Chapter 12

Green Engineering

Environmental Cost Accounting

Introduction

- Cost associated with poor environmental performance can be devastating.

- Waste disposal fees, permitting costs, and liability costs can all be substantial.

- Wasted raw material, wasted energy and reduced manufacturing throughput are also consequences of wastes and emissions.

- Corporate image and relationships with workers and communities can suffer if environmental performance is substandard.

- But, **how can these cost be quantified?**

Devastating=충격적인

Introduction

- This chapter will review the tools available for **estimating environmental cost.**

- Many of these tools are still in their developmental stages, and practices therefore vary widely from company to company. In general, however, <u>traditional accounting practices have acted as a barrier to implementation of green engineering projects because they hide the costs of poor environmental performance</u>.

- Many companies are now giving more consideration to all significant sources of environmental costs. The principle is that if cost are properly accounted for, business management practices that foster good economic performance will also foster superior environmental performance.

foster: 촉진하다

Introduction

- The relationships between economic and environmental performance are examined in a number of steps.

- First, in Section 12.2, ***a few key terms are defined*** to simplify and clarify the presentation of materials.

- In Section 12.3, ***the magnitude and types of environmental costs*** typically encountered by companies are reviewed.

- Then, in Section 12.4, ***a framework for assessing environmental costs*** is described.

- Finally, Section 12.5 through 12.8 describe specific methods for ***evaluating environmental costs***.

12.2 Definitions

Internal costs

External costs

Management accounting

Financial accounting

Overhead

Indirect costs

Full-cost accounting

Activity-based costing

Capital budgeting

Total cost assessment

Life-cycle costing

12.2 Definitions

Environmental expenses can be hidden in any of the management accounting categories, but charged most often as overhead (indirect cost).

Often, even the direct environmental costs that could be assigned to a particular process, product, or activity, such as waste disposal, are lumped together facility-wide. This is often done because of practices such as using waste disposal company to manage all of a facility's waste.

Other environmental costs, such as the costs of filling out forms for reporting waste management practices, are also hidden in the overhead category.

Because environmental costs are not traditionally allocated to the activity that is generating wastes, some of the benefits of green engineering projects are masked.

12.2 Definitions

Internal costs = costs for materials and labor

External costs = the cost associated with a loss of fishable water due to pollutants discharged by a facilities

Indirect costs=indirect materials and labor, capital depreciation, rent, property taxes, insurance, supplies, utilities, and repair and maintenace.

Often, environmental fees, regulations, and requirement act to internalize what would have otherwise been an external cost, so that a facility that produces waste must pay to reduce its quantity or toxicity or pay a premium for its disposal. This chapter focuses primarily on internal costs.

Environmental expenses can be hidden in any of the management accounting categories, but charged most often as overhead (indirect cost).

12.3 Magnitudes of Environmental Costs

All environmental costs are not captured in traditional accounting and capital budgeting practices. Nevertheless, some measures of environmental costs are available, providing a rough indication of the magnitude of environmental costs and the variation of those costs among industry sectors.

Among the easiest environmental costs to track are the costs associated with treating emissions and disposing of wastes. Direct costs of pollution abatement have been increasing steadily. (Expenditures: $52 billion in 1972 and $140 billion in 2000, 2-2.2% of GNP by US Cencus Bureau). These expenditures are not distributed uniformly among industry sectors (Table 12.3-1)

abatement = 감소, 경감, 완화

Magnitudes of Environmental Costs

Table 12.3-1 Pollution Abatement Expenditures by U.S. Manufacturing Industries (data reported by U.S. Congress, Office of Technology Assessment, 1994; original data collected by U.S. Census Bureau)

Industry Sector	*Pollution control expenditures (as a % of sales)*	*Pollution control exp. (as a % of value added)*	*Pollution control capital exp. (as a % of total capital exp)*
* Petroleum	2.25%	15.42%	25.7%
Primary metals	1.68%	4.79%	11.6%
Paper	1.87%	4.13%	13.8%
(pulp mills)	(5.70%)	(12.39%)	(17.2%)
* Chemical manufacturing	1.88%	3.54%	13.4%
Stone products	0.93%	1.77%	7.2%
Lumber	0.63%	1.67%	11.1%
Leather products	0.65%	1.37%	16.2%
Fabricated materials	0.65%	1.34%	4.6%
Food	0.42%	1.11%	5.3%
Rubber	0.49%	0.98%	2.0%
Textile	0.38%	0.93%	3.3%
Electric products	0.49%	0.91%	2.9%
Transportation	0.33%	0.80%	3.0%
Furniture	0.38%	0.73%	3.4%
Machinery	0.25%	0.57%	1.9%

* **In both industrial sectors, minimizing costs by preventing wastes and emissions will be far more strategic an issue than in other sectors.**

Magnitudes of Environmental Costs

Table 12.3-2 Summary of Environmental Costs at the Amoco Yorktown Refinery

Cost Category	*Percentage of annual non-crude operating costs*
Waste treatment	4.9%
Maintenance	3.3%
Product requirements	2.7%
Depreciation	2.5%
Administration, compliance	2.4%
Sulfur recovery	1.1%
Waste disposal	0.7%
Fees, fines, penalties	0.2%
Total costs	**21.9%**

Magnitudes of Environmental Costs

BP (Amoco) Refinery @ Yorktown, Virginia

Magnitudes of Environmental Costs

Table 12.3-3 Summary of Environmental Costs at the DuPont LaPorte Manufacturing Facility (Shields, et al., 1995)

Cost Category	*Percentage of manufacturing costs*
Taxes, fees, training, legal	4.0
Depreciation	3.2
Operations	2.6
Contract waste disposal	2.4
Utilities	2.3
Salaries	1.8
Maintenance	1.6
Engineering services	1.1
Total	**19.1%**

12.3 Magnitudes of Environmental Costs

Both cases of the Amoco Yorktown refinery and the Dupont's LaPorte chemical demonstrate that environmental costs are substantial (~20% of manufacturing cost), but that quantifying these costs is challenging.

The next sections of this chapter present a framework and procedures for estimating these costs.

12.4 A Framework for Evaluating Environmental Costs

Engineering projects are generally not undertaken unless they are financially justifiable. Projects designed to improve environmental performance beyond regulatory requirements usually must compete financially with all other projects under consideration at a facility. Fortunately, improved environmental performance is frequently profitable.

Since the profitability of environmental projects is difficult to assess, it is common to neglect many of the financial benefits of improved environmental performance when projects are analyzed. This is why a better understanding of methods for estimating environmental costs and benefits serves to promote green engineering.

In this section, the types and magnitudes of costs associated with emissions and waste generation are described and categorized. Five categories, or tiers, of costs will be considered.

12.4 A Framework for Evaluating Environmental Costs

The total Cost Assessment Methodology
by AIChE Center for Waste Reduction Technologies (CWRT)

Tier I	Costs normally captured by engineering economic evaluations
Tier II	Administrative and regulatory environmental costs not normally assigned to individual projects
Tier III	Liability costs
Tier IV	Costs and benefits, internal to a company, associated with improved environmental performance
Tier V	Costs and benefits, external to a company, associated with improved environmental performance

Tier I Costs

Tier I costs are the types of costs quantified in traditional economic evaluations. Specific examples are provide in **Table 12.4-1**. As discussed in sections 12.1 through 12.3, traditional accounting systems that focus on Tier I costs fail to capture some types of environmental costs.

Table 12.4-1 Costs that are traditionally evaluated during financial analyses of projects

- Capital equipment
- Materials
- Labor
- Supplies
- Utilities
- Structures
- Salvage value

Tier II Costs

The costs listed in Table 12.4-2 are generally charged to overhead and therefore may be "hidden" when project costs are evaluated.

These will be referred to as **Tier II - hidden costs**. Note that these costs are actually borne by facilities regardless of whether facilities choose to quantify them or assign them to project or product lines.

Tier II Costs

Table 12.4-2 Environmental costs that are often charged to overhead.

- Off-site waste management charges
- Waste treatment equipment
- Waste treatment operating expenses
- Filing for permits
- Taking samples
- Filling out sample reporting forms
- Conducting waste and emission inventories
- Filling out hazardous waste manifests
- Inspecting hazardous waste storage areas and keeping logs
- Making and updating emergency response plans
- Sampling stormwater
- Making chemical usage reports (some states)
- Reporting on pollution prevention plans and activities (some states)

Tier III Costs

A less tangible set of costs are those designated as **Tier III-liability costs**. An accounting definition of liability is a *"probable future sacrifice of economic benefits arising from present obligations to transfer assets or provide services in the future"*.

Financial Accounting Standards Board Concept Statement No. 6, Paragraph 35 (1985)

Institute of Management Accountants Statement No. 2A Management Accounting Glossary (1990)

Tangible= 유형의, 실체적인; Future sacrifice=미래손실

Tier III Costs

Liability costs (Tier III costs) could include:

- Compliance obligation
- Remediation obligation
- Fines and penalties
- Obligations to compensate privates parties for personal injury, property damage, and economic loss
- Punitive damages
- Natural resource damage

Compliance=순응; punitive damage= 처벌적 손해 배상금

Tier IV or Tier V Costs

A final set of costs are designated as **Image costs** (Tier IV costs) or **relationship costs** (Tier V costs) (AIChE CWRT, 200). These cost arise in relationships with customers, investors, insurers, suppliers, lenders, employees, regulators, and communities. They are perhaps the most difficult to quantify.

Thus, a basic framework for estimating costs and benefits associated with environmental activities consists of 5 tiers, beginning with the most tangible costs and extending to the least quantifiable costs.

Environmental Costs

The remaining sections of this chapter will focus on methods for estimating Tier II, III, IV, and V cost.

Tier I costs are captured effectively by conventional accounting methods and are described in detail in texts on engineering economics (see, for example, Valle-Riestra, 1983).

The description of Tier II costs in Section 12.5 focuses on methods for quantifying reporting, notification, and compliance costs. These are costs that are certain, yet are often difficult to separate from general overhead expenditures.

Environmental Costs

Estimating Tier III, IV, and V costs poses different challenges. These costs are often due to unplanned events, such as incidents that result in civil fines, remediation costs, or other charges.

While these events are not planned, they do occur, and it is prudent to estimate the expected value of these costs. Arriving at an expected value for Tier III, IV, and V costs will involve estimating three distinct parameters:

1. The probability that an event will occur.
2. The cost associated with the event.
3. When the event will occur.

prudent =신중한

Environmental Costs

For example, if the goal is to estimate the expected value of a civil fine or penalty (a Tier III cost), the likelihood that a fine will be assessed and the likely magnitude of that fine must be calculated. If the probability of a fine being assessed is 0.1 (1 chance in 10) per year and the likely magnitude of the fine is $10,000, the expected annual cost due to fines would be $1000.

For events that will occur in future years, such as costs of complying with anticipated future regulations, knowledge of when the event will occur is critical to determining the present value of the expected costs. These estimation methods are described in Sections 12.6 through 12.8

12.5 Hidden Environmental Costs

Table 12.4-2 described a number of emission and waste management charges that are frequently viewed as overhead costs, and therefore can be overlooked by traditional accounting systems. These charges can be grouped into a number of broad categories, specifically waste treatment costs, regulatory compliance costs, and hidden capacity costs.

Waste treatment costs are the most straightforward to estimate. They are frequently hidden because many facilities charge the capital and operating costs of centralized air and water treatment facilities to overhead, rather than to specific processes. Specific treatment costs will vary from facility and will depend strongly on the types of pollutants being treated. However, order-of-magnitude estimates of treatment costs can be estimated using values suggested by Douglas and co-workers, as shown in Table 12.5-1.

12.5 Hidden Environmental Costs

Table 12.5-1 Order of magnitude estimates of treatment costs developed by Douglas and co-workers (Schultz, 1998)

Treatment Technology	*Operating Cost ($/lb)*	*Capital Cost ($/lb)*
Air treatment	$1.5 * 10^{-4}$	$1. * 10^{-3}$
Water treatment		
Water flow	$7.4 * 10^{-5}$	$7.4 * 10^{-4}$
Organic loading	0.25	0.74
Incineration		
Organics/water	0.32	NA
Organic solids	0.80	NA
Landfill	0.12	NA
Deep well	0.30	NA

Example 12.5-1

A preliminary process design for a process to produce Bis (2-Hydroxyethyl) Terephthalate (BHET) from oxygen, ammonia, xylene and ethylene glycol results in the following estimates of raw material requirements and waste generation:

Raw Materials per mole of BHET (Molecular weight (MW) = 254)

1 mole para-xylene (MW= 106; cost=$0.40/lb)
2 moles ammonia (MW= 17; cost=$0.065/lb)
2 moles ethylene glycol (MW= 62; cost=$0.176/lb)
3+ moles oxygen (derived from air - no material acquisition cost)

Wastes generated per pound of product

3.17 pounds of gaseous effluent to be treated
0.39 pounds of water to be treated
0.01 pounds of organic solid waste to be incinerated

Provide a preliminary estimate of waste treatment costs and compare these to raw material costs per pound of product.

Example 12.5-1

Solution

The costs of raw materials per pound-mole of product are:

106*$0.40 + 2*17*$0.065 + 2*62*$0.176 = $66.4 per 254 lb product = **$0.26** per pound product

The waste disposal operating costs are:

3.17*$0.00015 + 0.39*$0.000074 + 0.01*$0.80 = **$0.0085** per pound

The cost total about 3% of raw material costs (reasonably consistent with the data presented in Section 12.3) and are dominated by the costs of incineration.

Example 12.5-2

A chemical manufacturing facility buys raw material for \$0.50 per pound and produces 90 million pounds per year of product, which is sold for \$0.75 per pound. The process is typically run at 90% selectivity and the raw material that is not converted into product is disposed of at a cost of \$0.80 per pound (by incineration). A process improvement allows the process to be run at 95% selectivity, allowing the facility to produce 95 million pounds per year of product. What is the net revenue of the facility (product sales - raw material costs - waste disposal costs) before and after the change? How much of the increased net revenue is due to increased sales of product and how much is due to decreased waste disposal costs?

Example 12.5-2

Solution

The net revenue before the change is:
(90 million pounds x $0.75/pound - 100 million pounds raw material x $0.50/pound -10 million pounds waste x $0.80) = $9.5 million/year

The net revenue after the change is:
(95 million pounds x $0.75/pound - 100 million pounds raw material x $0.50/pound - 5million pounds waste x $0.80) = $17.25 million/year

Of the difference ($7.75 million), about half ($3.75 million) is due to increased product sales and the remainder is due to decreased disposal cost.

Note that the disposal cost assumed in this example is very high and thus represents a likely upper bound on these costs. It should also be noted that the cost of capital depreciation, per pound of product is reduced after the change.

12.6 Liability Costs

Compliance obligations

Remediation obligations

Fines and penalties

Obligations to compensate private parties for personal injury, property damage and economic loss

Punitive damages

Natural resource damages

Tier III costs depend on

- Probability an event will occur
- Costs associated with the event
- When the event occurs

Table 12.6-1 Source of data used in AIChE CWRT Total Cost Assessment Methodology

Type III Cost	*Data Sources*
Compliance obligations	EPA's Basis and Purpose Documents (BPDs), Background Information Documents (BIDs), and Economic Impact Analysis (EIA) prepared by the U.S. EPA for proposed National Emission Standards for Hazardous Air Pollutants (NESHAPs)
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 natural resource damage amounts from published literature
Potentially Responsible Party liabilities for off-site contamination	EPA CERCLIS database
Industrial process risk	EPA ARIP database Production downtime (company-specific, e.g., daily cost of production downtime)

How much will it cost?

Table 12.9. Summary of Penalty Data assembled for the Total Cost Accounting Methodology of the AIChE CWRT (AIChE CWRT, 2000)

	Administrative Fines				Civil Judicial Fines			
Statute	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

CAA: Clean Air Act
CWA: Clean Water Act
EPCRA: Emergency Planning and Community Right to Know Act
FIFRA: Federal Insecticide, Fungicide and Rodenticide Act
RCRA: Resource Conservation and Recovery Act
SDWA: Safe Drinking Water Act
TSCA: Toxic Substances Control Act

Example 12.6-1

A manufacturing facility operates under an air permit and generates an industrial hazardous waste. The facility has a good record of compliance with air regulations (1 violation in the past 5 years due to a release during an emergency shutdown) and has had two violations under RCRA during the past five years - both due to improper completion of hazardous waste manifest reports). Estimate the annual costs due to civil and administrative fines and penalties.

Solution:

Based on the historical data, the probability of an air release resulting in fine is 0.2/year. If these releases are due to an emergency shutdown and the emergency release is properly reported, an administrative fine, rather than a civil fine, might be anticipated. The expected value of this cost could be calculated using either the average or median value of administrative fines under the Clean Air Act.

Expected annual cost of clean air act fines based on median fine = 0.2 * (10,000) = $2,000

Expected annual cost of clean air act fines based on average fine = 0.2 * (21,000) = $4,000

Example 12.6-1

In contrast if the violation resulted in a civil fine the expected costs would be:

Expected annual cost of clean air act fines based on median fine = 0.2 * (150,000) = $30,000

Expected annual cost of clean air act fines based on average fine = 0.2 * (486,000) = $100,000

Again, based on historical data, the annual probability of a violation of RCRA is 0.4. Assuming that a paperwork violation would result in an administrative fine, the expected cost would be:

Expected annual cost of RCRA fines based on median fine = 0.4 * (1,000) = $400

Expected annual cost of RCRA fines based on average fine = 0.4 * (31,000) = $12,000

The range of costs calculated in this example point out that fines and penalties can either be relatively minor costs or they can be major costs. The range of values highlights the importance of collecting company specific data in estimating likely fines and penalties.

Remediation costs depend on:

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

Remediation Costs

Table 12-10. Typical remediation costs (AIChE CWRT, 2000)

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

12.7 Internal Intangible Costs

Table 12.7-1 Sources of Data on Internal Intangible Costs

Type IV Cost	Data Sources
Staff (productivity, morale, turnover, union negotiating time)	Published literature on costs of injuries in specific industries; published literature on costs to employers of mortality and illness.
Market share	Published literature on market values of environmental reputation; published literature on loss of market share after environmental incidents; published literature on market share effects of negative news reports
License to operate	
Investor relationships	Published literature on the effects on share value of environmental reputation; published literature on decreases in stock prices following environmental incidents; published literature on the effect of negative news reports on share price
Lender relationships	Data on the effect of environmental incidents on credit ratings
Community relationships	Costs and benefits of public relations programs
Regulator relationships	Costs of new regulations

Intangible=무형의

12.8 External Intangible Costs

Table 12.7-1 Sources of Data on External Intangible Costs

Type V Cost	Data Sources
Pollutant discharges to air	Costs per ton of greenhouse gas emitted; Costs per case of disease or mortality; Published literature on the social costs of global warming
Pollutant discharges to surface water	Cost of lost fishing habitat and fisheries resources, using published literature; Cost of market transfers of water for environmental protection
Pollutant discharges to ground water/deep well	Costs of fresh water use; Costs to desalinate
Pollutant discharges to land	Published literature on willingness-to-pay scales, related to recreational land use or conservation of land; Costs and benefits of preserving undeveloped land
Natural habitat impacts	Published data on the costs of restoring wetlands, habitats or species; Violation of societal benefits of wetlands; Published literature on willingness-to-pay scales, related to preservation of natural habitat

Intangible=무형의

Example problem

. Lurmann, et al. (1999) have estimated the costs associated with ozone and fine particulate matter concentrations above the National Ambient Air Quality Standards (NAAQSs) in Houston. They estimated that the economic impacts of early mortality and morbidity associated with elevated fine particulate matter concentrations (above the NAAQS) are approximately $3 billion/year. Hall, et al. (1992), performed a similar assessment for Los Angeles. In the Houston study, Lurmann et al examined the exposures and health costs associated with a variety of emission scenarios. One set of calculations demonstrated that a decrease of approximately 300 tons/day of fine particulate matter emissions resulted in a 7 million person-day decrease in exposure to particulate matter concentrations above the proposed NAAQS for fine particulate matter, 17 less early deaths per year, and 24 fewer cases of chronic bronchitis per year. Using estimated costs of $300,000 per case of chronic bronchitis and $6,000,000 per early death, estimate the social cost per ton of fine particulate matter emitted. How does this compare to the range of values quoted by the AIChE CWRT? Review the procedures for estimating costs (see Hall, et al., 1992) and comment on the uncertainties associated with the methodology.

The cost of waste