? Describe impact.				
2. Are there any Compliance Orders or other legal actions that may affect the project? Describe impact				
3. Will the predicted air and water discharges from operation of the completed project comply with all applicable governmental rules? List significant applicable regulations?				
4. Will the planned storage, treatment and disposal of hazardous wastes comply with all applicable governmental rules? List significant applicable regulations?				

Environmental -- Compliance/Permits (continued)	Yes	No	Other	Comments
5. Have all required air, wastewater, stormwater and solid/hazardous waste permits and permit modifications been identified? List new permits/modifications needed.				
6. Are there any other environmental permits needed or which require modification (example: underground storage tanks, Corps of Engineers, wetlands...)? List new permits/modifications needed.				
7. Are any delays in construction or operations start-up likely due to permitting or other regulatory requirements?				

Environmental -- Site Condition	Yes	No	Other	Comment
1. Is background air quality monitoring data available for the past 12 months at the project site?				
2. If there are proposed wastewater or storm water discharges to surface water, is background water quality data available?				
3. Is the proposed project site to be located within ½ mile of any existing or potential surface or underground source of drinking water?				
4. Is there presently any known or suspected soil and/or groundwater contamination at the project site?				
5. Are there any active waste storage, treatment or disposal facilities located on the project site?				
6. Are there ongoing or past site investigations and/or remedial actions for present and/or past solid waste units that pose(d) a significant threat of release of hazardous constituents to the environment at the project site?				
7. Is there any material containing polychlorinated biphenyl (PCBs) located on the project site?				

Environmental -- Site Condition (continued)	Yes	No	Other	Comment
8. Are underground tanks located on the project site?				
9. Does the project site contain US Coast Guard designated wetlands?				
Reviewer:________________________		Date:________________________		

Safety and Health				
Safety and Health -- General	**Yes**	**No**	**Other**	**Comment**
1. Will toxic, flammable, corrosive or otherwise hazardous substances be transported, stored, processed or produced in facilities affected by this project?				
2. Will high noise levels (85 dBA and higher), radiation sources, heat stress, repetitive motion, or other new or unusual physical hazards be introduced by this project?				
3. Could any of the substances handled in facilities affected by this project cause an explosion if heated, contaminated, concentrated or otherwise mishandled?				
4. Is all necessary safety and health data known for each substance handled? (Include isolated intermediates)				
5. Do up-to-date Material Safety Data Sheets exist for each substance handled? (Include any stream or mixture handled or stored)				
6. Will this project introduce new chemicals that are highly reactive with other chemicals already handled at the location?				
7. Is there potential for mixing of incompatible chemicals in process, storage or waste disposal areas (in/outside boundaries) of this facility?				
8. Are operational safety standards required, and will they be prepared before startup?				
Safety and Health -- General	**Yes**	**No**	**Other**	**Comment**
9. Are inventories of hazardous or toxic materials minimized?				

Safety and Health -- Compliance	Yes	No	Other	Comment
1. Will any new safety or health programs be required to meet regulations?				
2. Have all Department of Transportation (or equivalent) requirements been identified for substances that will be shipped either to or from the plant location?				
3. Are there any proposed changes to safety and health regulations that could affect design or operation of project or facilities?				
4. Will the following be required to comply with safety and health regulations:				
a. Monitoring of employee exposure?				
b. Ventilation, noise suppression or other engineering controls?				
c. Special personal protective equipment?				
d. Special medical examinations or a medical surveillance program?				
e. Special operating or maintenance procedures?				
f. Regulated areas?				
5. Will employees need supplemental training beyond normal corporate or business programs to assure safe operation?				
6. Do any State or local regulations supersede Federal safety and health regulations?				
7. Are all chemicals that will be handled included in the governing chemical control law (TSCA in US) inventory or equivalent (including isolated intermediates)?				
8. Will this project involve installation or removal of asbestos or polychlorinated biphenyl (PCB) materials?				

Safety and Health -- Compliance (continued)	Yes	No	Other	Comment
9. Are new occupied buildings or expansions of existing occupied buildings planned?				
10. Will occupied buildings be affected by process changes that:				
a. Decrease the separation distance?				
b. Increase the hazard classification?				
c. Significantly increase the risk above current level (i.e., process complexity)?				
11. Will contractors be used for on-site work?				

Safety and Heath -- Public Impact	Yes	No	Other	Comment
1. Will emergency relief devices that protect facilities be affected by this project discharge directly to the atmosphere?				
2. Could releases from the emergency relief devices that discharge directly to the atmosphere have an adverse impact on the health or safety of the public?				
3. Could a process upset or other emergency situation (fire, explosion, spill, etc.) occur in the project facilities that could have an adverse impact on the public?				
4. In the event of the release of toxic chemicals from facilities affected by this project, would existing or planned monitoring, detection, and/or alarm systems be adequate?				

Safety and Health -- Facility Design	Yes	No	Other	Comment
1. Will extremes of temperature or pressure (i.e., temperatures above 400°C or pressures above 500 psig) exist in facilities affected by this project?				
2. Will there be any new ignition sources associated with this project?				
3. Will recognized industry practices be followed in the layout of the facility?				

Safety and Health -- Facility Design (continued)	**Yes**	**No**	**Other**	**Comment**
4. Will the pressure vessels, storage tanks, safety valves, piping, values and fittings that are part of the project facilities conform to applicable industry codes and standards and Federal, State and local laws and regulations?				
5. Will all normal project safety and health reviews be performed?				
6. Is there a need for a Process Hazard Analysis (PHA) of the facilities?				
7. Could the loss of any utility that supplies project facilities create a possible hazardous substance?				
8. Will flammable gas detectors be installed as part of this project?				
9. For facilities affected by this project, is any reaction sufficiently exothermic to result in a runaway reaction under any operating conditions that could occur?				
10. Does this project introduce a new process or incorporate process technology new to this location?				
11. Are process monitoring and control devices adequate to prevent upsets leading to hazardous operation or toxic releases?				
12. Would increased use of automation or advanced process control effectively reduce the risks of employee exposure?				
13. Will water spray protection be provided for processing, storage and distribution areas in accordance with corporate criteria?				
14. Are fire water supplies and distribution systems adequate to provide sufficient fire water to this facility?				
15. Could this project adversely impact on or be impacted by other facilities?				
16. Were there any areas considered for inherent safety that were rejected?				
17. Were there areas where inherent safety was incorporated? (If yes, where?)				
18. Have seismic zones been considered and appropriate design requirements used?				

E&H Screening Checklist

Safety and Health -- Facility Design (continued)	Yes	No	Other	Comment
1. Are considerations of ergonomic principles included in the facility and process design?				

Safety and Health -- Emergency Response	Yes	No	Other	Comment
1. Will additional fire and emergency response equipment, personnel or procedures be required as a result of this project?				
2. Will any changes to the location's Community Emergency Response Plan (evacuation, etc.) be required as a result of this project?				

Safety and Health -- ERMS Compliance	Yes	No	Other	Comment
1. Will this project change the ERMS Hazard Ranking Model (HRM) data?				
2. Has a consequence or other type analysis been conducted to evaluate potential for off-site fatality events?				
3. Have there been prior Risk Reviews done for this facility?				
4. Is a Risk Review required for this project (e.g., does off-site fatality potential exist?				
5. Have all scenarios identified by a Risk Review or Third Tier Study been mitigated as required by ERMS?				

Reviewer:______________________________ Date:___________________________________

Product Safety -- General	Yes	No	Other	Comment
1. Will any of the products from this facility be marketed as a consumer product?				
2. Will any of the products be used as an intermediate by this corporation or others to formulate a product that will be marketed as a consumer product?				
3. Are any of the products intended for use in the manufacture of food, drugs or their packaging materials?				
4. Are any of the products classified by the Food and Drug Administration as medical devices?				
5. Are any of the products subject to regulation under:				
a. Federal Insecticide, Fungicide, Rodenticide Act (FIFRA)				
b. Toxic Substances Control Act (TSCA)				
c. Consumer Product Safety Commission				
d. Federal Food, Drug and Cosmetic Act				
6. Are any of the product classified as toxic, explosive, flammable or otherwise hazardous?				
7. Can any product harm persons or property in normal use or any potential misuse?				
8. Does the product, or any component in the product, appear on any listing of chemicals requiring customer, employee or public notification?				

Product Safety -- Design	Yes	No	Other	Comment
1. Has the product undergone a product safety risk analysis to evaluate downstream exposure/health risk potential?				
2. Are any Premanufacture Notifications necessary for any of the products or intermediates?				
3. Does any product require certification or testing by Federal, State or local governmental agencies?				

4. Does any product require testing or approval by a nationally recognized testing agency?				
5. Will this project introduce new contaminants, increase existing hazardous contaminant level, or otherwise increase the hazardous nature of the product?				
6. Is this a new or modified product, or a product directed toward a new market?				
Product Safety -- Distribution	**Yes**	**No**	**Other**	**Comment**
1. Will distribution cause new or additional public exposure to this product?				
2. Have all regulatory requirements for shipping the products been identified?				
3. Has all labeling and Material Safety Data Sheet data been obtained for all products?				
4. Will any special handling, storage or shipping equipment or procedures be required for any of the product?				
Product Safety -- Image	**Yes**	**No**	**Other**	**Comment**
1. Is there any history of product liability with any of these products or similar products?				
2. Could any of the products be viewed by the public or regulatory agencies as presenting an unacceptable risk to health, safety or the environment?				
3. Will communication with any regulatory agency be required regarding the safety of any of the products?				

Reviewer:________________________________ Date:____________________________________

Project Description:

Project Title:	
Company:	
Location:	
Department:	
Prepared By:	
Project Description:	

Total Cost Assessment Summary

	Cost ($)		
Type I Costs: Non-Recurring Site Costs	$ -		
Type I Costs: Recurring Site Costs	$ -		
Type II: Corporate Costs	$ -		
Type III: Impact Costs	$ -		
Type IV: Internal Intangible Costs	$ -		
Type V: External Costs		$ -	
Total	$ -	$ -	

Type I Costs: Direct Capital and Expense Costs, Non-Recurring
Alternative (Baseline or Alternative):

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Site	Due diligence				$ -	
	Land cost				$ -	
	Demolition, clearing, etc.				$ -	
	New buildings				$ -	
	Other				$ -	
Purchased Equipment	Capital costs				$ -	
	Initial spare parts cost				$ -	
	Sales tax				$ -	
	Other				$ -	
Equipment Installation	Piping				$ -	
	Electrical				$ -	
	Instruments				$ -	
	Structural				$ -	
	Insulation				$ -	
	Equipment				$ -	
	Vendor				$ -	
	Contractor				$ -	
	In-house costs				$ -	
	Other				$ -	
Engineering/ Contractor	Feasibility				$ -	
	Engineering				$ -	
	Planning/scheduling				$ -	
	Contractor fees				$ -	
	Procurement				$ -	
	Consultants				$ -	
	Other				$ -	
Instrumentation/ Controls	Capital cost				$ -	
	Installation cost				$ -	
	Other				$ -	

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Service/Utility Costs	Capital				$ -	
	Installation cost				$ -	
	Other				$ -	
Service/Utility Hook-up Materials	Electrical				$ -	
	Steam				$ -	
	Cooling water				$ -	
	Process water				$ -	
	Refrigeration				$ -	
	Fuel (gas or oil)				$ -	
	Plant compressed air				$ -	
	Inert gases				$ -	
	Cooling towers				$ -	
	Other				$ -	
Raw Materials for Pilot Runs	Materials cost				$ -	
	Secondary materials				$ -	
	Other				$ -	
Support Facilities	QC lab buildings				$ -	
	Storage tanks				$ -	
	Containment				$ -	
	Hazardous material storage				$ -	
	Transportation docks				$ -	
	Loading/unloading equipment				$ -	
	Other				$ -	
Support Equipment	QC laboratory equipment				$ -	
	Protective equipment				$ -	
	ESH monitoring equipment				$ -	
	Cleaning equipment				$ -	
	Flammable storage cabinets				$ -	
	Other				$ -	
Solid Waste Treatment	Capital cost				$ -	
	Installation				$ -	
	Other				$ -	

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Wastewater Treatment	Capital cost				$ -	
	Installation				$ -	
	Other				$ -	
Air Pollution Controls	Capital cost				$ -	
	Installation				$ -	
	Other				$ -	
Permitting	Fees				$ -	
	In-house staff costs				$ -	
	Studies/risk modelling				$ -	
	Other				$ -	
Start-up Training	Vendor/contractor				$ -	
	In-house				$ -	
	Trials/Manufacture Variance				$ -	
	Other				$ -	
Manufactured Product	increase in maintenance cycle time				$ -	
	decrease in production flexibility				$ -	
	decrease in production capacity				$ -	
	product return				$ -	
	packaging				$ -	
	packaging return				$ -	
	transporation				$ -	
Co-Products	Collection				$ -	
	Packaging				$ -	
	Environmental controls				$ -	
Decommissioning	Closure/decommissioning				$ -	
	Dismantling				$ -	
	Remediation				$ -	
	Site survey				$ -	
	Post closure care				$ -	
	Other				$ -	
	Other				$ -	
	Other				$ -	
Contingencies					$ -	
Total					**$ -**	

Type 1 Costs

Direct - Recurring Manufacturing Site Costs
Alternative (Baseline or Alternative):

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Raw Materials and Supplies	Raw materials				$ -	
	Packaging materials/takeback				$ -	
	Supplies				$ -	
	Primary process materials				$ -	
	Ancillary catalysts/chemicals				$ -	
	Packaging disposal costs				$ -	
	Protective equipment				$ -	
	Other				$ -	
Utilities	Electricity				$ -	
	Steam				$ -	
	Cooling water				$ -	
	Air				$ -	
	Gases				$ -	
	Sewerage and public sewerage fees				$ -	
	Water and public water fees				$ -	
	Freshwater pump and treat				$ -	
	Freshwater heating				$ -	
	Stormwater management				$ -	
	Other				$ -	
Labor, Operations	Operators				$ -	
	Maintenance				$ -	
	Supervision				$ -	
	Support/General labor				$ -	
	Trades				$ -	
	Forklift operators				$ -	
	Other				$ -	
QC Laboratory Costs	Labor				$ -	
	Expense				$ -	
Technical Support	Labor				$ -	
	Expense				$ -	

]

Type 1 Costs

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Labor, other	Environmental staff				$ -	
	Procurement staff				$ -	
	Recycling				$ -	
	Wastewater trtmnt operators				$ -	
	Solid waste trtmnt operators				$ -	
	Air control trtmnt operators				$ -	
	Facilities				$ -	
	Other				$ -	
Internal pack/ship	Packaging operations costs				$ -	
	Internal shipping				$ -	
	Warehousing				$ -	
	Other				$ -	
Insurance	Equipment				$ -	
	People				$ -	
	Fire				$ -	
	Workers compensation				$ -	
	Earthquake				$ -	
	Environmental				$ -	
	Product liability				$ -	
	Other				$ -	
Taxes					$ -	
Maintenance	Maintenance supplies				$ -	
	Maintenance waste mgmt.				$ -	
	Vehicle maintenance				$ -	
	Production downtime				$ -	
	On-site fuel usage				$ -	
	Other				$ -	
Waste Treatment, equipment and supplies (on-site)	Wastewater treatment				$ -	
	Incineration				$ -	
	Waste material handling				$ -	
	Waste-end fees/taxes				$ -	
	Hauling insurance				$ -	
	Stormwater treatment				$ -	
	Other				$ -	
	Other				$ -	
	Other				$ -	

Type 1 Costs

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Waste Mgmt. for off-site disposal	Manifesting				$ -	
	Waste pre-treatment				$ -	
	Accumulation/storage				$ -	
	Transportation				$ -	
	Disposal costs				$ -	
	Insurance				$ -	
	Intermediate packaging disposal				$ -	
	Other				$ -	
Regulatory Compliance	Monitoring/testing				$ -	
	Notification				$ -	
	Spill response/reporting				$ -	
	Remediation				$ -	
	Studies				$ -	
	Routine E&H reporting				$ -	
	Emergency response preparedness				$ -	
	Permitting (renewals)				$ -	
	Training (refresher)				$ -	
	Personal protective equipment				$ -	
	Tracking/assessing new regulations				$ -	
	Self-assessments				$ -	
	Medical surveillance				$ -	
	Audits				$ -	
	Leak incident reporting				$ -	
	Spill response/reporting				$ -	
	Risk modelling				$ -	
	Testing				$ -	
	Labeling				$ -	
	Recordkeeping				$ -	
	Coordination with regulatory agencies				$ -	
	Other				$ -	
Public Affairs	Community relations				$ -	
	Lobbying				$ -	
	Other				$ -	

Type 1 Costs

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Manufactured Product	Shipping to customers/distributors				$ -	
	Shipping insurance				$ -	
	Distribution costs				$ -	
	External warehousing				$ -	
	Marketing				$ -	
	Administrative costs				$ -	
	R&D costs				$ -	
	Rework/repair/reject rate				$ -	
	Transportation				$ -	
	Other				$ -	
Co-Products	Collection				$ -	
	Packaging				$ -	
	Environmental controls				$ -	
Training	Personal protective equipment				$ -	
	Environmental recordkeeping				$ -	
	Fire prevention				$ -	
	COSH				$ -	
	Use of environmental control technologies				$ -	
	Use of environmentally controlled materials				$ -	
	General in-house environmental training				$ -	
Total					**$**	

]

Type II Costs

Corporate Overhead Costs
Alternative (Baseline or Alternative):

Costs Incurred						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (Number)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Beyond Compliance	Community relations/outreach				$ -	
	Monitoring/testing				$ -	
	Training				$ -	
	Audits				$ -	
	Qualifying suppliers				$ -	
	Reports (annual environmental reports, etc.)				$ -	
	Insurance				$ -	
	Planning				$ -	
	Feasibility studies				$ -	
	Remediation				$ -	
	Recycling				$ -	
	Environmental studies				$ -	
	R&D				$ -	
	Habitat and wetland protection				$ -	
	Landscaping				$ -	
	Financial support to environmental groups				$ -	
	Other environmental projects				$ -	
Employee	Re-training				$ -	
	Severance				$ -	
	Outplacement services				$ -	
	Civil liabilities				$ -	
	Other				$ -	
Facilities	Production space				$ -	
	Waste and wastewater treatment capacity				$ -	
	Title V permit				$ -	
	Land use opportunity cost				$ -	
	Other				$ -	

Type II Costs

Incurred Cost						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (No)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Staff	Environmental				$ -	
	Toxicological				$ -	
	Medical				$ -	
	Procurement				$ -	
	Facilities				$ -	
	Public relations				$ -	
	Inventory control				$ -	
	Legal				$ -	
	Marketing				$ -	
	Sales				$ -	
	Other				$ -	
Manufacturing	Time to market costs				$ -	
	Other				$ -	
Product mix/ demand	Sales/marketing costs				$ -	
	Sales ramp-up				$ -	
	Inventory build-up - raw materials				$ -	
	Inventory build-up - raw materials				$ -	
	Inventory build-up - packaging				$ -	
	Collateral revenue reduction (reduced production for identified product)				$ -	
	Other				$ -	
Compliance activities support	Notification				$ -	
	Reporting				$ -	
	Monitoring/testing				$ -	
	Studies/modelling				$ -	
	Remediation				$ -	
	Recordkeeping				$ -	
	Planning				$ -	
	Inspections/audits				$ -	
	Manifesting				$ -	
	Preparedness				$ -	
	Protective equipment				$ -	

Type II Costs

Incurred Cost						
Activity	**Cost Driver**	**Unit**	**Quantity of Units (No)**	**Cost per Unit ($/Unit)**	**Total Costs ($)**	**Comments/Documentation**
Regulatory (continued)	Medical surveillance				$ -	
	Environmental insurance				$ -	
	Financial insurance				$ -	
	Spill response				$ -	
	Pollution control				$ -	
	Stormwater management				$ -	
	Waste management				$ -	
	Taxes/fees				$ -	
	Other				$ -	
Total					**$ -**	

Type III Costs: Future and Contingent Liability Costs
Alternative (Baseline or Alternative):

Potential Future Costs						
Activity	**Cost Driver**	**Probability of Occurrence (%)**	**Frequency of Events per Year**	**Estimated Cost per Incident (x$1000)**	**Weighted Cost (x$1000)**	**Comments/Documentation**
Environmental/Human Health (Community)/Human Health (Employee)	Compliance obligations				$ -	
	Civil and criminal fines/penalties				$ -	
	Remedial costs of plant contamination				$ -	
	Compensation/punitive damages				$ -	
	Natural resource damage				$ -	
	Potentially responsible party (PRP) liabilities for off-site contamination				$ -	
Industrial Process Impacts					$ -	
Other					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
Total					**$ -**	

Type IV Costs: Internal Intangible Costs
Alternative (Baseline or Alternative):

Activity	Possible Factors Influencing Costs	Probability of Occurrence (as decimal)	Frequency of Events per Year	Estimate Cost per Incident ($x1000)	Weighted Cost ($x1000)	Comments/Documentation
Staff	productivity and morale				$ -	
	turnover					
	exposure					
	union negotiations time					
Market share	value chain perception				$ -	
	public perception					
	consumer perception					
License to operate	License to conduct business				$ -	
Relationships	investors/lenders				$ -	
	communities				$ -	
	regulators				$ -	
Other					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
					$ -	
Total					$ -	

Type V Costs: External Impact Costs
Alternative (Baseline or Alternative):

External costs						
Activity	**Cost Driver**	**Probability of Occurrence (%)**	**Frequency of Events per Year**	**Estimated Cost per Incident ($x1000)**	**Weighted Cost ($x1000)**	**Comments/Documentation**
Environmental	Pollutant discharges: to air				$ -	
	Pollutant discharges: to surface water				$ -	
	Pollutant discharges: to ground water				$ -	
	Pollutant discharges: to deep well				$ -	
	Pollutant discharges: to land				$ -	
	Natural habitat impacts: local community, wetlands, wildlife reserves				$ -	
Value chain impact					$ -	
Product health impact					$ -	
Sustainability Metrics	Material Intensity				$ -	
	Energy Intensity				$ -	
	Resource Depletion				$ -	
	Pollutants and Toxics				$ -	
	- Greenhouse gases				$ -	
	- Photochemical ozone creation potential				$ -	
	- Eco-toxicity				$ -	
	- Human health effects				$ -	
	- Acidification				$ -	
	- Eutrophication				$ -	
Other					$ -	
					$ -	
					$ -	
					$ -	
Total					**$ -**	

Goal Definition and Scoping - Decision Statement

Project Title	
Company	
Address	
Date	
Revision	
Department	
Prepared by:	
Project Description:	
Project Scope See "Goal Definition and Scoping" worksheet 1 = Mandatory 2 = Desirable	
Document Assumptions	
Review for Sustainability Goals See Sustainability Worksheet 1 = Mandatory 2 = Desirable	

Environmental Goals (Beyond Compliance) See "Environmental" worksheet 1 = Mandatory 2 = Desirable	
Review for Human Health Effects See "Human Health" Worksheet 1 = Eliminate 2 = Mitigate	

Site Constraints See "Siting" Worksheet 1 = Mandatory 2 = Desirble	
Other	

Goal Definition and Scoping

Project Phase											
Concept Shaping		Concept Analysis		Validation		Development		Implementation			

Type of Decision											
Baseline assessment		Baseline vs baseline assessment		Baseline vs. new assessment		New vs. new assessment					
Capital budgeting		Process design		Product design		Performance evaluations					

Financial Analysis											
Fully-allocated		Differential									

Range of Operations											
New products		Existing products		Exiting products		Import		Export			
New processes		Existing process, optimize		Existing process, modify		Existing process, shut-down		Existing process, decommission			
New services		Existing services		Existing services		Import		Export			

Siting											
New		Existing		Decommission		Not applicable					

Manufacturing Site Location											
US		Europe		Asia		Latin America		Australia		Africa	

Life Cycle Stages											
Raw material extraction		Manufacturing		Filling/packaging		Transportation/Distribution		Use/reuse/maintenance		Recycle/Waste Mgmt.	

Range of costs											
Type I Direct		Type I Direct, Recurring		Type II Corporate Indirect		Type III Contingent Liability		Type IV Internal Intangible		Type V External	
Internal costs only		Outsourced operations									
Costs incurred		Costs saved		Costs avoided							

Range of costs categories											
Current costs/past practices		Current costs/current practices		Future costs/past practices		Future costs/current practices		Future costs/future practices			

Corporate, Business Unit or Site Policy Drivers (Voluntary)											
Sustainability		Environmental		Ecosystem		Human health					

Possible Rating Scheme:
1 = Mandatory
2 = Desirable

Sustainability Goals for the Project			
Eco-Efficiency Goals	**Project Goals**	**Mandatory**	**Desirable**
Minimize Material Input Intensity			
Review project for opportunities to:	dematerialize (use less of all raw material inputs)		
	use recycled raw materials		
	use recycled water		
	use closed-loop water system		
	use recycled process co-products		
	recycle output water		
	use captured/recycled heat		
	other		
	other		
	other		
Renewable Materials			
Review project for opportunities to minimize	minerals		
use of non-renewable materials	metals		
	petroleum-based materials		
Review project for opportunities to replace	forest products		
semi-renewable materials	water		
	renewable natural products		
Natural Resource Depletion			
Review project for consumption of:	marine environment		
	land area, terrestrial habitat		
	land area, aquatic habitat		
	land area, soil		
	other		
	other		
Review project for impact on:	marine environment		
	land area, terrestrial habitat		
	land area, aquatic habitat		
	land area, soil		
	other		
	other		

Possible Rating Scheme:
1 = Mandatory
2 = Desirable

Eco-Efficiency Goals	Project Goals	Mandatory	Desirable
Minimize energy intensity			
Review project for consumption of:	electricity		
	fossil fuels, oil		
	fossil fuels, gas		
	fossil fuels, coal		
	non-renewable fuels, other		
	fuels, other		
Review project for opportunities to use	renewable energy sources, hydro		
	renewable energy sources, solar		
	renewable energy sources, other		
	renewable energy sources, other		
Enhance material recyclability			
Build into project end-of-life considerations	recycle		
for product produced or process equipment:	reuse		
	recondition/refurbish		
	remanfacture		
	retrofit with updates		
	responsible disposal		
	extend product durability		
	other		

Possible Rating Scheme:
1 = Mandatory
2 = Desirable

"Beyond Compliance" Environmental Goals for the Project					
Environmental Impact	**Project Goals**	**Expressed as**	**Reduction Goals (units)**	**Mandatory**	**Desirable**
Discharges to air	Greenhouse gases	tons of CO_2 equivalents			
	Acidification	tons of SO_2 equivalents			
	Groundlevel ozone	tons of O_3 equivalents			
	Stratospheric ozone depletion	tons of CFC-11 equivalents			
	Trace hazardous chemicals, respiratory or pulmonary hazard	tons of PM 2.5-10 microns equivalents			
	Trace hazardous chemicals, respiratory or pulmonary hazard	tons of PM <2.5 microns equivalents			
	Trace hazardous chemicals, aromatic (potential oncogenic)	equivalent tons			
	Trace heavy metals, potential oncogenic	equivalent tons			
	Other				
	Other				
	Other				
	Other				
Discharges to natural bodies of water	Eutrophying chemicals	tons of PO_4 equivalents			
	Total organic carbon (TOC) or biological oxygen demand (BOD),	tons of oxidizable carbon equivalents			
	TOC or BOD				
	Total suspended solids (TSS)				
	Other				
	Other				
	Other				

Possible Rating Scheme:
1 = Mandatory
2 = Desirable

Environmental Impact	Project Goals	Expressed as	Reduction Goals (units)	Mandatory	Desirable
Discharges to ground-water or natural bodies of water	Trace hazardous chemicals, heavy metals (acute ecotoxicity)	equivalent tons			
	Trace hazardous chemicals, non-metals (acute ecotoxicity)	equivalent tons			
	Other				
	Other				
	Other				
Waste, non-hazardous, disposal	Off-site disposal	equivalent tons			
	On-site treatment	equivalent tons			
	Other				
	Other				
Waste, hazardous	Off-site disposal	equivalent tons			
	On-site treatment	equivalent tons			
	Other				
	Other				
	Other				
Other ecosystem impacts	Noise	decibels			
	Thermal discharge	equivalent BTUs			
	Odor				
	Other				

Possible Rating Scheme:
1 = Mandatory
2 = Desirable

Ecosystem Impacts and Other Siting Constraints

External Site Constraints

Ecosystem Concerns and Constraints

Discharge Media	Impact Category	High	Low
Atmospheric	Ground level ozone (VOCs)		
	Particulates		
	Air toxics (proximity of sensitive areas such as schools, open bodies of water, wetlands, residential communities)		
	Visibility		
	Odor		
	Climate effects (both micro & macro)		
	Other		
Water	Toxicity impacts		
	Sensitivity to contamination		
	Existing contamination		
	Depletion of surface water		
	Depletion of groundwater		
	Thermal changes		
	Acidification		
	Eutrophication		
	Chemically altered		
	Other		
	Other		
	Other		
Soil	Toxicity impacts		
	Lateritization		
	Podzolization		
	Acidification		
	Fertilization		
	Erosion		
	Other		
	Other		
	Other		

Ecosystem Impacts and Other Siting Constraints

External Site Constraints			
Ecosystem Concerns and Constraints			
Others	Geomorphic effects		
	Biodiversity effects		
	Habitat alterations		
	Animal welfare		
	Other		
	Other		
Geographic			
Proximity of residential or sensitive	Noise		
communities	Odor		
	Community concerns		
	Other unique constraints		
	Other unique constraints		
Social			
Economic	Property value changes		
	Inflation		
	Opportunity costs		
	Sectoral effects		
Community	Public services		
	Infrastructure		
	Satisfaction		
Family	Employment		
	Stability changes		
Demographic	Migration		
	Morbidity		
	Fertility		
	Mortality		

Ecosystem Impacts and Other Siting Constraints

Internal Site Constraints			
Air	Title V or other air permits		
	Engage New Source Review		
	Unique employee exposure constraints		
Water	Discharges to sewers or POTWs		
	Wastewater treatment capacity		
	Leak/spill prevention required		
	Stormwater drain-off limitations		
	Source of water, limitations		
Solid and Hazardous Waste	On-site waste treatment		
	On-site landfill		
	Off-site waste treatment		
	Off-site landfill		
	Storage of wastes		
Other Unique Site Constraints	Sensitivity to explosions		
	Sensitivity to fires		
	Presence of underground storage tanks		
	On-site transportation requirements		

Potential Human Health Impacts

Potential Human Health Impact	Eliminate	Mitigate Impact
Human carcinogen (Class A)		
Irritant (eye, lung, skin, GI tract)		
Corrosive		
Respiratory system effects		
Central nervous system effects		
Allergenicity, sensitization		
Methemoglobinemia, blood disease		
Odors		
Renal effects		
Hepatoxic effects		
Endocrine system effects		
Bone effects		
Behavioral effects		
Reproductive system effects		
Cardiovascular system effects		
Other		
Other		
Other		
Other		

Appendix 3 Case Example

Total Cost Assessment (TCA) Methodology and Case Example

This appendix provides the user with an example of how the TCA methodology could be applied to a real world decision. The example is hypothetical, however the type of decision illustrated is representative of real world situations where TCA may provide additional relevant information for decision-making. The specific results of the TCA may be used differently by different users - the example provided here is not intended to indicate that one option is better than another. The main intent is to show how conventional costs typically used for decision purposes can be augmented with the TCA process. The example also shows how the concepts presented in the manual can be viewed in the context of an actual application. This test case has also been applied in the electronic/software version that has been developed in TCAce.

Figure 3-2 in Section 3 provides a flow chart that defines the main steps in the TCA process. As presented in Section 3, the TCA methodology is really a five-step process, although a sixth step (i.e., documentation) and a seventh step (i.e., a feedback loop to the company's main decision process) are included to show how the TCA will likely fit in a company's overall decision process.

Case Example: Determining the Priority of Two Waste Streams for R&D Funding

Step 1: Project Definition and Scoping

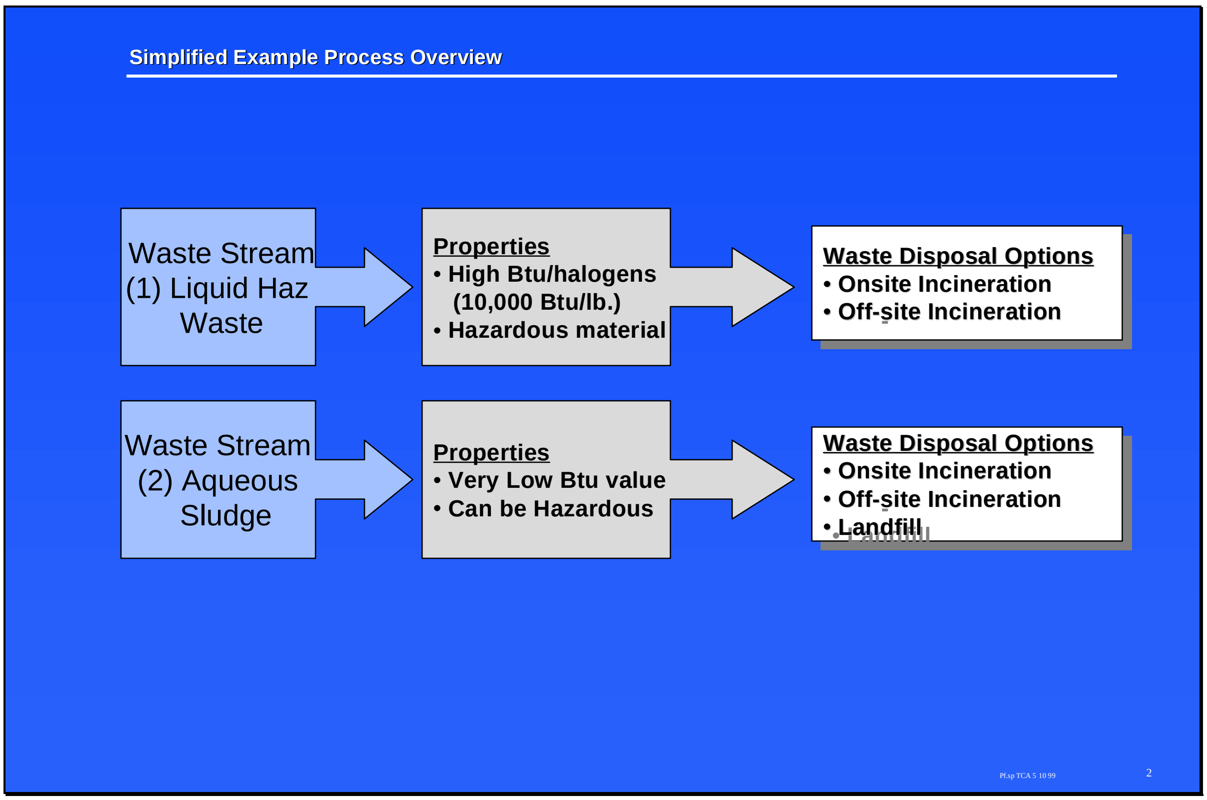
The first step in the TCA process is to define and scope the project. In practice, the types of decisions that are augmented with a TCA will probably already have been through a fair amount of internal discussion and review. In any case, this involves:

- (a) describing the project or decision to be evaluated
- (b) defining goals or constraints that may influence the project (e.g., corporate, stakeholder, etc.)
- (c) comparing and selecting relevant project/decision goals
- (d) deciding if project options are allowable

The Project Definition and Scoping step is a critical step in the TCA and it is recommended that it be performed with a multi-disciplinary team appropriate for the decision at hand. The team must carefully consider and then define the project and the comparisons that are desired. This will help to ensure that the end result provides value in the decision process.

In the example case, the decision to be evaluated using the TCA method involves the prioritization of research and development (R&D) funds relative to two waste streams. In this hypothetical example, a company has articulated several goals aimed at reducing waste generation from its industrial processes. The main question is how to decide which waste stream will receive priority for R&D funding in the implementation of the company's waste reduction strategy. Relying on conventional cost data (e.g., total Types I and II costs, or Types I and II costs presented as per ton disposed values) indicates that Waste Stream 1 (liquid hazardous waste) is consistently more expensive than Waste Stream 2 (aqueous sludge) for the company. Thus, the company could reasonably be expected to prioritize R&D funding towards reducing the more costly waste stream. The potential value in applying the TCA methodology is to determine how the cost profile, and possibly the prioritization decision, may change when Types III, IV, and V costs are considered.

The hypothetical waste streams and their attributes are shown below.



In this example, we have identified some of the waste treatment options available for these waste streams, but these options are not evaluated in the case example. The case example is a baseline assessment of the manner in which the wastes are currently being treated. The waste treatment options and their evaluations would be developed as part of the R&D assessment activities that presumably would occur later in the decision-making process.

For purposes of ensuring that the TCA methodology is including factors that are important to the company, the methodology includes a step for thorough identification of goals, requirements and constraints at multiple levels within the organization (e.g., corporate, regional, and local). In this example, goals, objectives, and constraints that may directly influence the project include the following:

Corporate Goals and Objectives

- Minimize waste and reduce the costs associated with waste disposal.
- Mitigate or eliminate future environmental (Superfund) liabilities.

Local Business Unit Goals and Objectives

- Demonstrate to corporate that the best pollution prevention strategies are being identified and implemented to reduce present and future risks/costs.
- Retain autonomy over local waste management and disposal decisions.

From these goals we can select project/decision goals by defining the following assumptions, limitations, scope, and boundaries:

- Non-limiting factor: Corporate goals are in line with the scope of the project and demonstrate the corporation's intent to support a comprehensive analysis of the total costs involved with disposal of the two waste streams.
- Potential limiting factor: Local business units desire to retain autonomy over decision-making may limit implementation of corporate recommendations.

In addition, we must determine whether the project options, in light of competing goals and limitations, are appropriately aligned with the various goals, requirements, and constraints. Given the competing goals and objectives listed above, the project options appear to be consistent with the internal objectives and do not seem to prevent proceeding to the next step. If the project options were inconsistent with the defined corporate, shareholder, or business unit goals, then the project would need to be reconsidered and a new project scope developed.

Step 2: Streamlining the Analysis

To accurately assess and compare present and future costs, the analysis should incorporate an understanding of common EHS accounting formulas. For example, common EHS cost accounting practices typically only include costs for direct labor, direct material, and overhead, as illustrated below.

By incorporating these commonly accounted EHS costs into the TCA, we will be able to perform an initial comparison of the costs associated with the management and disposal of the two waste streams. The first step is to determine the average annual operating costs for managing and disposing of each waste stream. Again, we will assume that Waste Stream 1 is incinerated on-site and Waste Stream 2 is landfilled off-site. Below are the Types I and II costs associated with the management and disposal of each waste stream.

Waste Stream 1 – Onsite Disposal (Incineration)

Costs	Amount
Corporate Overhead	$290,000
Depreciation	$1,230,000
External Services	$130,000
Internal Services	$850,000
Labor	$300,000
Utilities	$600,000
Raw Materials	$600,000
Total	**$4,000,000**

Waste Stream 2 – Offsite Disposal (Landfill)

Costs	**Amount**
Corporate Overhead	$50,000
Depreciation	$100,000
External Services	$2,200,000
Internal Services	$250,000
Labor	$150,000
Utilities	$50,000
Raw Materials	$200,000
Total	**$3,000,000**

After annual costs are forecasted using readily available data, the next step is to identify the cost driver or the overall cost on a per pound basis. For example, if the amount of Waste Stream 1 (liquid waste) incinerated annually is roughly 19 million pounds, then the cost per pound would be:

Waste Stream 1 (On-Site Incineration)	Incineration Cost per lb.
$4.0 MM/19 MM lbs. =	$0.21/lb.

Similarly, if 17.5 million pounds of aqueous sludge was disposed of annually, the associated cost would be:

Waste Stream 2 (Off-Site Landfill)	Landfill Cost per lb.
$3.0 MM/17.5 MM lbs. =	$0.17/lb.

Using the example case, an initial evaluation of the Type I and II costs associated with each disposal option would lead the decision-maker to make the judgement that Waste Stream 1 is more costly than Waste Stream 2, from both a total cost perspective and on a per pound basis ($.21/lb v. $.17/lb). In this example, the TCA method will be applied to assess how this result could change by looking at the additional Types III, IV, and V costs. For example, the TCA method uses similar data as a starting point but also incorporates additional costs which include the following:

Additional Costs	Cost Category
Transportation Risks	Type I
Operational Waste Generation (e.g., Maintenance Activities)	Type II
Future Compliance Costs	Type III
Future Contingent Liabilities	Type IV
Environmental Externalities	Type V

Step 3: Identifying Potential Risks

Incorporating Types III, IV, and V costs into the analysis, allows consideration of future and hidden costs that can greatly influence the overall problem solution. In the example case, we can define additional risk scenarios for each waste stream that fully incorporate these future potential costs. In practice, these risk scenarios would ideally be constructed by a multi-disciplinary team that can use brainstorming techniques, LCI principles and data, as well as other internal resources to identify appropriate risk scenarios that include more precise probabilities and consequences. To illustrate the method, the table below represents the risk scenarios and associated costs that are applied to each waste stream in the example. For the most part, these risks were arbitrarily defined, although they are generally plausible for each waste stream.

Alternative: Waste Stream 1

Scenario	Description	Implications	Probability	Cost Types
1	New MACT standard requires upgrade of air pollution control systems (e.g., upgrade scrubber and replace ESP with a baghouse).	End of year 2, capital equipment cost of $1.2 million. Probability is certain.	One time cost impact	Type III, Env. Compliance Obligation
		Year 3, $1.0 million in costs related to compliance trial burn, and 20% increase in internal services ($.85 million in '98) for compliance management insurance	Certain	Type III, Env. Compliance Obligation
2	Non-compliance with air emissions and new CEM requirements for incinerator	$150,000 fine in year 2 (20% probability). Fine in year 3 of $150,000 (probability 5%)	Uncertain	Type III, Env. Civil fine & penalty
		Client tracking suppliers environmental record identify fine history as a black mark in supply chain choice - Cost implication is 7.5% of 200 million account (probability of 2%)	Uncertain, Potential impact in Year 3	Type IV, intangible relationship cost with customer
3	Waste volume generated reduced by 30%	Reduction in waste results in 50% increase in utilities costs ('98 was .6 million) due to increase need for natural gas to meet temperature and combustion requirements	Occurs in year 3, with a certain probability	Type III, Env compliance obligation

Note: Costs either estimated or taken from data presented in Chapter 3.0.

Alternative: Waste Stream 2

Scenario	Description	Implications	Probability	Cost Types
1	Increase in price for future disposal. In the third year prices rise by 50%('98 prices was 2.20 million, so '00 price is up 1.1 million	in year 3 the cash outflow goes up by $1.1 million with a 50% probability	Uncertain	Type III, Env. Compliance Obligation with impact on projected Type I &II cost
2	Transportation mishap results in a spill in transit of hazardous materials	Environmental Civil penalty and remediation cost applicable. $810,000 from high cost category. Reduced the cost size by 70% to adjust for small spill	Uncertain, assume 5% probability of spill per year	Type III, Env. Remediation & fine
		Additional fine issued related to claimed community impacts, $50,000 per year	Uncertain, assume 5% probability of spill per year	Type III, community impacts human health
3	Discover in year 3 that bankrupt transporter illegally dumped several loads of hazardous waste in remote area	Assume that all liabilities related to this could reach $100 million. Also, could likely take longer time period to reach resolution - so discount over five years.	Assume one time occurrence, with a 10% chance over 5 years	Type III, Env remediation & civil penalties
4	RCRA fines related to labeling and manifest issues	Assume occurs in year 1 only, $100,000 fine with 1% probability	Only in year 1, assume corrected permanently	Type III, Civil penalty
5	Sara Title III public notices- shows company is high on release rate of hazardous wastes offsite for several years running. Result is a reduction in employee moral/productivity	Reduction in productivity simulated has having an impact in year 3 with a 5% increase in labor costs over the plant salary base - estimated at 50 million	Certain- since Sara Title III results are reported correctly each year and others publicize	Type IV, Public perception based impact on staff morale and productivity
6	Externality cost of land lost to forestation.	Assume that waste landfill contributes to removal of 1 acre per year from deforestation.	Certain- each year	Type V, Land lost

Note: Costs either estimated or taken from data presented in Chapter 3.0.

Step 4: Conduct Financial Inventory

The risk scenarios developed above were used to tabulate the results and calculate a total present value cost for each waste stream over a three-year evaluation period. Internal company costs were discounted to present day using a 12% discount rate, while social costs were discounted with a 2% discount rate. The choice of discount rate here is purely arbitrary and is not intended to imply any statement on the appropriateness of either value. The spreadsheets for each cost type in Appendix 2 were used as checklists for developing the cost categories included in the example. Then, the Types I and II costs presented earlier and the Types III, IV, and V costs presented in the Chapter 3 were applied.

The following tables illustrate the results of the TCA for the hypothetical case example. The tables show how costs were developed for the scenarios described in Step 3 and then combined for evaluation purposes. The user will note that totals are presented for the Costs Types I through IV separately, and then as a total. This was done so that all the internal costs potentially borne by the company could be viewed together. The Type V costs are presented separately at this point to emphasize certain differences:

- Type V costs are more likely to be borne by society, not the company.
- Type V costs should be discounted with a different rate.
- Type V cost estimates are derived from literature searches on publicly available data and are likely to vary significantly with many social and other factors.

It will be up to the user to determine how to use Type V costs in decision-making.

The following tables present the Types I through IV costs.

TCA Results for Waste 1 ($ in Millions)

Cost Type	**1998**	**1999**	**2000**	**Present Value Totals**
Types I & II	4.0	3.57	3.2	10.77
Types III				
Scenario 1 New MACT	--	1.07	0.94	2.01
Scenario 2 CEM Non-Compliance	--	0.027	0.012	0.039
Scenario 3 Reduction in Waste	--	--	0.24	0.24
Type IV				
Scenario 2 Client Relationships	--	--	0.24	0.24
Totals	4.0	4.67	4.63	13.30

TCA Results for Waste 2 ($ in Millions)

Cost Type	**1998**	**1999**	**2000**	**Present Value Totals**
Types I & II	3.0	2.68	2.4	8.08
Types III				
Scenario 1 Price Rise	--	--	0.44	0.044
Scenario 2 Remediation	0.012	0.011	0.010	0.033
Scenario 2 Penalty	0.003	0.002	0.002	0.007
Scenario 3 Landfill	--	--	7.12	7.12
Scenario 4 RCRA Fines	0.0001	--	--	0.001
Type IV				
Scenario 5 Worker Morale			2.0	2.0
Totals	3.02	2.69	11.97	17.68

The basis for the Type V cost estimates are presented in the following two tables for each waste stream. These costs were developed from a "nearest neighbor" LCI data set and applied the cost per ton values identified in the externalities cost basis table in Chapter 3. Using a cost range for each pollutant, we can compare the two waste streams using a life cycle inventory (LCI) of how much of each substance is released into the air on an annual basis. In this example, the LCI data was not directly developed for the example, but rather was taken from sources with some of the expected attributes for each waste stream. This application of previously published LCI may seem inaccurate, but it demonstrates that the user has the ability to use "nearest neighbor" data sources and adjust them as appropriate. It also highlights the fact that the TCA method can be used to look at a number of "what-ifs" and the process does not need to be paralyzed while extensive data gathering efforts are developed. For example, the disposal option utilized for Waste Stream 1 is incineration, which naturally creates more emissions than land disposal, the Waste Stream 2 disposal method. An LCI for coal/residue combustion was used for Waste Stream 1, but the sulfur dioxide and methane emissions were adjusted to be representative of a natural gas source (since many incinerators use natural gas to maintain temperature). Obviously other adjustments were possible, and likely would be necessary, in a real situation. A comparison of the potential externality costs is shown below.

Comparison of Environmental Externality Costs (Releases to Air)

Substance	**Incineration (Waste 1) (Annual Amt./ Cost [low-high])**	**Truck Transportation (Waste 2) (Annual Amt./ Cost [low-high])**
CO	(7.23 tons/ [$1.60-$17.21])	(2.02 tons/ [$.44-$4.81])
CO_2 (Fossil)	(18,500 tons/[$0-$60,125])	(239 tons/[$0-$776.75])
CO_2 (Non-Fossil)	(2,310 tons/[$0-$7,507.50])	(57.2 tons/[$0-$185.90])
Methane	(227 kg /[$0-$229])	(38 tons/[$0-38,285])
N2O	(664lbs/[$0-$22.70])	(.0579lbs/[Negligible])
NO_x	(43.3 tons/[$519.60-$120,027.60])	(2.05 tons/[$24.60-$5,682.60])
SO_2	(36,364kg/[$363-$242,000])	(582 kg/[$5.82-$3,871.46])
Ni	(17.7 lb./[$.27-$9.33])	(.0352 lb./[$0-$.02])
Formaldehyde	(7.39 g/[Negligible])	(.197 g/[Negligible])
Dioxins	(8.46 ug/[$.04-$.75])	(.235 ug/[Negligible])
Cr	(30.6 lb./[$20.29-$806.31])	(.00186 lb./[Negligible])
Hg	(184 g/[Negligible])	(.244 g/[Negligible])
Pb	(790 g/[$.33-$3.21])	(1.31 g/[Negligible])
Be	(771 g/[$.24-$9.31])	(.0516 g/[Negligible])
Total	$905-$430,758	$31-$48,807

LCI - Air Emissions

Pollutant	**Global Warming Potential (CO_2 Equivalents)**	**Low ($/ton)**	**High ($/ton)**
CO_2	--	$0	$3.25
CO	--	$0.22	$2.38
NO_x	--	$12.00	$2,772.00
Particulate	--	$483.00	$13,0660
PM10	--	$589.00	$6,731.00
SO_x	--	$10.00	$6,652.00
TNMOC	--	$405.00	$2,899.00
TSP	--	$483.00	$13,066.00
VOC	--	$405.00	$2,899.00
VOC, Unspeciated	--	$405.00	$2,899.00
Nitrous Oxide (N_2O)	21	$0	$3.25
Methane (CH4)	310	$0	$3.25

Step 5: Conduct Impact Assessment

The results of the TCA indicate that the costs for Waste Stream 1 are slightly larger than those expected for Waste Stream 2, until the third year. In the third year, the risk scenario identifies the potential impact of an unauthorized disposal activity. This future liability then sways the costs to indicate that Waste Stream 2 could be more costly when viewed in a TCA perspective. In the real world, the TCA would be reviewed at this point to reassess both the probability of the occurrence and the uncertainties in the cost magnitude. The TCA could then be re-run, with the application of a few other conditions. However, at face value, the new cost information provided by the TCA method could be useful to a group beginning to frame decisions in a more quantitative manner. In addition, by formally including these additional costs into planning and decision processes, improved management and communication of risks can result.

With respect to communications, similar topics (e.g., risks related to an activity) often have similar general attributes in most peoples' minds. However, when these topics are described in a more quantitative manner (e.g., the specific costs or probabilities attributed to these risks), then, typically, greater divergence exists. A TCA such as this example can provide a forum for communicating these differences among the various levels within a company and, hopefully, for addressing how these different perceptions can affect decisions.

Steps 6 and 7: Documentation & Feedback Loop

We have not formally treated these aspects of the TCA method in this case example. The TCA method was developed to allow a large degree of customization for documentation, however, the proper documentation of any analysis is very important. Thus, a specific recommendation for documentation and feedback of the results to company decision-makers has not been proposed in this example. Each company will have a unique process for incorporating TCA into their culture and processes.