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United Nations Industrial Development Organization

Training Course
Ecologically Sustainable Industrial Development

Learning Unit 6

LU6

Economic Techniques for Assessing Cleaner Production Options

Further information may be obtained from:
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Contents

LU6

Additional Course Material

Video: *Money Down the Drain*, a film by the Ontario Waste Management Corporation

Introduction

Cleaner Production usually requires an investment in time and resources. Often, this investment yields an immediate return in the form of savings at the plant level. At other times, the return on investment is a long-term improvement in the environment. When Cleaner Production leads to cost savings at the plant level, the investment can be justified with ordinary investment analysis techniques. When Cleaner Production results in higher manufacturing costs, then the investment must be justified by its environmental benefits. In these cases, micro-economic analyses are used to determine whether there will be adverse economic impacts on the industries concerned; benefit-cost analyses are used to determine whether the overall environmental benefits are greater than the costs; and macroeconomic analyses are used to estimate the impact on the entire economy. In Learning Unit 6 we present the basics of each of these economic analysis techniques.

LU6

Objectives

The specific learning objectives of this unit are as follows:

- To describe how investments in industrial environmental management may be justified at the plant, enterprise and national levels.
- To introduce analytical techniques for justifying Cleaner Production investments.

Key Learning Points

1 The economic analysis of environmental investments may take many forms and use a range of techniques, including:

- Financial analysis at the enterprise level.

Suggested Study Procedure

1 Take the test in the *Review*. Think about the questions raised and what you need to learn from this Learning Unit.

2 Work through the *Study Materials*, including the *Reading Excerpts* and the video.

3 Prepare answers to the questions posed for the *Case Studies*. If possible, work with a small group to discuss the questions raised. Compare your answers with those suggested.

4 Complete the exercises in the *Review*.

Study Materials

LU6

The economic analysis of environmental issues may take many forms and use a whole variety of techniques, including financial analysis (capital investment analysis), micro-economic impact analysis, benefit-cost analysis and macroeconomic impact analysis. These various techniques can provide very powerful and convincing arguments for justifying Cleaner Production investments. The following sections are designed to help you become familiar with each of the analytic techniques, to recognize which techniques to apply to different situations and to under- stand the limitations of each technique.

Financial Analysis

When a project involves new investment, then some form of financial analysis is required to justify the investment. The new investment may be roughly compared with the savings to indicate the number of months or years required to pay back the investment. Thus, simple financial analysis can produce a crude measure of payback of the cash to be invested. Such payback analysis is a very limited measure of investment. It takes no account of critical factors such as horizon (economic life), income tax or present value of cash flows.

A complete financial analysis requires using discounted cash flow analysis to determine the net present value or the internal rate of return on the investment. Discounted cash flow analysis, in turn, requires the following:

- Identifying all cash payments and receipts (or savings) that result from the investment, including the initial capital outlay, the annual change in operating and maintenance costs, taxes and the final salvage value of the equipment.
- Determining how long the equipment will be used

- Specifying an interest rate that represents the cost of capital.

Some Cleaner Production investments can be justified by their significant financial returns, particularly those with short (less than one year) paybacks. A payback period of one year is equivalent to a 100 per cent annual return on capital.

Some Cleaner Production investments may, however, have payback periods of 10-20 years or they may not produce a financial benefit. In such cases, Cleaner Production or even end-of-pipe technology may have to be justified by other types of economic analysis. In the United Nations context, the most commonly used investment criteria besides payback are internal rate of return and net present value.

LU6

Normally, financial analysis considers only direct costs such as capital expenditures, maintenance and expenses as well as savings in raw materials, labour, waste disposal, energy etc. Cleaner Production projects however, often have indirect and difficult-to-value benefits in areas such as regulatory compliance, insurance, workers' compensation, on-site waste management, liability, product image, company image, employee health and morale etc., and these should somehow be considered.

Next Steps

1 Read "Economic analysis of pollution prevention projects", included in the *Reading Excerpts* at the end of this Learning Unit.

2 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

1 What is total cost assessment?

2 What types of costs and benefits does a total cost assessment analyse? How does this compare to a normal investment analysis?

3 What could be the indirect cost/savings of a pollution prevention project?

4 How can reduced liability costs, which are difficult to value, still be incorporated in the investment analysis?

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5 Why are the financial indicators net present value and internal rate of return more suitable than payback period to judge pollution prevention projects?

Answers

1. *It is an investment analysis method suitable for pollution prevention projects because it accounts for the fact that such projects often affect multiple production areas and have long time horizons and benefits of a probabilistic nature that are difficult to value.*
2. *Total cost assessment analyses direct costs, indirect costs, liability costs and less tangible benefits. A normal investment analysis usually considers only direct costs.*
3. *Administrative costs, regulatory compliance costs (issuing permits, record-keeping and reporting, monitoring, manifesting), insurance, workers' compensation, costs of on-site waste management and on-site pollution control equipment operation.*
4. *By including an estimate or a qualitative description in the narrative part of the investment analysis or by loosening the financial performance requirements of projects that reduce liability.*
5. *Net present value and internal rate of return account for project cash flows and time value of money. The payback period does not meet these criteria and is therefore unsuitable for pollution prevention projects, which often have benefits stretching beyond the payback time.*

Next Steps

1 Look over the questions below so that you have some idea of what you need to learn from the video.

2 Watch the video *Money Down the Drain*.

3 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

LU6

1 How did the firm that made motor parts transform the disposal of waste caused by washing the produced parts in hot alkaline cleaning solution? What was the greatest source of cost savings?

2 How did the electroplating firm replace the cost-intensive removal of heavy metals from the rinse-water solution? What was the greatest source of cost savings?

3 For the firm that had to paint metal parts, what was the source of cost savings of changing from liquid to powder paints? If the payback period had been 24 months rather than 12 months, what would the capital investment have been?

4 What gains were realized when the firm that made parts for car motors installed a centrifuge? How would the payback have changed if the centrifuge had cost US$ 12,000 instead of US$ 8,000?

5 What would have been the payback period for Uniroyal if the cost of the SO_2 scrubber had been US$ 1,500,000?

LU6

Answers

1. *By installing an ultrafiltration system that separated the oil and the debris from the cleaning solution and water. The greatest cost savings come from the reuse of wash water.*
2. *By installing an evaporator that collected the rinse water containing heavy metals. Water is evaporated and water vapor is released to the air. The greatest cost savings came from the reduced cost of waste treatment.*
3. *The changes reduced paint losses from 35 per cent to 5 per cent of total paint used. These losses came from overspray and run-off. The capital investment would have been US$ 1,000,000.*
4. *Owing to the reduced waste production the firm saved costs of administrative, labor and time. The quality of the parts increased and more parts could be produced.*
5. *5 years.*

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Micro-Economic Impact Analysis

Micro-economics can be used to estimate the economic impact of environmental investments on an entire industry. micro-economic analysis looks at the effect of environmental investments on prices, plant closing, employment, capacity expansion and export potential.

Such analysis often shows that the economic impact of the Cleaner Production investment is not significant, with only small increases in prices (1-3 per cent) and little reduction in industrial output.

Some Cleaner Production investments can be justified by showing that a major reduction in pollution problems can be achieved without causing a significant economic effect on productive activities.

Next Steps

1 Read "Choosing an appropriate water treatment", included in the *Reading Excerpts* at the end of this Learning Unit.

2 Test your comprehension of the information presented by answering the questions below. Compare your answers with those suggested.

Questions

1 Why did the authors of this study recommend that the Government of Thailand relax its effluent standards for the tapioca starch mills?

2 **Why did the autho[illegible] recommend that second-grade mills should not be required to meet 1979 standards?**

3 **The article was written in 1977. How might the current discussion of Cleaner Production change the analysis?**

Answers

1. The current standards are not technically fea[illegible]ble, so they are not enforceable. Lower standards could be enforced, resulting in a significant re[illegible]ion in waste discharges.

2. The micro-economic impact analysis showed [illegible] most second-grade mills would not be able to afford the more stringent standard and would [illegible] forced to close. Also, it is likely that they contribute only a small share of the organic pollution [illegible] tapioca starch industry.

3. This analysis focused on end-of-pipe treatm[illegible] analysis of Cleaner Production techniques might suggest larger but more affordable reducti[illegible] waste generation and pollutant discharges.

Benefit-Cost Analysis

LU6

Benefit-cost analysis compares the benefits of improving the environment to the costs of achieving that improvement.

Benefit-cost analysis can be applied at the local, regional, national or even global level.

Benefit-cost analysis can be used to justify Cleaner Production investments that have no positive financial returns to the enterprises but significant benefits in terms of reduced risks to health and the environment.

Estimating the benefits of environmental investments requires linking the effect of pollutant reduction on ambient environmental quality, determining the effects of improved ambient en- vironmental quality on humans and the environment and establishing the value of these effects.

In a few cases, the value of environmental benefits is reflected in market prices, such as those for agricultural and forestry products. In most cases, however, the value of environmental benefits must be either

- Directly derived from complementary markets (housing prices as influenced by ambient air quality) or surveys (asking individuals what they are willing to pay for environmental quality improvement).
- Indirectly derived from physical science data and imputed market values.

There is often considerable uncertainty in linking changes in ambient environmental quality to physical effects (e.g. the relationship between exposure to sulfur dioxide and mortality) and in valuing these effects (e. g. what is the value of improved human health, atmospheric visibility etc.).

Some environmental effects, particularly effects on ecosystems and effects occurring in the distant future (e.g. leaking hazardous waste sites), are difficult to include in benefit-cost analyses.

Next Steps

1 Read chapters 1-4 and 6 from "Benefits estimates and environmental decision-making", included in the *Reading Excerpts* at the end of this Learning Unit.

2 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

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1 What is one of the main difficulties of benefit-cost analysis?

2 How can some environmental investments that have no positive financial returns be justified?

3 Why is it important to place monetary measures on environmental gains and losses?

Answers

1. It is often difficult to quantify physical effects on health and environment.

2. These investments often reduce risks to health and improve the environment.

3. Monetary measures make it possible to measure the degree of concern and offer a supportive argument for environmental quality. They permit comparison with other monetary benefits arising from the alternative uses of funds.

LU6

Macroeconomic Impact Analysis

Macroeconomic models are useful for tracing the impact of pollution control expenditures on major variables in an economy: economic growth, inflation, unemployment, productivity and the balance of payments.

The difference between macroeconomic analysis and micro-economic analysis is that macroeconomic analysis assesses the overall effects that environmental expenditures exert on a national economy, whereas micro-economic analysis looks at the impacts on a particular plant, enterprise or industry.

Macroeconomic analysis captures important multiplier and feedback effects, such as the effects of price changes on firms that purchase the output of polluting companies and the effects of increased demand on the suppliers of pollution control equipment.

The macroeconomic consequences of environmental expenditures in developed countries have been quite small. The annual expenditure has been between 0.8 and 1.5 per cent of GDP. Industry accounts for about 25 per cent of this expenditure. The other sectors that must invest in the environment are Governments, households and transport.

The public ultimately pays the costs of environmental improvements, if not directly then indirectly through higher taxes, higher prices or reduced services.

Next Steps

1 Read "Macroeconomic modelling techniques", included in the *Reading Excerpts* at the end of this Learning Unit.

2 Test your comprehension of the information by answering the questions below. Compare your answers with those suggested.

Questions

1 **What is the difference between micro-economic and macro-economic impact analysis?**

2 **In which cases does the use of macroeconomic impact analysis make sense?**

LU6

3 **What percentage of GDP in developed countries is being spent on environmental protection measures?**

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1. micro-economic impact analysis looks at the impacts of environmental investments on an enterprise or industry. Macroeconomic impact analysis explains the impacts on the entire national economy, including effects on economic growth, inflation, unemployment, productivity and the balance of pay-

2. Macroeconomic impact analyses are necessary when environmental issues overall effects, including important multiplier and feedback effects, a national economy.

3. Between 1 and 2 per cent of the GDP.

Additional Suggested Readings

This concludes the study section of Learning Unit 6. For additional information on financial and economic analysis, you may refer to the following sources.

LU6

Behrens, W., and P.M. Hawranek, *Manual for the Preparation of Industrial Feasibility Studies* (UNIDO publication, Sales No. E.91.III.E.18).

Pearce, D.W., and A. Markandya, *Environmental Policy Benefits: Monetary Valuation* (Paris, OECD, 1989).

Tietenberg, T., *Environmental and Natural Resource Economics*, 2nd ed. (Glenview, Illinois, Scott, Foresman, 1988).

USEPA, Office of Policy Analysis, *Guidelines for Performing Regulatory Impact Analysis*, EPA-230-01-84-003, 1983.

USEPA, Office of Pollution Prevention and Toxics, *Total Cost Assessment: Accelerating Industrial Pollution Prevention Through Innovative Project Analysis: Unit Applications to the Pulp and Paper Industry*, EPA/741/R-92/002, 1992.

Case Studies

Case Study 1: Waste Reduction Audit for a Cement Plant

Based on UNIDO project US/INT/91/217, Demonstration of Cleaner Production Techniques.

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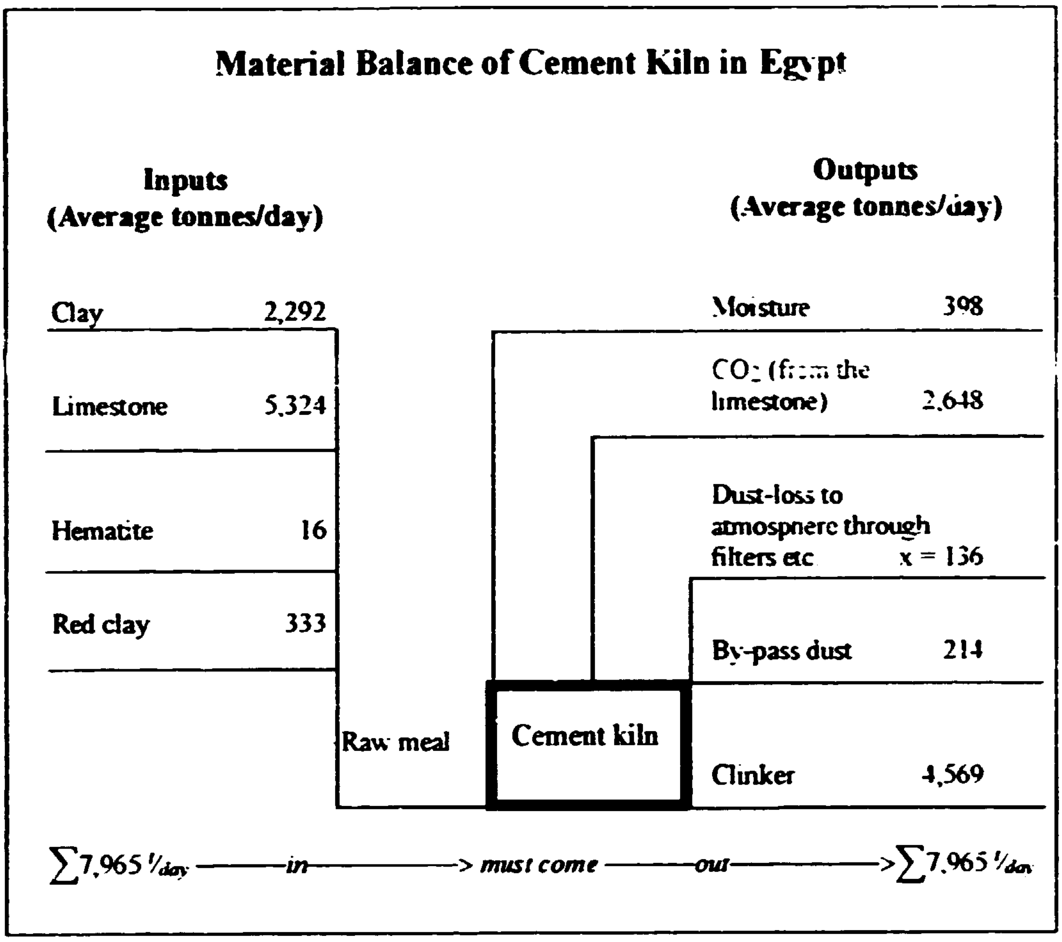
Cement manufacture requires the burning of fuel together with limestone and clay, yielding a clinker which is then ground with gypsum to give cement. Burning with the modern energy- efficient dry process requires very large and efficient filters be- cause the combustion gases flow counter to the dry preheated raw material feed in the rotating kiln, carrying 10-20 per cent of the feed to the stack. Failure to catch and return this material to the process results in severe dust emissions and production losses.

In a pilot project to test the waste auditing technique, UNIDO assisted a cement industry in Egypt. After the initial preassessment, it was decided to focus on the cement kiln. Production records and laboratory data were used to determine input and output quantities over a period of one year and to derive a material balance for the kiln operation (see figure). Fuels and products of combustion were not included in the material balance since associated losses were deemed insignificant compared with the dust losses. Because there were no direct measurements of dust losses to the atmosphere, this quantity was determined by subtracting all known outputs from the inputs.

The material balance made management aware that potential product, 136 tonnes per day, was being lost through the stack.

LU6



Because equipment specification data suggested that something less than 18 tonnes per day should be escaping this way, the cement-making process and the filters were examined closely. Two important observations were made: (a) one filter, the gravel bed filter, was not functioning properly; (b) there were numerous kiln stoppages throughout the year (the electrostatic filters at the main stack work optimally only after some time in operation).

Emissions from the gravel bed filter were quickly addressed, reducing dust losses to the atmosphere by approximately 12 tonnes per day.

The company was already aware of the by-pass duct losses as this waste was being hauled by trucks and dumped in the surrounding desert. The problem is caused by the high alkali content of the Egyptian raw materials, which makes it necessary to bleed alkali-rich dust from the kiln to prevent clogging of the preheating equipment. The waste audit exercise spurred the company to find a sustainable and profitable solution. Trials suggested that the 214 tonnes per day of by-pass dust could, with the addition of 4 tonnes per day of additives, be successfully converted to clinker in a small dry kiln without preheaters. The processing would drive off an additional 26 tonnes per day of CO_2, thus yielding 192 tonnes per day of clinker. The investment for such a kiln is estimated at 10 million Egyptian pounds (LE) and the operating costs at LE 20 per tonne.

Questions

1 How much did the company increase its daily revenues by repairing the gravel bed filter, given that the semi-finished clinker escaping to the atmosphere is worth LE 110 per tonne?

LU6

2 What is the remaining potential for reducing dust emissions to the atmosphere at the plant? Suggest ways to achieve these savings.

3 How many years would be required to pay back the investment of the suggested by-pass dust kiln, given that the clinker is worth LE 120 per tonne and 300 operating days per year?

4 Do you think that the process technology in use (dry process preheating) was developed in Egypt?

5 Why were average data for one year used instead of making measurements over one day when the kiln was working properly?

6 What is the main advantage and the main disadvantage of determining the losses by difference, as was done in this case, and not by direct measurements?

7 World production of cement was in 1988 more than one billion tonnes. Estimate, using the material balance data for the Egyptian cement plant, how much CO_2 was emitted from the cement industry worldwide in that year and compare this with the estimate of CO_2 from fossil fuel burning given in Learning Unit 2. For ease of calculation, neglect the fact that gypsum has to be added to the clinker to make cement, the burning of fuel in the cement process and other processing. Having the answer, would you say that it is important to reduce losses of semi-finished clinker in the context of global warming?

LU6

Answers

1. 12x110 LE 1,320 per day (US$ 400 per day).

2. 136-12-18 = 106 tonnes per day; or 110x106 LE 11,660 per day. Improve preventive maintenance of the kiln and filters to reduce the number of kiln stoppages and increase the efficiency of the filters.

3. 10,000,000 [(120-20)x300x192] - 1.7 years.

4. No, because if it had been, the alkali content of the raw materials would have been considered. This shows how difficult it is to transfer technology.

5. Kiln stoppages, build-up of dust in equipment etc. would not have been taken into account by measuring over one day only.

6. Losses are rarely measured, at least not continuously. It is therefore easier to determine them by subtracting process outputs from process inputs. The main drawback is that the figure thus derived cannot be checked.

7. 2,648 4,569x1,000,000,000 = 580 million tonnes CO_2, which is a bit more than 10 per cent of the 5,700 million tonnes estimated yearly releases of CO_2 from fossil fuel burning. Yes, but it would be even better if this concentrated CO_2 stream could be captured and made use of.

Case Study 2: The Ismailia Waste-Water Project

Next Steps

1 Read "Benefit-cost analysis for the Ismailia waste-water project", a case study included in the *Reading Excerpts* at the end of this Learning Unit.

2 Answer the questions below. Compare your answers with those suggested on the following pages.

LU6

Questions

1 What is the difference between financial analysis and benefit-cost analysis?

2 How would waste-water treatment reduce recreation-related illnesses?

3 What is the basis for valuing changes in illness?

4 Why might one be sceptical about the results of this analysis?

LU6

5 List some fundamental data based on questionable assumptions.

Answers

1. Financial analysis looks at the financial costs of and revenues from an investment, while benefit-cost analysis examines all of the benefits and costs, including social and environmental benefits and costs.

2. The difference is the avoidance of 10,000 cases of acute gastrointestinal symptoms and 5,000 cases of rash/infection, because the waste-water treatment plant will reduce the fecal concentrations to an acceptable level.

3. The basis for assigning values to changes in illness is the cost of medical service, the value of lost wages and a premium for pain and suffering.

4. One might be sceptical of the amenity value because (a) it is based on an estimate of the amount and value of the housing stock around the beach in the late 1990s and (b) it accounts for about 50 per cent of the total benefits from the project.

5. Number of people, user days, incidence of illness, rental incomes, number of housing units and effects on commercial fisheries.

Review

Test

The following test will help you review the material presented in this Learning Unit.

LU6

1 Environmental economic techniques include all of the following except

a. Environmental impact assessment
b. Micro-economic impact analysis
c. Macroeconomic impact analysis
d. Benefit-cost analysis

2 To justify a Cleaner Production investment, the economic technique that measures cash flows and profitability over a future period at plant level is

a. Financial analysis
b. Micro-economic analysis
c. Macroeconomic analysis
d. Environmental impact assessment

3 A payback period of one year is equivalent to a

a. 25 per cent return on capital
b. 50 per cent return on capital
c. 100 per cent return on capital
d. 200 per cent return on capital

4 Payback analysis is a limited measure of investment because it fails to account for

a. Economic life of the investment
b. Income tax
c. Present value of cash flows
d. All of the above

5 In developing countries, the key economic motivation for Cleaner Production is usually

a. Reduced expenditures for employee health care
b. Quick financial payback
c. Low internal rate of return
d. Cultural benefits

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6 A discounted cash flow analysis requires

a. Choosing an appropriate technology
b. Determining how long the technology will be used
c. Selecting the manufactures of the technology
d. All of the above

7 The technique that estimates the economic impact of Cleaner Production investment at an industry level is

a. Environmental impact assessment
b. Micro-economic analysis
c. Macroeconomic analysis
d. Financial analysis

8 Micro-economic impact analysis examines all of the following except

a. Plant closing
b. Product price increases
c. Capacity expansion
d. Balance of payments

9 In practice, the micro-economic impact of pollution control programmes on many industries will normally be

a. Very significant
b. Significant
c. Small
d. Zero

10 The economic technique that measures the cost of a Cleaner Production activity against possible benefits is

a. Marginal cost analysis
b. Financial analysis
c. Macroeconomic analysis
d. Benefit-cost analysis

11 The main difficulty with benefit-cost analysis is usually

a. Quantifying health effects
b. Estimating the costs
c. Valuing the benefits
d. Arithmetical

12 In environmental benefit-cost analysis, values can be

a. Market values based on prices and cost savings
b. Surrogate values based on land values, wage premiums, travel costs etc.
c. Survey values
d. All of the above

13 Computation of the economic benefits to justify an environmental project using benefit-cost analysis is

a. Usually adequate to justify a project
b. Both scientific and economic analysis
c. Not usaally dependent on the underlying assumptions
d. Often used to justify investments at the plant level

14 To justify a Cleaner Production investment, the economic tool that measures the effect of environmental expenditures on GDP, consumer prices and unemployment is

a. Environmental impact assessment
b. Micro-economic analysis
c. Macroeconomic analysis
d. Financial analysis

LU6

15 Expenditure in pollution prevention and control in most developed countries accounts for what share of GDP?

a. 2 per cent
b. 5 per cent
c. 8 per cent
d. 10 per cent

Answers:
1-5 aacdb
6-10 bbdcd
11-15 adbca

Some Ideas to Think About

The following are some additional questions raised by the *Study Materials*. Take some time to think about them. If possible, work in a small group and try to achieve consensus.

1 Why do experienced business managers still perceive the environment as another cost of doing business that has no benefit?

2 Does business adopt only the "environmental morality" that it can afford? Is severe pollution inevitable?

3 Why would the business community support and/or oppose the use of benefit-cost analysis in environmental decision-making?

4 What are possible economic justifications for exempting plants from environmental regulations?

5 How useful is an economic justification for an environmental project if the underlying assumptions are not stated or justified?

6 If a new Cleaner Production idea indicates immediate substantial profitability, will every enterprise in the industry be enthusiastic about adopting it?

Reading Excerpts

Economic Analysis of Pollution Prevention Projects

Excerpted, with permission, from USEPA, Office of Solid Waste, *Facility Pollution Prevention Guide*, EPA/600/R-92/088, chap.6.

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Although businesses may invest in pollution prevention because it is the right thing to do or because it enhances their public image, the viability of many prevention investments rests on sound economic analyses. In essence, companies will not invest in a pollution prevention project unless that project successfully competes with alternative investments. The purpose of this chapter is to explain the basic elements of an adequate cost accounting system and how to conduct a comprehensive economic assessment of investment options.

Total Cost Assessment

In recent years industry and the EPA have begun to learn a great deal more about full evaluation of prevention-oriented investments. In the first place, we have learned that business accounting systems do not usually track environmental costs so they can be allocated to the particular production units that created those wastes. Without this sort of information, companies tend to lump environmental costs together in a single overhead account or simply add them to other budget line items where they cannot be disaggregated easily. As a result, companies do not have the ability to identify those parts of their operations that cause the greatest environmental expenditures or the products that are most responsible for waste production. This chapter provides some guidance on how accounting systems can be set up to capture this useful information better.

It has also become apparent that economic assessments typically used for investment analysis may not be adequate for pollution prevention projects. For example, traditional analysis methods do not adequately address the fact that many pollution prevention measures will benefit a larger number of production areas than do most other kinds of capital investment. Second, they do not usually account for the full range of environmental expenses companies often incur. Third, they usually do

LU6

not accommodate a sufficiently long time horizon to allow full evaluation of the benefits of many pollution prevention projects. Finally, they provide no mechanism for dealing with the probabilistic nature of pollution prevention benefits, many of which cannot be estimated with a high degree of certainty. This chapter provides guidance on how to overcome these problems as well.

In recognition of opportunities to accelerate pollution prevention, the USEPA has funded several studies to demonstrate how economic assessments and accounting systems can be modified to improve the competitiveness of prevention-oriented investments. EPA calls this analysis Total Cost Assessment (TCA). There are four elements of TCA: expanded cost inventory, extended time horizon, use of long-term financial indicators, and direct allocation of costs to processes and products. The first three apply to feasibility assessment, while the fourth applies to cost accounting. Together these four elements will help you to demonstrate the true costs of pollution to your firm as well as the net benefits of prevention. In addition, they help you show how prevention-oriented investments compete with company-defined standards of profitability. In sum, TCA provides substantial benefits for pre-implementation feasibility assessments and for post-implementation project evaluation.

The remainder of this chapter summarizes the essential characteristics of TCA. Much of the information is drawn from a report recently prepared for the USEPA by the Tellus Institute. The Tellus report addresses TCA methodology in much greater detail than can be provided here and provides examples of specific applications from the pulp and paper industry. The report also includes an extensive bibliography on applying TCA to pollution prevention projects. In a separate but related study for the New Jersey Department of Environmental Protection, Tellus analyzed TCA as it applies to smaller and more varied industrial facilities. A copy of this report can be obtained from the N.J. Department of Environmental Protection.

Expanded Cost Inventory

TCA includes not only the direct costs factors that are part of most project cost analyses but also indirect costs, many of which do not apply to other types of projects. Besides direct and indirect costs, TCA includes cost factors related to liability and to certain "less-tangible" benefits.

TCA is a flexible tool that can be adapted to your specific needs and circumstances. A full-blown TCA will make more sense for some businesses than for others. In either case it is important to remember that TCA can happen incrementally by gradually bringing each of its elements to the investment evaluation process. For example, while it may be quite easy to obtain information on direct costs, you may have more trouble estimating some of the future liabilities and less tangible costs. Perhaps your first effort should incorporate all direct costs and as many indirect costs as possible. Then you might add those costs that are more difficult to estimate as increments to the initial analysis, thereby highlighting to management both their uncertainty and their importance.

Direct Costs

For most capital investments, the direct cost factors are the only ones considered when project costs are being estimated. For pollution prevention projects, this category may be a net cost, even though a number of the components of the calculation will represent savings. Therefore, confining the cost analysis to direct costs may lead to the incorrect conclusion that pollution prevention is not a sound business investment.

Indirect Costs

For pollution prevention projects, unlike more familiar capital investments, indirect costs are likely to represent a significant net savings. Administrative costs, regulatory compliance costs (such as permitting, recordkeeping, reporting, sampling, preparedness, closure/post-closure assurance), insurance costs, and on-site waste management and pollution control equipment operation costs can be significant. They are considered hidden in the sense that they are either allocated to overhead rather than their source (production process or product) or are altogether omitted from the project financial analysis. A necessary first step in including these costs in an economic analysis is to estimate and allocate them to their source. See the section below on Direct Cost Allocation for several ways to accomplish this.

Liability Costs

Reduced lability associated with pollution prevention investments may also offer significant net savings to your company. Potential reductions in penalties, fines, cleanup costs, and personal injury and damage claims can make prevention investments more profitable, particularly in the long run.

In many instances, estimating and allocating future liability costs is subject of a high degree of uncertainty. It may, for example, be difficult to estimate liabilities from actions beyond your control, such as an accidental spill by a waste hauler. It may also be difficult to estimate future penalties and fines that might arise from noncompliance with regulatory standards that do not yet exist. Similarly, personal injury and property damage claims that may result from consumer misuse, from disposal of waste later classified as hazardous, or from claims of accidental release of hazardous waste after disposal are difficult to estimate. Allocation of future liabilities to the products or production processes also presents practical difficulties in a cost assessment. Uncertainty, therefore, is a significant aspect of a cost assessment and one that top management may be unaccustomed to or unwilling to accept.

Some firms have nevertheless found alternative ways to address liability costs in project analysis. For example, in the narrative accompanying a profitability calculation, you could include a calculated estimate of liability reduction, cite a penalty or settlement that may be avoided (based on a claim against a similar company using a similar process), or qualitatively indicate without attaching dollar value the reduced liability risk associated with the pollution prevention project. Alternatively, some firms have chosen to loosen the financial performance requirements of their projects to account for liability reductions. For example, the required payback period can be lengthened from three to four years, or the required internal rate of return can be lowered from 15 to 1[illegible] percent. (See the USEPA's Pollution Prevention Benefits Manual, Phase II for suggestions on formulas that may be useful for incorporating future liabilities into the cost analysis).

Less-Tangible Benefits

LU6

A pollution prevention project may also deliver substantial benefits from an improved product and company image or from improved employee health. These benefits, listed in the cost allocation section of this chapter, remain largely unexamined in environmental investment decisions. Although they are often difficult to measure, they should be incorporated into the assessment whenever feasible. At the very least, they should be highlighted for mangers after presenting the more easily quantifiable and allocatable costs.

Consider several examples. When a pollution prevention investment improves product performance to the point that the new product can be differentiated from its competition, market share may increase. Even conservative estimates of this increase can incrementally improve the payback from the pollution prevention investment. Companies similarly recognize that the development and marketing of the so-called "green products" appeals to consumers and increasingly appeals to intermediate purchasers who are interested in incorporating "green" inputs into their products. Again, estimates of potential increases in sales can be added to the analysis. At the very least, the improved profitability from adding these less-tangible benefits to the analysis should be presented to management alongside the more easily estimated costs and benefits. Other less tangible benefits may be more difficult to quantify, but should nevertheless be brought to management's attention. For example, reduced health maintenance costs, avoided future regulatory costs, and improved relationships with regulators potentially affect the bottom line of the assessment.

In time, as the movement toward green products and companies grows, as workers come to expect safer working environments, and as companies move away from simply reacting to regulations and toward anticipating and addressing the environmental impacts of their processes and products, the less tangible aspects of pollution prevention investments will become more apparent.

Expanded Time Horizon

Since many of the liability and less-tangible benefits of pollution prevention will occur over a long period of time, it is important that an economic assessment look at a long time frame, not the three to five years typically used for other types of projects. Of course, increasing the time frame increases the uncertainty of the cost factors used in the analysis.

Long-Term Financial Indicators

When making pollution prevention decisions, select long-term financial indicators that account for:

- all cash flows during the project
- the time value of money.

Three commonly used financial indicators meet these criteria: Net Present Value (NPV) of an investment, Internal Rate of Return (IRR), and Profitability Index (PI). Another commonly used indicator, the Payback Period, does not meet the two criteria mentioned above and should not be used.

LU6

Discussions on using these and other indicators will be found in economic analysis texts.

Direct Allocation of Costs

Few companies allocate environmental costs to the products and processes that produce these costs. Without a direct allocation, businesses tend to lump these expenses into a single overhead account or simply add them to other budget line items where they cannot be disaggregated easily. The result is an accounting system that is incapable of (1) identifying the products and processes most responsible for environmental costs, (2) targeting prevention opportunity assessments and prevention investments to the high environmental cost products and processes, and (3) tracking the financial savings of a chosen prevention investment. TCA will help you remedy each of these deficiencies.

Like much of the TCA method, implementation of direct cost allocation should be flexible and tailored to the specific needs of your company. To help you evaluate the options available to you, the discussion below introduces three ways of thinking about allocating your costs: single pooling, multiple pooling, and service centers. The discussion is meant as general guidance and explains some of the advantages and disadvantages of each approach. Please see other EPA publications, general accounting texts, and financial specialists for more detail.

LU6

Single Pool Concept

With the single pool method, the company distributes the benefits and costs of pollution prevention across all of its products or services. A general overhead or administrative cost is included in all transactions.

Advantages. This is the easiest accounting method to put into use. All pollution costs are included in the general or administrative overhead costs that most companies already have, even though they may not be itemized as pollution costs. It may therefore not be a change in accounting method but rather an adjustment in the overhead rate. No detailed accounting or tracking of goods is needed. Little additional administrative burden is incurred to report the benefits of pollution prevention.

Disadvantages. If the company has a diverse product or service line, pollution costs may be recovered from products or services that do not contribute to the pollution. This has the effect of inflating the costs of those products or services unnecessarily. It also obscures the benefits of pollution prevention to the people who have the opportunity to make it successful—the line manager will not see the effect of preventing or failing to prevent pollution in his area of responsibility.

Multiple Pool Concept

The next level of detail in the accounting process is the multiple pool concept, wherein pollution prevention benefits or costs are recovered at the department or other operating unit level.

Advantages. This approach ties the cost of pollution more closely to the responsible activity and to the people responsible for daily implementation. It is also easy to apply within an accounting system that is already set up for departmentalized accounting.

Disadvantages. A disparity may still exist between responsible activities and the cost of pollution. For example, consider a department that produces parts for many outside companies. Some customers need standard parts, while others require some special preparation of the parts. This special preparation produces pollution. Is it reasonable to allocate the benefit or cost for this pollution prevention project across all of the parts produced?

Service Center Concept

A much more detailed level of accounting is the service center concept. Here, the benefits or costs of pollution prevention are allocated to only those activities that are directly responsible.

Advantages. Pollution costs are accurately tied to the generator. Theoretically, this is the most equitable to all products or services produced. Pollution costs can be identified as direct costs on the appropriate contracts and not buried in the indirect costs, affecting competitiveness on other contracts. Pollution costs are more accurately identified, monitored, and managed. The direct benefits of pollution prevention are more easily identified and emphasized at the operational level.

Disadvantages. Considerable effort may be required to tack each product, service, job, or contract and to recover the applicable pollution surcharges. Added administrative costs may be incurred to implement and maintain the system. It may be difficult to identify the costs of pollution when pricing an order or bidding on a new contract. It may be difficult to identify responsible activities under certain conditions such as laboratory services where many small volumes of waste are generated on a seemingly continual basis.

Summary

Environmental costs have been rising steadily for many years now. Initially, these costs did not seem to have a major impact on production. For this reason, most companies simply added these costs to an aggregate overhead account, if they tracked them at all. The tendency of companies to treat environmental costs as overhead and to ignore many of the direct, indirect, and less-tangible environmental costs (including future liability) in their investment decisions has driven the development of TCA.

Expanding your costs inventory pulls into your assessments a much wider array of environmental costs and benefits. Extending the time horizon, even slightly, can improve the profitability of prevention investments substantially, since these investments tend to have somewhat longer payback schedules. Choosing long-term financial indicators, which consistently provide managers with accurate and comparable project financial assessments, allows prevention oriented investments to compete successfully with other investment options. Finally, directly allocating costs to processes and products enhances your ability to target prevention investments to high environmental cost areas, routinely provides information needed to do TCA analysis, and allows managers to track the success of prevention investments. Overall, the TCA method is a flexible tool, to be applied incrementally, as your company's needs dictate.

Choosing an Appropriate Water Treatment

Excerpted, with permission, from R.A. Luken and Y. Unkulvasapaul, "Choosing an appropriate water treatment", *Environmental Science and Technology*, vol. 11, No. 13 (December 1977).

Increasing environmental awareness in the 1970's has led both developed and developing nations to adopt more stringent effluent standards. They have tended to establish uniform standards for similar categories of activities because uniform requirements are easier to administer. In addition, developing nations have tended to base their standards on the experiences of European and North American countries.

While the adoption of more stringent effluent standards is usually a wise decision, it is more important that these standards be implemented by developing nations. In many cases these standards are not implemented because they do not take into account:

- the waste treatment technology available to industrial and municipal dischargers
- the cost of the technology
- the economic impact on industry
- the local environmental conditions.

Thus the rate of compliance with the effluent standards has been slow in many cases.

Obviously, the rate of compliance with effluent standards would be increased if they were tailored to the unique conditions in each developing nation. One way to adjust the effluent standards for unique conditions is to take into account technological, environmental, and social conditions in each country.

For example, facultative oxidation ponds are usually much more appropriate than activated sludge waste-water treatment systems in the Southeast Asian countries because the latter require too much mechanical equipment and maintenance. Another example is that the permissible level of dissolved oxygen in rivers may be lower in Southeast Asia than Europe because aquatic organisms are more adaptable to adverse conditions in the tropics.

Assessment

The primary recommendation emerging from the technological and economic impact study [of the tapioca starch industry in Thailand] is

LU6

that the Thai government adopt the 1977 and 1979 proposed effluent standards for first-grade mills, but only the 1977 proposed effluent standards for second-grade mills. For both categories of mills, appropriate technologies are available and effective. However, on the basis of economic analysis, only the first-grade mills would be required to meet the 1977 and 1979 standards. Requiring the second-grade mills to meet the 1979 standards is not recommended because of the severe economic impact and because trends in the market alone may force these plants to close in a few years.

The current and proposed effluent standards are very different. The current Thai effluent standards do not allow for significant variation between the two different types of production technologies and exceed the capacity of commonly used environmental control technology. While the proposed effluent standards are not as stringent as the current standards, they would result in a significant pollution reduction. More importantly, they would probably be implemented because they are feasible and do not impose significant adverse economic impacts.

LU6

Table 1. Size Distribution of Plants

Sub-categories	Estimated no. of mills	Size range	Size distribution
First-grade starch	27	40-59 t/day	15%
		60-69	55%
		70-120	30%
			100%
Second-grade starch	72	0-2.9	90%
		3.0-9.0	10%
			100%

The Starch Industry

Three representative starch mills rather than all 90-110 mills in Thailand were analyzed because of the impossibility of considering all mills. In defining representative mills, all mills were first classified as either first- or second-grade starch mills (table 1). First-grade mills are more capital intensive and thus more mechanized than second-grade mills. They have better extraction rates and are always significantly larger than second-grade mills. Within the second-grade category, mills were classified as either large (3-9 tons/day) or as small (less than 3 tons/day) mills. This distinction was made because of concerns about the impacts on very small mills.

Two rather than one set of effluent limitations were considered for each of the three representative mills. A less stringent limitation (low removal of organic material) was proposed for 1977. A more stringent limitation (higher removal of organic material) was proposed for 1979.

Control Technology and Costs

Several factors were used in selecting appropriate technologies on which to base the 1977 and 1979 effluent limitations. These factors were:

- sufficient data about the engineering design and removal efficiencies
- technology appropriate for reducing organic wastes
- costs
- availability of land.

Fortunately, the works by Pescod and Thanh (1976) and Unkulvasapaul (1975) reviewed the appropriate technologies on the basis of these criteria and the following material is a brief summary of their work. These studies have many of the features of a U.S. Environmental Protection Agency Development Document.

The selection of appropriate waste-treatment technologies assumes that starch mills would install primary clarification ponds as part of the production process. The settled starch would be recovered and sold along with other starch output.

As a first-stage limitation, the above-mentioned sources agreed that the anaerobic ponds appear to be the best choice. Anaerobic ponds are earthen basins in which the raw waste load is retained for a short time to contact with deposited digested solids. These ponds are most appropriate in view of the very high BOD concentration, low costs of treatment, and general availability of land.

As a second-stage limitation, the above-mentioned sources reviewed several technologies:

- One is a facultative oxidation pond that allows for sufficient surface area and detention time to stimulate aerobic reactions. This technology is appropriate where large land areas are available and cheap.
- Another is an aerated lagoon, which treats waste water on a flow-through basis and oxygen is supplied usually by means of surface aerators or diffused aeration units. This technology is appropriate where land is available to a limited degree, but is costly.
- A third is a rotating biological drum filter, which treats waste water in a heavy wire mesh drum filled with equal-sized plastic spheres. This technology is appropriate where land use must be minimized and land is very costly.

LU6

- A fourth is completely mixed continuous-activated sludge, which treats wastewater in a dispersed media by using diffused air. This technology is appropriate where land is available to a limited degree, but is costly.

Of the four available technologies, the best choice for the tapioca starch industry in Thailand appears to be aerated lagoons (table 2). A survey of the industry indicates that land is relatively available, particularly to first-grade mills, and is relatively inexpensive. Thus utilization of a rotating biological drum filter, which is a capital-intensive treatment system, is not necessary to minimize land use. The estimated cost of activated sludge is too high.

The work of Unkulvasapaul (1975) compared the capital, and operation and maintenance costs for a facultative oxidation pond and an aerated lagoon and found that both types of costs were greater for a facultative oxidation pond given land costs in the south of Thailand. The higher operation and maintenance costs were attributed to the monthly land rental, which accounted for 75% of these costs. In addition, facultative oxidation ponds probably could not achieve the same removal efficiencies as aerated lagoons. Thus utilization of an aerated lagoon rather than a facultative oxidation pond as the second-stage requirement is preferable on the basis of cost minimization.

LU6

Table 2. Technologies Available and Evaluations

Technology	Tested removal efficiency in Thailand	Appropriate for reducing organic wastes	Relative costs	Relative land requirements
First-stage requirement				
Anaerobic pond	Yes	Yes	low	medium
Second-stage requirement				
Facultative pond	No	Yes	low-medium	high
Aerated lagoon	Yes	Yes	low-medium	medium
Rotating drum	Yes	Yes	high	low
Activated sludge	Yes	Yes	high	medium

Source: Pescod and Thanh (1976) and Unkulvasapaul (1975)

Treatment costs for representative plants for first- and second-stage requirements are summarized in table 3. Actual treatment costs will vary largely from plant to plant depending upon the design and operation of the production facilities and local conditions, particularly land prices.

Furthermore, effluent treatment costs vary greatly from one installation to another, depending upon bookkeeping procedures.

Economic Impact

Several economic factors were also important in determining appropriate technologies. The factors considered were:

- price
- production
- employment and plant closure
- balance of payments and
- growth.

Potential price increases are based on the additional costs per ton of starch that might be incurred by a plant having to purchase an entire treatment system to achieve the proposed effluent limitations (table 4). These price increases would be less than estimated because the treatment costs do not take into account in-place technology. In addition, part of the costs might be passed on by an increase in the selling price of production wastes, which are used as animal feed.

The potential price effects through the 1970's for segment categories are insignificant except for small second-grade mills. However, even this price increase is dwarfed by variations in the market price, which has increased and decreased annually by as much as 30% and increased by 140% from 1970 to 1974.

The ability of the segments to pass environmental control costs on to the consumer will depend upon future supply/demand balances and substitute products. For the domestic market, the supply/demand balance is expected to be loose through the 1970's. However, there are no competitive substitutes for starch, so it is likely that a small price increase can be passed forward.

Social Consequences

Production effects would vary among the three categories of mills. For first-grade mills, no shutdowns or production curtailments are projected owing to environmental control regulations for either 1977 or 1979 requirements. These larger mills have sufficient return on investment, available capital, and cash flow to finance expected pollution control expenditure through the 1970's. However, if the market deteriorates as it did during 1975, some mills would curtail production for reasons other than pollution control costs.

Large second-grade mills would not shut down with the 1977 requirements. While the owners would not receive any return on their capital investment, they would cover the additional operating costs. However, the seven mills would shut down with the 1977 requirements. In this case, the owners would not be able to cover their operating costs. Closure of these seven mills would decrease total industry capacity by three per cent.

Table 3. Summary of Costs per Representative Plant

Segment	Capital cost $	Operation & maintenance cost $/month
First Stage:		
First grade 60 t/day	6900	40
Second grade 8.4 t/day	1100	20
Second grade 2 t/day	300	10
Second Stage:		
First grade 60 t/day	37 300	2600
Second grade 8.4 t/day	7300	300
Second grade 2 t/day	3200	100

Source: Unkulvasapaul (1975)

Small second-grade mills would probably not shut down with the 1977 requirements, in spite of the fact that the owners would not be able to cover their operating costs. They probably would not shut down because they might be able to reduce operating costs or disregard pollution control requirements. In the latter case, the operating costs are too large to be absorbed by skillful management of the plants. Closure of these mills would decrease total industry capacity by seven per cent.

LU6

Table 4. Annual Treatment Costs per Representative Plants[a]

	Cost per ton of starch production	Potential incremental pollution control cost $/ton		Incremental pollution control cost as percent of year end 1975 starch prices	
Segment	$	1977	1979	1977	1979
First grade 60 t day	145	.10	2.0	<1%	1.5%
Second grade 84 t day	15[illegible]	.15	2.1	<1	1.7
Second grade 2 t day	150	.25	3.3	<1	2.8

[a] Includes capital recovery and operation and maintenance costs. Assumes no environmental control facilities are in place. Assumes a 20-year life of facilities, 12% interest rate, and 12-month operation.

LU6

Both the large and small second-grade mills might close even in the absence of environmental control requirements. Over the past ten years, the number of second-grade mills has decreased by approximately 50%. These mills, particularly the small ones, barely covered their variable costs in 1975.

If pellet producers continue to bid up the price of roots and labor costs increase more rapidly than the selling price of outputs, the second-grade mills could easily be in a situation where they would not cover variable costs. Most likely, this situation would occur some time during the next five years. Thus the environmental control problems caused by second-grade mills might be solved by general economic conditions, which would induce the second-grade mills to cease production.

Similarly, employment effects would vary among the three categories of mills. No adverse employment effects are projected for the first-grade mills because there are no production curtailments foreseen as a result of pollution control. While there are no adverse employment effects associated with large second-grade mills meeting the 1977 requirement, there would be adverse effects meeting the 1979 requirement. As many as 60 employees could lose their jobs if all seven plants close.

Similarly, there are no adverse employment effects associated with small second-grade mills meeting the 1977 requirement, but there would be adverse effects meeting the 1979 requirement. As many as 260 employees could lose their jobs if all 65 plants close.

Thailand's balance of payments would not be adversely affected by the proposed effluent limitations because they would not significantly

LU6

affect the cost of production for 90% of industry capacity (first-grade mills). This statement is reinforced by the fact that factors other than export price, particularly Japanese tariff barriers, are more significant determinants of Thai starch purchased abroad.

Environmental control expenditures may affect growth by reducing profitability or by reducing the amount of capital available for expansion. This analysis is based on the assumption that, in most cases, the cost of environmental control could be passed on through price increases. Even if the industry (first-grade mills) could not pass on prices, they would expand if there were not excess capacity.

While the 1977 and 1979 effluent limitations would decrease the internal rate of return on investment from 26 to 20%, the rate would still be sufficiently high to attract new capital. This estimate would be low if the industry experiences another year like 1974 in which plant owners apparently repaid their capital investment in one year. Therefore, it is not anticipated that the proposed effluent limitations could deter expansion in a tight supply/demand balance, although in the short run, they might slow down addition to capacity.

Table 5. Current and Proposed Effluent Standards for Thai Tapioca Starch Industry

	Raw waste load		Current		Proposed[a]		
Sub-category	BOD mg/L	SS mg/L	BOD mg/L	SS mg/L	BOD mg/L	SS mg/L	Year
First grade	4500	2000	20-60	30-150	1800	360	1977
Second grade (large)	3500	1000	20-60	30-150	1400	180	1977
First grade	4500	2000	20-60	30-150	270	360	1979
Second grade (large)	3500	1000	20-60	30-150	1400	180	1979

Source: Unkulvasapaul (1975) and Parker (1971)

[a] These proposed effluent limitations are seen as averages of daily values for thirty consecutive days. There should be a maximum value for any one day, but data to make this estimate were not available at the time of the study.

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Benefits Estimates and Environmental Decision-Making

Excerpted, with permission, from OECD, ***Benefits Estimates and Environmental Decision-Making*** (Paris, 1992), chaps. 1-4 and 6.

Chapter 1

Introduction

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Benefit and damage estimation (BDE) involves the placing of money values on the gains and losses from economic activity. Benefit estimation has a long history in terms of activities such as valuing increases in agricultural productivity induced by water resource projects and time savings and losses in transportation projects, but it is of relatively recent origin in terms of environmental impacts. A number of surveys of both the theory and practice of BDE exist.[1] Still less researched is the way in which BDE is actually used in decision-making. This is the purpose of the current report. The aim is:

- to see how far BDE is actually used in government (central and local),
- what the experience of using it is,
- what the obstacles to its more widespread use might be, and
- and how wider adoption of BDE techniques might be encouraged.

The report builds on previous OECD work, notably a report on the available techniques and the results they have so far produced,[2] and a report on the use of BDE in six countries: USA, UK, Netherlands, Germany, Norway and Italy.[3] The six country studies have been supplemented here with a further OECD questionnaire carried out in 1990 in seven further countries: Sweden, Finland, Greece, Austria, Portugal, Turkey and Japan.

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[1] On the theory, see Freeman, A.M. (1979), ***The Benefits of Environmental Improvement***, Johns Hopkins University Press, Baltimore; Johannsson, P-O. (1987), ***The Economic Theory and Measurement of Environmental Benefits***, Cambridge University Press, Cambridge. On the practice, see Kneese, A.V. (1984), ***Measuring the Benefits of Clean Air and Water***, Resources for the Future, Washington D.C., and Pearce, D.W. and Markandya, A. (1989), ***Environmental Policy Benefits, Monetary Valuation***, OECD, Paris

[2] Pearce and Markandya, in OECD, 1989, *op.cit.*

[3] See Barde, J.Ph., and Pearce, D.W. (1991), *Valuing the Environment. Six Case Studies, Earthscan*, London, 1991

Chapter 2

Why Value Benefits?

BDE is controversial. It is important to understand what economists do when they 'value things'. Misconceptions about the purpose and nature of economic valuation account for the major part of the dispute between economists and non-economists.

Value, to the economist, resides *in people*. Value arises whenever a want or preference is satisfied. Value is lost whenever a 'negative want' or 'dispreference' occurs, i.e. there is dissatisfaction. Gains in value are also termed *benefits* and losses in value are termed costs. Values are instrumental, i.e. they are of and in people, *for* things. Traditionally, economists would have reserved this sense of the term 'value' to mean 'value in use' i.e. the capacity of something, when used, to satisfy a want or preference, as opposed to 'value in exchange', i.e. the worth of something in terms of its capacity to be exchanged for something else.[4,5] As we shall see, the term value in use is now somewhat misleading, since the same type of value—i.e. the capacity to satisfy wants—arises in contexts where use does not occur. A major part of the recent and substantial literature on valuation has been devoted to this 'non-use value' phenomenon. The process of *valuation* is then any procedure which uncovers or elicits instrumental values.

LU6

Instrumental value needs to be contrasted with *intrinsic* value which is regarded by ecological philosophers as being *in things*. There is a wide spectrum of opinion as to what class of things possess intrinsic value, as illustrated by the debates about the 'new naturalistic' ethics,[6] especially whether conscious things only have values, or non-conscious things do as well[7]. Typically, debates between advocates of one form of value or the other tend to assume that the pursuit of instrumental value is inconsistent with the protection of intrinsic values. By and large, this is because value in use is incompatible with much intrinsic value, e.g. the

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[4] The distinction between value in use and value in exchange was first developed by Aristotle in his *Politics* and was elaborated on by Adam Smith in his *Wealth of Nations*. Interestingly, however, Aristotle did not advocate the design of social systems according to the maximisation of value in use. Rather the *common good* could be achieved only by limiting wants and desires. Wants were relevant only in so far as some basic goods—agricultural goods and necessities—were concerned. Thereafter, denial of wants was necessary to achieve the common good. To some extent therefore, Aristotle advocated 'limits to growth', a viewpoint which some environmentalists find attractive to this day.

[5] The 'theory of value' in economics is, however, about the theory of determining value in exchange. Value in use is, of course, essential for exchange to take place, otherwise there would be no incentive for exchange. See Allingham, M. (1982), *Value*, Macmillan, London.

[6] See Turner, R.K., "Wetland Conservation: Economics and Ethics", in Collard, D., Pearce, D.W. and Ulph, D. (1988), Economics, Growth and Sustainable Environments, Macmillan, London.

[7] See Regan T., "The Nature and Possibility of an Environmental Ethic", *Environmental Ethics*, 1981, Vol. 3, pp. 19-34; and Naess, A., "The Shallow and the Deep Long Range Ecology Movement: A Summary", *Inquiry*, Vol. 16, No. 1, 1973, pp. 95-100.

use of land for development is inconsistent with the use of the land as a wilderness. But, as we shall argue later, the inconsistency is only partial. The extreme position taken by advocates of intrinsic value ends to rest on too narrow an Aristotelian interpretation of use values, ignoring the ways in which non-use values arise. These points will become more clear as we proceed.

Pursuing economic values as a goal is a value judgement. The implication is quite clear, i.e. that economic values rather than intrinsic values should be pursued. 'Justifying' one value judgement rather than another requires a meta-ethical judgement. Some factors relevant to this consideration are supplied later.

At the practical level, BDE matters for several reasons.

First, environmental services often have the appearance of 'free goods' because there are no obvious markets in them. Clean air is not directly bought or sold, for example. An implicit pricing of many environmental services emerges however through the regulatory system. As environmental standards are set, so polluters have to invest in abatement technology which raises their costs and the prices of the goods they produce. The environment ceases to be 'free' once environmental regulation occurs. Nonetheless, many environmental resources are not subject to regulation. The global atmosphere, for example, is not currently 'regulated' in respect of a number of important greenhouse gases such as CO_2, methane and nitrous oxides (it is regulated with respect to CFCs). The world's oceans are similarly treated as 'open access' resources, i.e. as being, to all intents and purposes, free. By placing values on the services of such environments societies come to learn that natural environments are not free goods—they have bounds to what they can provide. By not valuing them, there is a risk of perpetuating the 'free good' syndrome, and anything that is free tends to be over-used. Valuation then becomes part of the process of *correcting economic distortions* in the market place.

LU6

Second, valuation encourages consistency in decision-making. If there is no consistency in values, say about risks to human life, then there is a danger of over-allocating resources to, say, a health sector as opposed to a transport sector, and so on. Once again, the valuation process is part of a wider process of correcting economic distortions.

Third, valuation can frequently serve the quasi-political end of demonstrating that natural environments matter. This is an extension of the first observation. It is easy to ignore environmental impacts if they are thought to be unimportant, and 'importance' is often best demonstrated by putting environment on the same economic footing as the benefits of economic development, i.e. by using money values.

Fourth, valuation measures preferences. It is therefore inherently 'democratic', although, as is well known, measuring preferences through willingness to pay means that the recorded measures are weighted by income (as are market prices). Ignoring valuation approaches does not mean that preferences are ignored, but using valuation techniques does mean that individuals' preferences are more likely, rather than less likely, to be integrated into the process.

Overall, the rationale for monetary valuation lies in the search for *economic efficiency*. Valuation assists that process. It also raises the profile' of environmental concerns by placing environment on an equal footing with other values, e.g. development values.

Chapter 3

Basic Concepts in Benefit Estimation

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This section and annex 1 briefly review the central concepts in benefit estimation. More extensive treatment is to be found in the surveys of the theory of BDE (see footnote 1).

The basic cost-benefit decision rule is that a project, policy or programme is acceptable in economic efficiency terms if the total benefits generated over time are greater than the total social (land, labour, capital and environmental impacts) costs incurred over the same time horizon. Both cost and benefit streams are discounted by an appropriate rate of discount and the result is usually expressed as a net present value number, or a discounted benefit-cost ratio. Positive net present values and benefit cost ratios >1 signify economically efficient projects, policies or programmes.

Take a development decision that involves displacing an alternative land use, as well as the generation of environmental pollution. Imagine a port and marina complex is scheduled and that it is to be sited so that it intrudes into an environmentally valuable wetland area. An important question to answer is what exactly does society lose if the wetland is damaged or displaced completely. It turns out that what we need to know is the total economic value of the foregone wetland resource. Total economic value is the sum of all economic values. All economic values are either use values (e.g. walking, birdwatching, rambling etc. in the wetland undertaken by visitors and residents) or existence values (e.g. residents and visitors may value the wetland quite independently of any use they make of it, as indeed might non-resident, non-visitors).

The possible loss of both wetland use and existence values, as well as any pollution impacts should all be taken into account in any benefit-cost appraisal of the port and marina project. Only if the project benefits outweigh all these combined social costs can the project be said to be economically efficient.

In the real world there is often the further complication of uncertainty. In the environmental context there will be uncertainty about the continued availability of the environmental asset in question. It is not clear how much damage some wetlands can sustain before they are effectively lost altogether. Alternatively the prospects for wetland restoration or new wetland creation are difficult to judge. It is also the case that we cannot be sure now whether an individual expressing a valuation may still 'demand' the commodity at the time of use in the future.

The incorporation of uncertainty into the benefit-cost procedure is not a straightforward matter. But a majority of analysts have argued for the recognition of a further value concept, option value. In certain conditions this value is related to a kind of 'insurance premium' that individuals are prepared to pay in order to retain the option of future use of an environmental asset.

The basic cost-benefit model (CBA) can therefore be extended to include estimates of expected use values, option value, existence value relating to a given environmental asset, plus pollution damage costs. It is the total sum of all these costs that must be weighed against the project benefits, if the economic efficiency status of the project is to be established.

Chapter 4

Valuation Techniques

This section offers a very brief overview of the available techniques for BDE. Full expositions are available elsewhere.[8]

Four different methodologies have been suggested for securing money measures of environmental benefits/damages in the absence of markets:

a) Identification of Surrogate Markets (Revealed Preference Approaches)

This method requires finding a market in some other good or service which is influenced by the non-market environmental good. Taking the property market as an example, one of the factors influencing this decision to buy or sell may well be the level of air pollution in the neighbourhood, or the level of noise, or proximity to waterfrontage, or changes in aesthetic surroundings, or some combination of factors. The so-called *hedonic* price method and technique therefore seeks to identify the inferred preferences of individuals for environmental quality via an analysis of the housing market.

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[8] See Pearce, D.W., and Markandya, A. (OECD, 1989) and Johannson, P.O. (1987) *op.cit.* On contingent valuation, see Mitchell, R. and Carson, R. (1989), *Using Surveys to Value Public Goods*, Resources for the Future, Washington, DC

Another revealed/inferred preference approach, the travel cost method, has been tested in the recreation context. The extent to which individuals' willingness to spend time and incur costs travelling to a recreation site has been used to infer their valuations.

b) Market 'Creation' via Questionnaire-Based Methods (Stated/Expressed Preference Approach)

Individuals are surveyed and asked directly what they are willing to pay or willing to accept in compensation for environmental gains and losses. The contingent validation method (CVM) offers much promise as long as individual responses in the survey can be relied upon, with some acceptable margin of error, to reflect what their values would be if a real world market existed. It may also be possible to use CVM to model aspects of public preference expression, by reflecting what values would be in real world situations involving taxes and rates payments made by households.

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c) Dose-Response Data Linked to Valuation

The first stage in this approach is the identification of a *dose-response relationship*, i.e. a connection between some level or change in pollution and observable physical/biological changes (especially damage) in the ambient environment. Thus, one could model the relationship between air pollution and vegetation damage, or erosion of building surfaces. The value of the damage (damage cost) done could then be approximated by looking at the monetary cost of crop loss (adjusted for taxes and subsidies), or accelerated replacement or repair of buildings (market prices). A related method, the ***alternative cost method***, investigates what 'defensive' expenditure would be necessary to remove the environmental damage impact in question, i.e. expenditure on double glazing to reduce external noise nuisance inside buildings.

In cases where "critical natural capital assets" are threatened by development projects some investigations of potential substitutions seems sensible.[9] Valuable habitats threatened with destruction or quality deterioration because of development may be replaceable. There may be degraded habitats elsewhere in the region which could be restored, or alternative habitats may be artificially created. It is even possible that a habitat could itself be transferred to a new site.[10] If an environmental standards (sustainability constraints) approach is adopted then the analyst would be required to quantify the expenditure necessary to satisfy the constraint (e.g. cost of some substitute for the threatened environmental asset, known as the 'shadow project'). This expenditure would have to be incurred if the development project were to go ahead.

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[9] Pearce D.W., Markandya, A. and Barbier, E.B. (1989), *Blueprint for a Green Economy*, Earthscan, London.
[10] G.P. Buckley, ed. (1989), *Biological Habitat Reconstruction*, Belhaven Press, London

If adequate substitutes are not available then the sustainability constraint becomes binding. The social opportunity costs of foregoing the development option will then have to be balanced against the loss of the environmental asset.

d) Public Preference Identification

Identification of public (social) preference values, as reflected in social norms, rules, regulations and legislation. Proxy measures of public preference value may be reflected by expert opinion and/or political weights. The European Community's Environmentally Sensitive Area payments to farmers and management agreement payments (adjusted for management costs), for example, could be interpreted as crudely indicating the social value of environmental conservation.

e) Hypothetical/Indirect Approach to Valuation

These methods are based on procedures in which individuals are asked to respond to hypothetical market situations, but their responses are only indirectly related to valuing the environmental good in question. Among the methods in this category are contingent ranking and the priority valuation technique.

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Contingent ranking (CR) can be combined with other methods. CR and travel cost (TC) methods can be used to value a proposed recreation site. Under a hypothetical TC method respondents might be asked how far they would drive to use such a site. Under the CR method, they would then be asked how they would rank a set of sites with different attributes. The assumption in this two-stage approach is that respondents are better able to give meaningful answers to related behaviour questions than they are to direct valuation questions.

Methodologies *a)* and *b)* are sometimes referred to as Direct Valuation Methods and techniques and *c)* and *d)* as Indirect Valuation Methods and techniques.

Chapter 6

The Purpose of Benefit Estimation

Benefit estimation involves the use of monetary values to indicate the social worth of an environmental improvement or the social cost of environmental damage. Benefit and damage estimation are obverses: a benefit can be thought of as reduced or avoided damage. Damage, or cost, can be thought of as a foregone benefit.

Although BDE has primarily been developed in the context of cost-benefit analysis, its uses are broader. Table 1 illustrates these uses in terms of:

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- stimulation of environmental awareness. e.g. of the scale of environmental damage or gains;
- influencing decisions. At one extreme, decisions might be made wholly on the basis of BDE compared to costs. At the other, decisions might be only marginally influenced by BDE;
- identifying decisions, i.e. establishing what type of decision should be made;
- justifying decisions, either ex ante, before a decision is made, or ex post after a decision is made and support for it needs to be found.

Table 1 suggests various levels where BDE is used. These are:

- policy choice—i.e. the use of BDE to establish the importance of environmental policy relative to other policy areas;
- regulation—i.e. the use of BDE in an analysis of the desirability of a given regulation or the degree of regulation;
- project appraisal, as in the cost-benefit analysis of projects.

The "cells" in the matrix in table 1 have been completed on the basis of an analysis of the six case studies of benefit estimation plus seven further less-detailed questionnaires.

Table 1. Functions and Levels of Benefit Estimation

Function Level	Stimulates Awareness	Influence Decisions	Identify Decisions	Justify Decisions
Policy	Yes	Possible	Unlikely	Unlikely
Regulation	Yes	Likely	Possible	Possible
Project	No	Yes	Likely	Likely

In addition to the general functions illustrated in table 2 BDE assists in integrating environmental concerns into other policy areas. Thus, all economic policies impact on the environment and BDE assists in ensuring that environmental impacts are properly accounted for in policies which are not ostensibly concerned with the environment—e.g. industrial and agricultural policy, regional development, energy policy etc.

BDE also contributes to the consistent treatment of environmental gains and losses across sectors. Thus the "weight" given to a defined environmental impact should be the same regardless of the sector in which that impact occurs.

Finally BDE is an integral part of policies to secure sustainable development. Ultimately, sustainable development is about underscoring the importance of environmental stocks and quality in securing balanced economic progress. As long as environmental assets are treated as if they had zero prices, the environment will be abused and resources will be wrongly allocated within the economy To secure a proper balance between environmental and man-made assets it is essential to place the environment's economic functions on a comparable basis to other economic functions. This is an important feature of sustainable development and BDE contributes to the process of ensuring comparability. Table 2 shows more detail of countries' responses.

Table 2. What is the Purpose of BDE?

	AUS	POR	NETH	NOR	JAP	G	GRE	UK	FIN	USA	ITA	SWE
To stimulate awareness	X		X	•	(X)	X	(X)		X	•		
To justify a decision	X	X	X	X	(X)	X	•	X	X	X	X	
To evaluate regulations	X	X		X	(X)		(•)			X		
To indicate relevance to macroeconomic objectives	X				(X)	(•)	(•)				X	
To determine compensation									X			

KEY:

AUS	= Austria	X	= yes
NETH	= Netherlands	(X)	= yes, to some extent
NOR	= Norway	•	= moderate use
G	= Germany	(•)	= limited use
UK	= United Kingdom		
FIN	= Finland		
USA	= United States		
ITA	= Italy		
POR	= Portugal		
TUR	= Turkey, no responses to this question		
JAP	= Japan		
GRE	= Greece		

On the basis of the six detailed case studies the following general observations may be made about BDE in OECD countries.

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- BDE is more extensive than might be thought from casual observations (see table 3);
- the use of BDE is increasing;
- its use is increasing in countries where legislation mandates or permits its use and in countries where there is no decision-making framework which particularly favours BDE;
- BDE influences policy on the environment through the stimulation of awareness, but is limited in its direct use for determining environmental policy;
- the use of BDE in project appraisal is increasing;
- BDE is used in some countries to evaluate regulations;
- techniques for more reliable BDE are improving;
- while environmental impact assessment (EIA) procedures exist in countries, BDE is not generally part of EIA;
- BDE has covered both "hard" values (e.g. changes in crop yields, building corrosion etc.) and "soft" values (e.g. aesthetic preferences)—see tables 4 and 5;
- "hard" values have more acceptability to decision-makers than "soft" values because of concerns over accuracy, limited capability to comprehend soft valuation procedures, and concerns that some issues are not susceptible to BDE (e.g. "human life," some nature conservation), and concerns that BDE fails to capture legitimate social objectives concerning future generations;
- some objections to BDE are "political" due to the potential of BDE to force a more open statement of alternative values; political "reluctance" is also due to the lack of knowledge about BDE techniques and results;
- the costs of performing BDE are not (generally) an obstacle to BDE, but time taken is a factor;
- BDE is seen as a contributing factor in the "fusing" of economics and ecology.

Table 3. The Use of BDE in Selected OECD Countries

	GRE	JAP	SWE	NETH	NOR	TUR	G	AUS	UK	POR	USA	ITA	FIN
Wide	-	-	-	-	-	-	X	-	-	-	X	-	-
Medium	-	-	-	X	X	-	-	-	X	-	-	X	-
Limited	X	X	X	-	-	-	-	X	-	X	-	-	X
Nil	-	-	-	-	-	X	-	-	-	-	-	-	-

Source: OECD

Table 4. Type of Benefit or Damage Measured+

	FIN	NETH	NOR	SWE	G	UK	GRE	USA	ITA	AUS	POR
User values:											
(a) Direct use											
- market/ shadow prices	X	X	X	X	X	X	X	X	X	X	X
- option values	X	(X)	X	X	X	(X)	-	X	-	X	X
(b) Indirect use											
-ecosystem function	-	(*)	-	X	-	(*)	-	(X)	-	-	-
Non-use values											
- existence	-	(X)	X	X	X	(X)	-	X	-	-	X
- bequest	-	(X)	X	-	X	-	-	X	-	-	-

+Japan and Turkey produced a nil return on this question

Note: All countries indicated expectations of more extensive benefit and damage estimation in the future.

Source: OECD

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Table 5. Areas of Application of BDE

	SWE	NETH	NOR	FIN	G	UK	AUS	USA	POR	ITA	JAP
National Damage Estimate	-	X	-		X	-	(•)	X	(•)	-	
Specific Pollution Damage											
-air	(•)	X	X	•	X		-	X	•	-	x
-water	(•)	X	X	X	X	X	-	X	•	X	
-soil/land	-	-	-	(•)	X	(•)	-	X	•	X	-
-toxics	(•)	(X)	-	•	-	-	-	X	(•)	-	-
-noise	-	X	X	(•)	X	(•)	-	(X)	-	X	-
-waste	-	X[1]	-	(•)	-	-	-	X	•	X	-
-oil spills	-	-	-	(X)	-	-	-	X	•	-	-
-other	-	-	-		sea defence	-	-	-	-	-	-
Resource Concerns:											
-wetlands	-	-	-	•	-	X	•	X	-	-	-
-forests	X	-	-[2]	(X)	X	(X)	X	X	•	X	-
-coastal zones	-	-	-	(X)	-	-	-	X	(X)	X	-
-wildlife/nature	•	-	X	•	X[3]	(•)	(X)	X	-	X	-
-fish stocks	(•)	-	X	(X)	•	-	-	-	-	-	-
-recycling	-	X	-	•	-	X	(X)	-	(•)	X	X
Risks:											
-'life'	-	-	-	(•)	-	X	-	X	-	-	
-pollution	-	-	-	•	-	-	-	X	-	-	
-ecological	-	-	-	(•)	-	(•)	-	X	(•)	-	

Source: OECD
1 agricultural waste
2 under way
3 in the near future

Case Study of the Use of Benefit-Cost Analysis in Decision-Making: Lead in Gasoline

Under Executive Order 12291 of 1981 in the USA, government agencies were required to use 'Regulatory Impact Analysis' (RIA) and to adopt regulatory processes that would maximize 'the next benefits to society'. The Order was the first to establish the net benefit objective as the criterion for adopting regulatory processes, although its adoption has been circumcised by existing laws relating to other objectives.

Benefit-cost analysis played an important role in the adoption of regulations concerning lead in gasoline. Ambient lead concentrations were thought to be linked to serious health effects, including retardation, kidney disease and even death. The Environmental Protection Agency conducted a benefit-cost study with the results shown in Table 6.

The regulation involved reducing lead in gasoline from 1.1 grams per gallon (gpg) to 0.1 gpg. The costs of the rule are shown as 'total refining costs'. Refinery costs increase because lead has traditionally been used to boost octane levels in fuel, and other means would have to be found to achieve this. The benefits included: LU6

- improved children's health;
- improved blood pressure in adults;
- reduced damages from misfuelled vehicles, arising from hydrocarbon, NO_X and CO emissions;
- impacts on maintenance and fuel economy.

Children's health. The EPA study found that blood lead levels closely tracked trends in gasoline lead. Medical costs for the care of children would be reduced by reducing lead concentrations, and there would be less need for compensatory education for IQ-impaired children. These savings are shown as 'children's health effects' in Table 6.

Adult blood pressure. Blood lead levels were thought to be associated with blood pressure and hypertension. Medical costs would be saved if these illnesses could be reduced. Moreover, some heart attacks and strokes would be avoided. A value of a 'statistical life' of $1 million was used for the latter. The resulting values show up in the 'adult blood pressure' row of table 6. They are seen to be high because of the involvement of mortality-avoidance in this benefit.

Other pollutants. Reducing lead in gasoline also reduces other pollutants. This is because making unleaded fuel the 'norm' reduces the risk of 'misfuelling'—i.e. using leaded fuels in vehicles designed for unleaded fuels. The mechanism whereby misfuelling is reduced is through the higher cost of leaded fuels at the new low-lead concentration. This deters drivers from purchasing the leaded fuel. As misfuelling is reduced, so emissions of HC, NO_x and CO are reduced. Damage done by these pollutants was estimated by studies of ozone pollution damage (ozone arises from HC and CO emissions), but estimates were also made of the value of the equipment destroyed by misfuelling. The figures appearing in the row 'conventional pollutants' in table 6 are in fact an average of the two methods.

Maintenance and fuel economy. Maintenance costs for vehicles were expected to fall due to reduced corrosive effects of lead and its scavengers on engines and exhaust systems. Fewer engine tune-ups and oil changes would be needed, exhaust systems would last longer. Fuel economy was expected to rise as the new technologies to raise octane levels to what they were previously also increase the energy content of fuels. There would also be reduced fouling of oxygen sensors. Maintenance benefits outweighed fuel economy benefits by around 6 to 1. The totals are shown in table 6.

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Table 6. Year-by-Year Costs and Monetized Benefits of Final Rule, Assuming Partial Misfuelling (Millions Of 1983 Dollars)

	1985	1986	1987	1988	1989	1990	1991	1992
Monetised benefits								
Children's health effects	223	600	547	502	453	414	369	358
Adult blood pressure	1,724	5,897	5,675	5,447	5,187	4,966	4,682	4,691
Conventional pollutants	0	222	222	224	226	230	239	248
Maintenance	102	914	859	818	788	767	754	749
Fuel economy	35	187	170	113	134	139	172	164
Total monetised benefits	2,084	7,821	7,474	7,105	6,788	6,517	6,216	6,211
Total refining costs	96	608	558	532	504	471	444	441
Net benefits	1,988	7,213	6,916	6,573	6,248	6,045	5,772	5,770
Net benefits excluding blood pressure	264	1,316	1,241	1,125	1,096	1,079	1,090	1,079

The net benefits from reducing lead in gasoline are seen to be substantial, even if the blood pressure benefits (which dominate the aggregate benefits) are excluded. Indeed, inspection of table 7 shows that the regulation would be worthwhile ***even if all health benefits are excluded***. In the event, the blood pressure benefits were excluded from the final decision because the research establishing this link was judged too recent to permit adequate review. The lead regulation was also of interest because of the introduction of a 'lead permits system' to reduce the financial burden on the refining industry. Essentially, this allowed 'lead quotas' to be traded between refiners. Refiners who found it easy to get below the limit were allowed to sell their 'surplus' lead rights to refiners who found it expensive to get back to desirable octane levels without lead. The particular feature of the lead-in-gasoline benefit-cost study that made it a powerful aid to decision-making was the clear-cut nature of the net benefits even when uncertainties about benefits were allowed for. But it was also executed carefully and in comprehensive detail. As Portney (1990)[11] puts it: "It is important to realize that in spite of the difficulties that arise, benefit estimation is a useful input in policy making when used carefully".

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[11] Portney, P., "Air Pollution Policy", in Portney (ed.) *Public Policies for Environmental Protection*, Resources for the Future, Washington, D.C. See also USEPA, EPA's *Use of Benefit-Cost Analysis 1981-1986*, EPA 230-05-87-028, Washington, D.C., August 1987.

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Macroeconomic Modeling Techniques

Excerpted, with permission, from OECD, *The Macroeconomic Impact of Environmental Expenditure* (Paris 1985), pp. 8-12.

Macrosimulation models start with small units, evaluating the effect of a policy change on individual households or businesses, and work up, tracing the effect of those responses on changes in demand, product and prices. In contrast, macroeconomic models work from the top down. A system of aggregate relationships is specified, and the ways in which a policy change may effect one or more important variables in the system are identified.

Macroeconometric models, usually based on some form of Keynesian economic theory, start estimating aggregate variables, such as Gross Domestic Product (GDP) or total employment. They also break the variables down into their component parts. GDP, for example, can be broken down into consumption, investment, imports, exports and government spending. Consumption and investment are in turn linked to such variables as income, interest rates and profits. Relationships between industries are often described by an input/output matrix, and the level of employment is determined by the demand for labour from the productive sectors, and by the amount of labour supplied by various categories of workers. The model may include a financial sector, and sets of estimated equations, to show the effect on prices of changes in production costs and the amount of utilised capacity.

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Evaluation of Environmental Regulations in OECD Countries

Summary of Findings

Since the early 1970s, a number of OECD-member countries have been developing macroeconomic modelling capabilities, and using these capabilities to assess the economic impact of their pollution control programmes. These assessments try to quantify the direct and indirect effects that environmental programmes might have on the major macroeconomic variables in each country. The first studies in this area, reviewed in an earlier OECD report[1], were carried out at a time when the economies of most member countries were operating at close to full capacity. They therefore tended to stress the unfavourable short-term effects which

[1] Source: *The Macro-Economic Impact of Environment Expenditure*, OECD (1985)

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pollution control programmes were likely to have on inflation and on international competitiveness.

The changed economic circumstances prevailing at present in most OECD countries suggest that a somewhat different emphasis may be more appropriate. In addition to the continuing interest in price and balance of payments effects, policy-makers may also wish to know what impact environmental expenditure may have on employment trends and on longer-term growth of productivity and output.

The present report summarizes the results from recently completed modelling in six countries—Austria, Finland, France, the Netherlands, Norway and the United States. A summary of the results, which are displayed in table 1, is given below:

- The effects of increased pollution control expenditures on the growth of output are indeterminate. The range of results suggests that the level of GDP in the final programme year could be either higher (1.5 per cent over 10 years in the case of Norway) or lower (1 per cent over 18 years in the case of the United States), with most results showing intermediate values.

- The effects on inflation would appear to be slightly unfavourable. In virtually all countries, the programmes boost consumer prices: in some cases the increase over the period would be as much as 5 to 7 percentage points, equivalent to an average annual increase of about 0.3 to 0.5 percentage points.

- Conversely, employment is stimulated. With few exceptions, unemployment levels are reduced by pollution-control expenditure, particularly under some variants in the United States, France and, especially, Norway. The counterpart of this result is an implicit worsening of productivity growth (output per unit of labour). This occurs because GDP growth rates are either somewhat lower, or only slightly higher, than they otherwise would have been, while labour input increases because of environmental measures.

- Developments through time suggest that the initial impact of environmental expenditures is more favourable than the long-term effects. In the short-term, increased investment in pollution control equipment boosts output and activity. Over the longer-term, however, lower profits and/or higher prices erode some or most of the short-term gains.

While these various results are of interest in their own right, the main conclusion which emerges from them is that the macroeconomic effects of environmental policies are relatively small. Most of the figures reported—with the exception of some of the results for consumer price inflation—are in the range of a few tenths of a percentage point per year. Furthermore, it is important to recall that these small effects were registered during a period (the 1970s) of peak pollution-control activity, when efforts were directed not only at limiting on going pollution, but also at clean ing-up the backlog caused by neglect of the environment during the 1950s and 1960s.

This general conclusion on the relatively minor estimated impact also suggests that pollution control measures were not a major cause of the slowdown in productivity growth of the 1970s, as has sometimes been argued. By the same token, environmental measures are not likely to be a major constraining factor in a more expansionary strategy for the 1980s.

Table 1. Effects of Additional Environmental Programmes on Selected Economic Variables

(Range of differences between level with and without environmental programmes)

	Effects on:					
	GDP		Consumer Prices		Unemployment	
	First year	Final year	First year	Final year	First year	Final year
	(percentage points)				(thousands)	
Austria	..	-0.6 0.5	..	0.4/1.7 (a)	..	
Finland	0.3	0.6	0.2	0.2	-3.5	-7.5
France	-	0.1 0.4	-	0.1	-0.2/-1.1	-13.2/-43.5
Netherlands	0.1	-0.3 -0.6	0.2 0.4	0.8 4.3	-1.4/-2.3	-3.8/6.9
Norway		1.5		0.1 0.9	..	-25.0
United States	0.2	-0.6 -1.1	0.2	5.0/6.7	-80.0	-150.0/-300.0 (b)
Memorandum items (c)						
Italy	..	-0.2 0.4		0.3 0.5	..	..
Japan	1.2 2.6	0.1/0.2 (d)	-	2.2 3.8	(lower)	(lower)

(a) GDP deflator.
(b) Partly estimated by Secretariat.
(c) Published in earlier OECD report.
(d) For period as a whole, suggesting negative results for final year.
.. = Not available
\- = Nil

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Benefit-Cost Analysis for the Ismailia Waste-Water Project

Excerpted from R. Luken, "Benefit-Cost Analyses for the Ismailia Waste Water Project", United States Agency for International Development (Washington, D.C., 1987).

Introduction

Statutory Versus Legal Mandates

The usual justification for building waste water treatment facilities is a statutory mandate. Public Law 48 of the Government of Egypt (GOE) requires that domestic waste be treated to meet discharge standards of 40 mg l of Biological Oxygen Demand (BOD) and 50 mg/l of Total Suspended Solids (TSS). Similarly, Public Law 92-500 of the U.S. requires treatment to meet discharge standards of 30 mg/l of BOD and 30 mg/l of TSS. At least in the case of the U.S., there are exemptions from these standards where holding lagoons are feasible, usually in rural areas, and where ocean discharge is feasible. In these cases the standards are not as stringent because holding lagoons are an adequate form of treatment and ocean discharge usually does not result in serious environmental deterioration.

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For many nations, the transition from uncontrolled to controlled discharge of waste water is viewed as a benchmark of progress. Substantial resources are often devoted to this effort, at the expense of other programs, without the benefit of detailed economic and environmental analyses.

Much of the emphasis placed on improved management of human wastes is related to concerns over the relationship between basic sanitary conditions and public health. Economic assessments of the benefits are problematic, due to uncertainties regarding the quantification of health effects and valuation of changes in morbidity and mortality. These problems are compounded in developing countries because of scarcity of data. Nonetheless, sufficient information is available that an attempt at a quantitative economic evaluation is possible.

Methodology

The study examines the economic benefits of building a waste-water treatment plant in Ismailia, Egypt. It first characterizes the environmental situation there with and without the water and waste-water projects and then estimates the potential benefits.

The benefits assessment is conservative. It is only the annual benefits anticipated in 1995 when these facilities will begin operation rather than levelized annual benefits. Levelized annual benefits would account for the growth in benefits over the 30 year life of the projects because it is an average over 30 years rather than benefits in year one of the project. Levelized annual benefits were not calculated because no reasonable data were available to make 30 year projections.

Ismailia Waste-Water Project

Introduction

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The city of Ismailia is located on the north and west shore of Lake Timsah, which is an integral part of the Suez Canal. Lake Timsah is a relatively shallow saline waterbody of 12 km^2. The present waste-water treatment plant discharges untreated waste into the West Lagoon area of the lake. The proposed waste-water treatment facility would be a new land disposal system that would eliminate domestic waste-water discharge into the lake.

The population of Ismailia was estimated at 300,000 in 1985 and is projected to reach 470,000 in 1995.

Existing and Proposed Uses of Lake Timsah

Current Uses of Lake Timsah

The lake provides opportunities for recreational swimming, boating and fishing. Swimming beaches are currently on the northwest shore, south shore and north end of the lake. The lake is used for sailing, rowing and power boating with docking facilities concentrated on the north shore. Recreational fishing takes place throughout the lake, west lagoon and the drains entering the system, such as El Mahsama Drain. Total recreation use in 1987 is estimated at 750,000 - 1,000,000 recreation days with 80 to 90% of the users coming from Cairo.

Finfish, shellfish and crustaceans are harvested commercially, providing the main source of income for a number of area residents. The commercial catch in 1965 was 352 t, consisting primarily of mullet (170 t), loot (76 t) and shrimp (59 t), and the value of the catch was LE 763,800 (LE 1986).

The high aesthetic quality of Ismailia is due largely to Lake Timsah. This quality makes passive use such as walking, sitting and relaxing extremely important. The presence of a presidential retreat on the north shore also attracts attention and visitors to the area.

Finally, an important use of the lake system is the topic of this evaluation, namely, as the receiving waters for waste water generated in the area. The waste-water treatment plant discharges to the lake via El

Mahsama Drain. Raw waste water, originating from unsewered areas or overflows in the sewer system, is also discharged to the lake.

Proposed Uses of Lake Timsah

Major studies have outlined specific proposals for the future uses of the Ismailia area and Lake Timsah. These are the Ismailia Master Plan.[1] and the Tourism Development Plan for the Suez Canal Zone.[2] The Suez Canal Authority has also proposed specific future uses for portions of Lake Timsah.

The Ismailia Master Plan proposes a number of uses for the lake which are anticipated to become integral and essential elements in the future development of the city.[3] In general the plan recommends maximum utilization of Lake Timsah to promote domestic tourism and recreation.

The Ismailia Master Plan recommends use of the lake's aesthetic quality through development of walking and sitting areas to enjoy visits of the lake. Development of properties with views of the lake is proposed. This development includes day cabins, hotel sites, casinos, apartments, restaurants, and walking paths on the west bank of Lake Timsah. Potential hotel sites are identified on the west end of Chevalier Island and the west bank of the Suez Canal on the north end of the lake. The expansion of active forms of recreation including swimming, rowing, sailing, and water-skiing is recommended. Also proposed is expansion of the lake's commercial fisheries.

The Tourism Development Plan recommends extensive use of Lake Timsah for recreation and tourist-related activities. The tourism plan recommendations center on international tourism in contrast to the prime consideration given to domestic tourism in the Master Plan. The tourism plan, like the master plan, proposes the west shore of the lake for extensive development. The study calls for an international hotel and beach facilities at this location. The report considers extensive domestic and possibly international tourism and recreational development on the east bank of the lake.

The Suez Canal Authority (SCA) has proposed uses for the Lake Timsah system which could affect existing conditions in the lake.[4] The SCA is presently straightening the navigation channel through Lake Timsah. When this work is completed, the existing channels and portions of the lake will be used as an anchorage for canal traffic. The SCA also

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[1] Culpen and Partners (1976), "Ismailia Master Plan Study" (Arab Republic of Egypt, Funded by UNDP).

[2] Ismail, Professor Dr. Hassan and Partners, et al., *Tourism Development in the Suez Canal Zone*, (Arab Republic of Egypt, United Nations Development Program, Draft Final Report, 1973).

[3] Metcalf and Eddy, "Ismailia Waterworks and Waste Water Facilities Master Plan", (Arab Republic of Egypt, Funded by USAID 1979)

[4] Metcalf & Eddy, Vol 6, Appendix Q

has long-range plans for constructing a new navigation channel which would bypass Lake Timsah. A navigation connection between the lake and the canal would be maintained to allow for ship anchorage in the lake and canal-related maintenance activities.

Water Quality Problems

Past investigations indicate that overall water quality in Lake Timsah is good. However, there are areas with the potential for creating both immediate and long-term water quality problems. Both the in-depth quality survey in 1978[5] and the 1986-87[6] data show several areas with fecal contamination (fecal coliform concentrations in excess of 1,000/100 ml, which is the WHO standard for contact recreation). The area of immediate concern is the northwest shore of Lake Timsah. The north and south shore, as well as the west Lagoon, are all areas with potential water quality problems given the anticipated increase of waste-water discharge.

LU6

Economic Evaluation

The economic evaluation is based on anticipated use patterns of Lake Timsah in 1995. One pattern assures building of the waste-water treatment plant and elimination of fecal contamination of Lake Timsah. As a result recreation use and tourism development will occur as anticipated by the Department of Tourism. The other pattern assumes that the plant is not built and that Lake Timsah becomes polluted to the extent that recreation activities and tourism development are discouraged. The economic benefits of the project are the differences between the two patterns.

The potential economic benefits fall into four categories: recreation use, recreation related illness, amenity value and commercial fishing.

Recreation Use

An estimate of recreation benefits must be based on the predicted level and value of recreation activities. The Department of Tourism provided their best estimates of future use of Lake Timsah for recreation. With no significant pollution of the lake, recreation use is projected to be 1,500,000 visitor days in 1995. Without the project, recreation use is projected to be 500,000 visitor days.

To value each user day, two techniques are used. The first is a simple travel cost model. The underlying idea of this technique is to use information on the amount of money and time that people have spent in getting to a recreation site to estimate their willingness to pay for the experience.

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[5] Metcalf & Eddy, Vol 6, Appendix Q.

[6] Governorate of Ismailia, Department of Health, (1987)

The application of the technique here estimates the willingness to pay on the assumption that users of Lake Timsah come from either Cairo or Ismailia. The direct costs for recreationists from Cairo for a day trip to the lake amount to roughly LE 11-12 per user (LE 4-5 for round trip transportation costs[7] and LE 6 for the value of time[8]). The direct costs for recreationists from Ismailia is zero.

The consumer surplus for recreationists without maintaining water quality in Lake Timsah is LE 3,500,000 (table 1). The consumer surplus per visit is LE 7.00. The consumer surplus for recreationists with the maintenance of water quality is LE 16,500,000 (table 2). The consumer surplus per visit is LE 11.00.

Table 1. Lake Timsah Travel Cost Calculations —Without Project

Origin	Visits	Population	Per capita visits	Travel cost
Cairo	450,000	12,000,000	0.04	11.00
Ismalia	50,000	400,000	0.13	0.00
Consumer surplus (LE):		Total	3,500,000	
Consumer surplus (LE):		Per visit	7.00	

Table 2. Lake Timsah Travel Cost Calculations —With Project

Origin	Visits	Population	Per capita visits	Travel cost
Cairo	1,400,000	12,000,000	0.08	11.00
Ismalia	100,000	400,000	0.25	0.00
Consumer surplus (LE):		Total	16,500,000.00	
Consumer surplus (LE):		Per visit	11.00	

1 US $ = LE 2.18 (June 1987)

An alternative estimate of the value of a day of recreation may be obtained by utilizing estimates derived in the U.S. Several studies have derived reliable estimates of the average consumer surplus of a day of recreational fishing. These values range from roughly $25-to $35 per day

[7] The round trip travel expenses range from 400-500 piasters (pt) per person. The 400 pt is based on the cost of a round trip bus ticket from Cairo to Ismailia. The 500 pt is based on travelling in a private car for 250 km at 10 pt per km with 5 people in the car.

[8] According to the Department of Tourism, 20% of the Egyptian population takes a vacation and recreation day trips from home. The average household income for this 20% of the population in 1986 is estimated at LE 3,000 year. Thus, the weekly income is LE 58.00 and the hourly income assuming 40 hours, is LE 1.45/hour. Assuming 2 hours travel time in each direction, the value of travel time is approximately LE 6

LU6

($1982) depending on the desirability of the species sought. Evidence on the willingness to pay for swimming are less reliable, but indicators are that a day at the beach is valued at least as highly as a day of fishing.

It would be inappropriate to assert that a typical Egyptian values a beachday as much as an American because the standard of living is significantly different between the two countries.

However, a meaningful comparison can be made by relating leisure values (such as for recreation) to income. In the U.S. average weekly earnings are between $275-$300. Therefore a day of water based recreation is valued at roughly 10% of the weekly gross earnings of the average worker ($30/$287).

A reasonable assumption is that a comparable recreation experience in Egypt is valued at the same rate relative to local earnings. As indicated in an earlier footnote, the average weekly earnings for those likely to participate in recreation activities is LE 58.00. Applying the leisure value income ratio described above, a value of LE 6.10 per recreation day is derived (10.5% x LE 58.00). It is important to note that this value of a day of water contact recreation applies to all users, not just workers. Earnings have simply served as a metric by which to gauge relative values. This value is consistent with the consumer surplus value derived with the simple travel cost method under the without project scenario.

In addition, the recreation benefits should reflect more than the use value to those who recreate in Lake Timsah. There are intrinsic or non-use benefits (existence of resources in pristine conditions and bequest for future generations), due to preserving water quality. In the U.S. several studies have found that total non-use benefits amount to roughly half the recreation benefits. In a developing country such as Egypt, existence benefits are a smaller percentage of the total value of environmental improvement, due to income effects and cultural attitudes. Therefore, a reasonable assumption is that existence/bequest values would equal 10% of the recreation values. Moreover, this value applies only to the recreation benefits associated with the project given that the project would maintain satisfactory water quality in the lake.

In summary, the values for recreation use are estimated at LE 3,500,000 for the without project scenario and at LE 16,500,000 for the with project scenario. The total recreation value for the with project scenario would be slightly higher if existence/bequest values were included in the analysis.

Recreation-Related Illness

An estimate of recreation related illness must be based on the predicted level of morbidity associated with water contact and the value that individuals would pay to avoid the illness. The usual approach to an economic assessment is the indirect estimation procedure that relies on an exposure response relationship and an enhanced cost of illness valuation. Such data are not available for recreational related illness in Egypt. However, information is available from the U.S. that may be adjusted for Egyptian conditions and that will give estimates of morbidity and an approximate value to avoid the illness.

Studies about the relationship between water quality and enteric diseases in the U.S. date from the 1950s. The most accepted exposure response relationship relates fecal contamination to acute gastrointestinal (AGI) symptoms, such as vomiting, diarrhea, stomach-ache, and nausea. Health statistics on AGI are usually reported as enteric diseases – typhoid and paratyphoid, hepatitis and dysentery.

In order to estimate the risk of bacterial infection associated with recreational contact, the following assumptions are used:

- The attack rates observed by Cabelli[9] of 16 cases/1,000 marine exposures is increased to 20 cases/1,000 marine exposures because of high level of fecal contamination.
- Fecal concentrations at all r... eation areas will exceed the 1,000/100 ml WHO standard for co... act recreation.
- All 500,000 recreation days in 1995 will result in some water contact recreation.

An estimate of the potential AGI can be calculated as follows:

$$\frac{20 \text{ cases}}{(1000 \text{ exposures})} \; x \; \frac{X \text{ cases}}{(500{,}000 \text{ exposures})} = 10{,}000 \text{ cases}$$

Studies about the relationship between water quality and viral diseases (in this case skin rashes and eye, ear and nose infections) are limited in number and not of the same scientific quality as those for bacterial diseases. Given the limited available data, the Higher Institute of Health in Alexandria suggested that the rate of viral diseases is approximately one half the rate for AGI.

Given the same general assumptions used for calculating cases of bacterial induced disease, an estimate of the potential rashes/infections can be calculated as follows:

$$\frac{10 \text{ cases}}{(1000 \text{ exposures})} \; x \; \frac{X \text{ cases}}{(500{,}000 \text{ exposures})} = 5{,}000 \text{ cases}$$

The cost-of-illness approach is the usual starting point for determining the benefits of avoiding illness.[10] However, the cost of illness

LU6

[9] Cabelli, V.J., A.P. Dufour, J.J. McCabe, and M.A. Levin, "A Marine Recreational Water Quality Criterion Consistent with Indicator Concepts and Risk Analysis", *Journal Water Pollution Control Federation, (1983) Volume 55, Number 10, pages 1306-1314*

approach understates the benefits of health protection in that it excludes pain and suffering costs. In other words, the cost of illness is a lower bound of the willingness to pay for sustained good health. Several adjustments are made here, however, in an attempt to account for this shortcoming.

First, wage earners suffering a parasitic episode are presumed to miss one week of work, implying an average loss per worker of roughly LE 58.00. Next, this figure is doubled to account for pain and suffering. Based on the Cooper and Rice findings for the U.S., direct (medical) costs for infective and parasitic diseases were roughly 18% greater than earning losses. Such medical expenses undoubtedly would be much lower in Egypt, but until better information is available, it is assumed that LE 68.45 (1.18 x LE 58.00), is the per case cost. This results in a rather liberal total of LE 184.45 per case per Egyptian worker affected (LE 58.00 in lost earnings, LE 58.00 for pain and suffering and LE 68.45 for direct medical expenditures). If one-third of the affected population are workers (including housewives and others who perform tasks for which they do not receive financial reimbursement), and the other two-thirds too young, old or for some reason unable to work, then the average value per case avoided would be reduced to LE 144.30.[11]

[10] Cooper, B.S. and D.P. Rice, "The Economic Cost of Illness Revisited", *Social Security Bulletin* (1976), vol 39, pages 21-36

[11] (For non-workers, the value per case avoided would equal LE 58.00 for pain and suffering and LE 68.45 for medical expenditures. A weighted average of this total of LE 126.45 with the LE 184.45 per case per worker yields LE 144.30)

Table 3. Estimated Economic Benefit in 1995 With and Without the Ismailia Waste Water Treatment Plant

Benefit Categores	With Project	Without Project
Quantitative/Qualitative Estimates		
Recreation		
User days	1,500,000	500,000
Illness	Negligible	10,000 AGI 5,000 rash infection
Amenity Value		
Rental income	Full increase in rental income for 5,000 - 10,000 units	10-25% Decrease in rental income for 5,000 - 10,000 units
Commercial Fisheries		
Net returns	Negligible	Negligible
Monetary Estimates (LE 000)		
Recreation		
User days	16,500	3,500
Illness	2,100	
Amenity Value		
Rental income	12,500 - 25,000	11,250 -18,700
Commercial Fisheries		
Net returns	—	—
Sum	31,100 - 43,000	14,750 - 22,000

Lower Bound Estimate for the Benefits 16,350

Upper Bound Estimate for the Benefits 21,400

1 US $ = LE 2.18 (June 1987)

LU6

The benefit per case avoided for skin rashes and eye and ear infections would not include foregone wages because these infections would not result in lost work. Consequently, the value for case avoided is LE 126.45 (LE 58.00 for pain and suffering and LE 68.45 for medical expenditures).

Combining the cases of morbidity for the with and without project scenarios with the values per case avoided provides a basis for calculating a total health benefit for the year 1995. With the project, there would be no more parasitic infections as a result of water contact recreation. Without the project, there would be 500,000 recreation days at the lake. These 500,000 recreation days would result in 10,000 case of AGI and 5,000 case of rashes and infections. The benefit of avoiding these cases is LE 2,236,250 (10,000 case times LE 144.30 for a total of LE 1,555,000 and

5,000 cases times LE 126.5 for a total of LE 632,500. These health damages resulting under the without project scenario should be attributed to the with project scenario as a benefit because they would be avoided if the project were built.

Amenity Values

One direct valuation technique, property values studies, can provide a surrogate measure of the value of environmental amenities. Economists have conducted numerous studies of the influence or absence of pollution levels on the property markets.[12,13] With sufficient market and pollution data and use of appropriate statistical techniques, the property value approach attempts to infer how much people are willing to pay for an improvement or to prevent deterioration in environmental quality. Although data and time are not available to conduct a full scale property value study, a simplified version of the approach is used to infer willingness to pay.

LU6

The number of housing units along Lake Timsah is approximately 1,000. The potential number of housing units could be between 5,000 and 18,000 units. In the absence of alarming information about water pollution and adequate infrastructure development, the number of housing units could reach the lower bound estimate of 5,000 and might be as high as 10,000 units by the late 1990s. Approximately 24 million people are projected to live within 150 km of Lake Timsah by the year 2000. Assuming that 20% of these people take weekend vacations and that there are 5 people per household, approximately 1,000,000 households will take vacations and weekend trips. Assuming that one percent of these households maintain second homes on Lake Timsah appears to be reasonable. The approximate value of these housing units, mostly for weekend recreation activities, is estimated at LE 125,000,000 - 250,000,000 (this assumes each unit is valued at LE 25,000). The implied annual rental income is 10% of the market value, giving an annual rental income between LE 12,500,000 and LE 25,000,000.

The with project scenario assumes that all these housing units will be built and that they will achieve potential rental income. The without project scenario assumes that these units would loose between 10-25% of their rental income if the lake becomes too polluted for safe water contact recreation. The housing income would be only LE 11,250,000 to LE 18,750,000. The benefit of maintaining lake water quality would be the difference in rent between the two situations. These benefits are in addition to the recreation days because they reflect amenity values to property owner rather than recreation users.

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[12] Freeman, A. Myrick, III. *The Benefits of Environmental Improvement. Theory and Practice Baltimore (The Johns Hopkins University Press for Resources for the Future, 1979)*

[13] Brookshire, D.S., M.A. Thayer, W.D.Schulze, and R.C. d'Arge, "Valuing Public Goods: A Comparison of Survey and Hedonic Approaches", *The American Economic Review* (1982), vol. 72, pages 165-177

Commercial Fishing

Commercial fishing in the lake is limited and would not be significantly diminished even if the project were not built by 1995. Water quality in the West Lagoon, the current discharge point of domestic waste, would continue to serve as a large holding basin and should be able to assimilate most of the organic matter, according to the Master Plan for Water and Waste Water.[14]

Cost-Benefit Analysis

All that remains now is to sum the benefits in each category for the with and without project scenarios. The economic benefits in the with project scenario range between LE 31,100,000 and LE 43,600,000; the economic benefits in the without project scenario range between LE 14,750,000 and LE 22,200,000 (table 3). The annual benefits that could be derived from the waste-water treatment project range between LE 16,350,000 and LE 21,400,000.

LU6

The annual cost of the project is LE 18,540,000 (this sum includes the full amortization of debt and operation & maintenance). The annual cost is on the high side given the number of conservative assumptions built into the technical analysis. Changing some of the conservative assumptions could reduce the annual costs by approximately 25 per cent. The mid-point estimate of annual benefits, LE 18,875,000, exceeds the annual costs.

The project is justified on economic grounds because there is a postive cost-benefit ratio. The mid-point estimate of annual benefits, LE 18,875,000 slightly exceeds the conservative estimate of annual costs, LE 18,540,000.

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[14] Metcalf & Eddy, Vol 6, Appendix Q