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United Nations Industrial Development Organization

Training Course
Ecologically Sustainable Industrial Development

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Learning Unit 5

Analytical Tools for Identifying Cleaner Production Opportunities

Further information may be obtained from:
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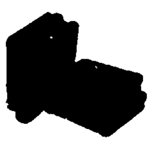
Contents



Additional Course Materials

Reading: ***Audit and Reduction Manual for Industrial Emissions and Wastes*, a UNIDO/UNEP technical report**

Video: ***Competitive Edge*, a film by the Ontario Waste Management Corporation**

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Introduction

Cleaner Production opportunities abound. Identifying them is mainly a matter of being observant and thinking through the production and waste disposal processes. The most important analytical tool to be used by companies should be a waste reduction audit. Other tools include environmental compliance audit, product life-cycle analysis and environmental impact assessment. In Learning Unit 5 we present the basics of each of these analytical tools for identifying Cleaner Production opportunities.

Objectives

The specific learning objectives of this unit are as follows:

- To introduce the analytical tools that can be used to identify Cleaner Production opportunities: waste reduction audit, environmental compliance audit, product life-cycle analysis and environmental impact assessment.
- To develop special knowledge and skills in waste reduction auditing, which will enable you to communicate the specific steps in the audit process to workers and staff in an industrial enterprise or trade association.
- To determine when, where and how each tool can be used effectively.
- To examine the special difficulties and constraints on using these tools in developing countries.

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Key Learning Points

1 A waste reduction audit is a systematic examination of the materials flow in a process or plant to identify opportunities to reduce emissions and wastes, thereby saving money.

2 An environmental compliance audit assesses how an enterprise complies with current and anticipated future environmental standards. It creates a more positive organizational setting for introducing Cleaner Production.

3 A product life-cycle analysis estimates the environmental impacts of a product from raw materials extraction through final disposal and identifies cost-effective options for minimizing wastes at each stage of the product life cycle. Usually, the most cost-effective options are those that prevent pollution.

4 An environmental impact analysis predicts the most significant environmental impacts of a project. It also identifies opportunities for avoiding adverse impacts. The least-cost mitigation opportunities are often source reduction measures rather than pollution control technologies.

5 A waste reduction audit is applied to an existing plant that is seeking to minimize its waste generation. An environmental compliance audit is applied to an existing plant concerned about compliance with environmental norms. Product life-cycle analysis is applied to a product, either existing or new, to determine its overall ecological impact. An environmental impact assessment is applied to a new plant or a major modification of an existing plant to assess its potential impact on the environment.

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 for each of 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*.

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Study Materials

There are four principal analytical tools for identifying Cleaner Production opportunities and thereby encouraging the adoption of Cleaner Production technologies:

- Waste reduction audit.
- Environmental compliance audit.
- Product life-cycle analysis.
- Environmental impact assessment.

These tools for identifying Cleaner Production opportunities are designed to support the objectives of the industrial enterprise: survival, profitability and growth.

Waste Reduction Audit

A waste reduction audit is conducted at an industrial facility to see what comes into the plant and what goes out, to make sure that resources are being used efficiently and to identify ways to reduce or eliminate the generation of wastes.

The main activities in a waste reduction audit are as follows:

- Prepare audit procedures.
- Determine process inputs.
- Determine process outputs.
- Derive a material balance.
- Identify waste reduction options.

- Evaluate waste reduction options.
- Prepare a waste reduction action plan.
- Implement the action plan.

The material balance demonstrates the opportunities for reducing the use of resources: water, chemicals, raw materials and energy.

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A waste reduction audit is the analytical tool most central to achieving Cleaner Production, because it follows material inputs through the production process and accounts for them quantitatively to identify wastes that can be reduced.

A waste reduction audit is a highly cost-effective tool for Cleaner Production that often provides immediate cost savings and in the long-run provides the "competitive edge" for industrial survival.

Next Steps

1 Familiarize yourself with the UNEP/UNIDO publication *Audit and Reduction Manual for Industrial Emissions and Wastes.*

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

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Questions

1 Why should a company do a waste reduction audit?

2 What is the principle of a material balance?

3 What are some causes for discrepancies in a material balance? (Hint: see step 13 in the manual)

4 What are some characteristics of a good waste reduction audit?

Answers

1. For many reasons, including complying with regulations, reducing wast; disposal costs, addressing complaints and staying competitive.

2. What goes into the process must come out, either as product or waste.

3. Overlooked outflows, poor measurement, incorrect recording of data and spills or leaks.

4. It draws attention to process inefficiencies and areas of poor management; permits the development of cost-effective waste management strategies; increases knowledge of the process.

Next Steps

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

2 Watch the video *Competitive Edge*.

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

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Questions

1 What is meant by the term competitive edge?

2 What is a material balance?

3 What happens in the first walk-through of the plant?

4 **In the example of material imbalance, what was the output error?**

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5 **What are the intangible benefits of the longer term alternatives?**

Answers

1. A reduction in production costs relative to those of your competitor.

2. The reconciling of inputs and outputs for a process.

3. Processes, raw materials and obvious wastage are identified, material flow diagrams are drawn up and leaks, spills and excessive water use are looked for.

4. Wash water was incorrectly measured.

5. Improved worker health, cleaner plant, better public image, market access, ability to withstand a supplier audit by a major customer.

Environmental Compliance Audit

An environmental compliance audit assesses how enterprises are complying with both current and anticipated future environmental norms. It is thus a systematic review of the manage- ment, production, marketing, product development and organizational systems of an enterprise to assess how well they are performing with regard to accepted, or even anticipated, environmental standards and practices.

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To conduct an environmental compliance audit requires the full cooperation of top management, managers and workers.

An environmental compliance audit may be done in response to an emergency situation, but it is more useful to management when it is carried out routinely each year by external, independent environmental auditors.

The main activities in an environmental compliance audit are as follows:

- Pre-audit activities
  - Select and schedule facility to audit.
  - Select audit team members.
  - Contact facility and plan audit.
- Activities at the site
  - Identify and understand the management control system.
  - Assess the management control system.
  - Gather audit evidence.
  - Evaluate audit findings.
  - Report findings.
- Post-audit activities
  - Issue draft report.

- Issue final report.
- Prepare action plan.
- Implement action plan.

The advantages of an environmental compliance audit include:

- Safeguarding the environment.
- Assuring compliance with environmental laws and regulations.
- Assuring compliance with company environmental policies.
- Identifying matters that need correction.
- Reducing exposure to litigation and regulatory enforcement actions.
- Reducing potential liabilities.
- Making the company more environmentally proactive.

An environmental compliance audit can change environmental attitudes throughout an industrial organization, shifting them from reactive secrecy to proactive problem-solving, thereby creating a positive organizational atmosphere in which to introduce Cleaner Production policies.

The term environmental audit is often used to refer to what is called here an environmental compliance audit, but this can lead to confusion because environmental audit can also refer to a waste reduction audit, discussed above.

Next Steps

1 Read *Environmental Auditing*, 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 the goal of an environmental compliance audit?

2 What is the main difference between an environmental compliance audit and a waste reduction audit?

3 Why is the term environmental audit confusing?

Answers

1. An environmental compliance audit is a technique to make enterprises more proactive in their environmental policies by assessing compliance with both current and anticipated future environmental norms.

2. An environmental compliance audit assesses how well an organization is performing in regard to environmental norms. A waste reduction audit identifies opportunities to minimize waste in the production process.

3. Because it can refer to both environmental compliance audits and waste reduction audits.

Product Life-Cycle Analysis

Product life-cycle analysis is an analytical tool that considers all stages of the production and consumption of goods and services, with the aim of minimizing the use of resources and preventing the production of waste. This concept is often referred to as cradle-to-grave environmental management.

Product life cycle analysis seeks ways to minimize adverse impacts on the environment at each phase in a product's life cycle. Usually, the most cost-effective options are those that prevent pollution.

There may be many reasons for conducting a product life-cycle analysis:

- To mitigate the environmental impact of a product.
- To support environmental certification, for example, eco-labelling.
- To provide information that will help market a product.
- To educate management and personnel about the environmental consequences of their activities.
- To educate consumers about how best to use and dispose of a product.

The main activities in a product life-cycle analysis are as follows:

- Inventory analysis
  - Define the purpose and the system boundaries of the analysis.
  - Gather data.
  - Construct a model of the environmental impacts.
  - Interpret the results.

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- Impact analysis
  - Assess the environmental effects of resource requirements and environmental loadings.
  - Assess risks to human health and the environment.
- Improvement analysis
  - Identify the environmental burdens that need reducing.
  - Evaluate reduction opportunities.

Product life-cycle analysis is most appropriate at a broad policy-making level to influence major decisions on product design, process engineering etc.

Next Steps

1 Read the chapter from *Life-Cycle Assessment: Inventory Guidelines and Principles*, 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.

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Questions

1 **Why is product life-cycle analysis often considered cradle-to-grave environment management?**

2 **What are the three main components of a life-cycle analysis?**

3 **What are the main stages in a typical product's life cycle?**

Answers

1. Product life-cycle analysis is a tool that considers all stages in the production and consumption of goods and services to minimize the use of resources and prevent the production of waste.

2. Inventory analysis, impact analysis and improvement analysis.

3. Raw materials acquisition, manufacturing, including materials and final product fabrication packaging and distribution; consumer use, reuse and maintenance; and recycle/waste management.

Environmental Impact Assessment

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An environmental impact assessment estimates the possible environmental consequences of a new plant or a major modification of an existing plant. It also identifies opportunities for avoiding the adverse impacts (mitigation opportunities).

Cleaner Production is highly relevant to environmental impact assessments, because the best mitigation opportunities are usually source reduction or pollution prevention.

There are five important principles in managing an environmental impact assessment:

- Focus on the main issues.
- Involve the appropriate persons and groups.
- Link information to decisions about the project.
- Present clear options for the mitigation of impacts.
- Provide information in a form that is useful to decision makers.

The main activities in conducting an environmental impact assessment are as follows:

- Planning the environmental impact assessment.
  - Screen the environmental impacts of similar projects.
  - Conduct a preliminary assessment of anticipated impacts.
  - Organize the study.
  - Define the scope of the environmental impact assessment.
- Conducting the environmental impact assessment.
  - Identify the potential environmental impacts.

- Estimate the extent of the impacts.
- Evaluate their significance.
- Identify mitigation opportunities.
- Document the environmental impact assessment process and the conclusions.

- Using the environmental impact assessment.
  - Prepare a plan for reducing environmental impacts.
  - Allocate institutional responsibilities.
  - Carry out the plan.
  - Conduct a post-audit to evaluate the results.

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The quality of an environmental impact assessment depends very much on the professional competence of the staff involved and their economic/political independence. Environmental impact assessment reports should communicate all essential matters to the general public, should clearly set out their underlying assumptions and should be subject to rigorous professional analysis before being accepted. A professional analysis of environmental impact assessment reports in the United Kingdom during 1985-1990 indicated that 40 per cent of them were defective.

Many times, an environmental impact assessment is prepared to obtain approval for a project but is not followed up to ensure that the project complies with the environmental plan.

The World Bank refers to an environmental impact assessment as an environmental assessment.

USEPA distinguishes between an environmental impact assessment (the activity) and an environmental impact statement (document).

Next Steps

1 Read *Environmental Impact Assessment: Basic Procedures for Developing Countries*, 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 an environmental impact assessment?

2 List five principles in managing an environmental impact assessment.

3 What questions does an environmental impact assessment ask?

Answers

1. *An environmental impact assessment predicts the environmental consequences of a proposed development project and identifies opportunities for avoiding adverse environmental impacts.*
2. *Focus on the main issues.*
   Involve the appropriate persons.
   Link information to decisions about the project.
   Present clear options for the mitigation of impacts.
   Provide information in a form useful to the decision-makers.
3. *What will happen as a result of the project?*
   What will be the extent of the environmental impacts?
   Do the impacts matter?
   What can be done about them?
   How can decision makers be informed about what needs to be done?

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Applying the Tools

A waste reduction audit should be applied to existing processes/plants to determine whether there is wastage of raw materials and energy and if there are financially attractive opportunities to reduce the wastage. It is often conducted after an environmental compliance audit has identified pollutant discharges that are violating norms.

An environmental compliance audit should be applied to existing facilities to determine how well environmental organization, management and equipment are performing in regard to environmental norms. Environmental compliance audits are usually conducted in situations where there is a strong government regulatory programme and the penalty for violating norms is high. The identification of specific pollutant reduction measures would require a waste reduction audit.

A product life-cycle analysis should be applied in industrial sectors with rapidly changing technologies and new products. It is also useful for new factories that need to evaluate alternative production processes. A product life-cycle analysis is a data-intensive effort that must be done with care to produce usable results. Product life-cycle analysis cannot, and should not, be used to assess the severity of environmental impacts, because it is not conducted for specific environmental settings. If this type of information is desired, an environmental impact assessment would be the appropriate analytical tool.

An environmental impact assessment should be applied to new plants and major modifications of existing plants that have the potential for significant adverse environmental impacts. The scope of the analytical effort depends on the significance of the impact and the potential for modification of project design.

Questions

1 Which Cleaner Production analytical tool must be applied in each of the following situations?

a A producer of cotton shirts wants to know which impacts result from his production directly and indirectly.

b An entrepreneur is thinking about developing an aluminium plant. He wants to know whether production in his plant will be clean enough to obtain the required permissions from the responsible authorities.

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c The owner of a chemical plant pays a lot for waste treatment. He wants to know whether he can reduce these costs by decreasing the wastage of raw materials.

d A government announces its intention to enact new, strong environmental regulations. An entrepreneur wants to know how he has to change the environmental organization, management and equipment of his facility to comply with the expected norms.

Answers

a. Product life-cycle analysis.

b. Environmental impact assessment.

c. Waste reduction audit.

d. Environmental compliance audit.

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Additional Suggested Reading

This concludes the study section of Learning Unit 5. For additional information on tools for identifying Cleaner Production opportunities, you may refer to the following sources.

Curran, M.A., "Broad-based environmental life-cycle assessment", *Environmental Science and Technology*, vol. 27, No. 3 (1993).

International Chamber of Commerce, *An ICC Guide to Effective Environmental Auditing* (Paris, 1991).

Luebkert, Barbara, and others, *Life-Cycle Analysis Idea: An International Database for Ecoprofile Analysis: A Tool for Decision Makers* (Laxenburg, Austria, International Institute for Applied Systems Analysis, 1991).

UNEP, *Environmental Auditing*, Technical Report Series No. 2 (United Nations publication, Sales No. 90.III.D.1).

Case Studies

Next Steps

1 Think about the questions raised in each of these *Case Studies* and prepare answers to the questions, preferably working with a small group.

2 Compare your answers with those suggested.

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Case Study 1: Waste Reduction Audit for a Peanut Factory

Provided by Rene van Berkel, IVAM Environmental Research, University of Amsterdam, the Netherlands.

For this *Case Study* you will be looking at a factory that produces deep-fried salted peanuts, using shelled, blanched peanuts. The next two paragraphs describe the factory; the third paragraph describes one process in that factory.

The peanuts, which are supplied in plastic bags, are emptied directly onto a conveyor belt. They are transported through a deep-frying oven; then they pass through a cooling unit. Finally they are sprinkled with oil and salt. The peanuts are then poured into containers for interim storage. After several hours they are ready to be packaged. The containers are attached to a packaging machine, which forms bags from rolls of foil and then fills them with peanuts. To prevent loss of flavour, the air is removed from the bag, using nitrogen.

From time to time, the oil used for deep-fat frying must be replaced, as a residue gradually accumulates at the bottom of the

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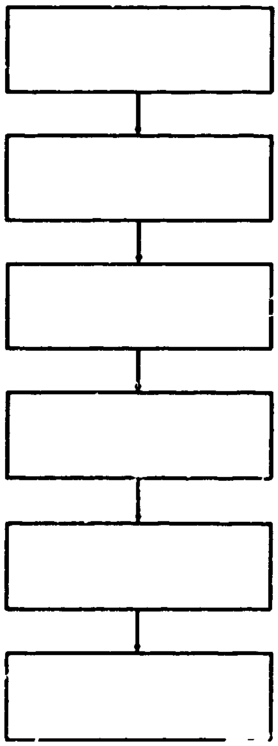
oven (due to broken peanuts and decomposition of the oil). The deep-fried peanuts are cooled by means of outside air. The salt is brought into the plant in paper bags and the oil in metal drums.

The process of deep-frying the peanuts can be described as follows. The peanuts are poured onto a conveyor belt which transports them at a constant speed through a frying oven filled with oil. They are deep-fried for 10 minutes in this frying oil, which is kept at a constant temperature of 160°C. Broken peanuts drop to the bottom of the oven, and this residue speeds up the process of decomposition. For this reason the quality of the frying oil is monitored every 15 minutes. If the concentration of decomposition products is too high, the process is halted and the oil replaced. The used frying oil is stored in a drum, and the oven is thoroughly cleaned with hot water and detergent. When the oven is completely clean, the oven is filled with new frying oil and the process is restarted.

Question

1 Draw up a process flow diagram for this peanut factory. List potential wastes and emissions.

Inputs **Unit Processes** **Waste Streams**



2 **Does the process suggest to you any changes that might be made to the process flow diagram? Give your reasons.**

3 **Analyze this process description to generate opportunities for the prevention of waste and emissions, using the five prevention techniques listed in Learning Unit 4, pages 9 and 10. Solve the waste problems by finding appropriate answers to the following questions.**

a. Which improvements in housekeeping could be considered to minimize each of the waste streams?

b. Which input substitutions could be considered to minimize each of the waste streams?

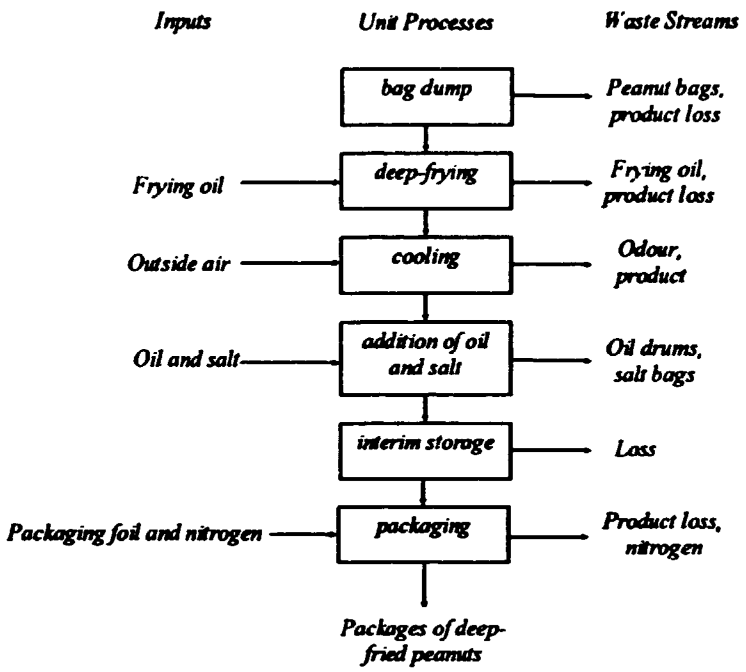
c. Which product modifications could be considered to minimize each of the waste streams?

d. Do opportunities for on-site recycling exist? How do these contribute to the minimization of waste and emissions?

e. Which technology modifications could be considered to minimize each of the waste streams?

Answers

1. The process flow diagram for the peanut factory is divided into six stages: bag dump, deep-frying, cooling, adding oil and salt, interim storage and packaging. When the peanuts are poured onto the conveyor belt, this results in packaging waste (plastic bags). At the deep-frying stage, oil is used which is supplied in metal drums, while another waste flow is formed by the used frying oil. Outside air is used in the cooling of the peanuts; this air is later expelled, which causes odours. When oil and salt are added to the peanuts, this results in packaging waste (drums and paper). The interim storage stage does not involve any material flow other than that of the product itself. During packaging, foil and nitrogen are consumed; this stage also involves nitrogen emissions and waste (when the foil rolls are changed). And finally, product loss occurs at each of these stages when peanuts get broken or fall off the conveyor belt.



2. This process flow diagram represents only the production-related waste streams. It is clear from the description that there is also a non-production-related source of waste water, which originates when the deep frying equipment is cleaned before being filled with new oil.

3. a. According to the process description, the production processes in the peanut factory are highly automated. However, at the cleaning stage simple good housekeeping is an important factor. The amount of water and cleanser used could be reduced to a minimum, leading to a considerable reduction in waste generation. LU5

b. Another possibility is to switch to a frying oil that is less susceptible to decomposition: it would not have to be changed as often, which would help to reduce waste. Moreover, if an environment-friendly oil were used, the waste oil produced would be less harmful to the environment.

c. Certain adjustments to plant equipment might be considered. As we have seen, broken peanuts left behind in the oven speed up the decomposition of the frying oil. If this residue were continuously filtered out of the deep fryer, the decomposition of the frying oil would be slowed down. This would mean that the frying oil could be changed less frequently, thus reducing the amount of waste oil.

d. It may be possible to recycle the frying oil within the plant, if it can be reprocessed. It is not clear from the description whether this is feasible.

e. Changing the type of product could help to reduce the waste generation; a type of peanut would have to be found that is less subject to breakage.

Case Study 2: Environmental Compliance Audit

Provided by R.G.A. Bolands, AGL International, Previssins-Moens, France.

The board of directors of the Hobbs Corporation has proposed that the corporation be subject to an annual external environmental compliance audit. Four senior line managers refuse to submit to an external environmental compliance audit. They resent the interference of corporate personnel and external experts. They feel that their job is primarily to produce goods for their customers and not to worry about peripheral environmental issues that are, after all, only a passing fashion and best handled by the public relations division.

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Questions

1 What misconceptions might managers have about environmental compliance auditing?

2 Develop a list of specific benefits that could persuade them to take a more positive attitude.

Answers

1. Misconceptions about environmental compliance audit·

Environmental compliance audit is not cost-effective.

Environmental compliance audit is a policing function.

Audit teams are not professionals.

External experts cannot offer new perceptions and ideas.

Environmental compliance audit does not seek business goals: profit, growth and survival.

Environmental compliance audit does not seek to help managers do a better job for the customers.

2. A fresh view of the problems may stimulate some new ideas.

It may uncover serious, high-risk environmental impacts.

Other departments have used suggestions emanating from an environmental compliance audit to reduce waste and costs and to improve efficiency and profitability.

An environmental compliance audit generates information on the basis of which the board of directors can justify its environment-related decisions to operating managers. It does not interfere with day-to-day operations.

Older managers can begin to become familiar with current and developing environmental management tools.

Environmental compliance audit is the inevitable long-term solution for business that will allow it to face the increasing political, economic and legal pressures generated by environmental concern.

Case Study 3: Product Life-Cycle Analysis

Adapted from "Washed up", *The Economist*, 1 August 1992, p. 54.

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A report prepared by the Ministry of Environment of the Netherlands attempts to answer the question: which are more environmentally friendly, china coffee cups and saucers, polystyrene (styrofoam) mugs or paper mugs? To find the answer the study examines the life cycle of the coffee cup from cradle-to-grave: from the extraction and processing of raw materials through production and use to final disposal. It takes account of the consumption of raw materials, the use of energy (for processing, transport and cleaning), the output of hazardous substances into the air and water and the volume of rubbish created (assuming 40 per cent is incinerated). It ignores some other environmental effects that are more locally varied, such as noise, smell and harm to the landscape.

China cups and saucers start with one big handicap: they need to be washed. "To wash a porcelain cup and saucer once, in an average dishwasher", avers the report, "has a greater impact on the water than the entire life cycle of a disposable cup". The surfactants in detergents, which clean off the grease, see to that. In their impact on air, energy consumption and volume of rubbish, china cups may do less harm in the end than their disposable rivals. But each time a china cup and saucer are put through a dishwasher, they use energy, cause nasty gases to be released into the air and create a bit more solid rubbish.

Whether it is greener to drink coffee from a china cup and saucer or a plastic or paper one depends on two things: how many times the china cup and saucer are used and how frequently they are washed. Have only one cup between washes, and the cup and saucer need to be used 1,800 times before they have less impact on the air during their lifetime than a polystyrene mug. That still gives china the edge: Dutch caterers reckon to use a china cup and saucer 3,000 times. But ask for a refill, and the china crockery need be used only 114 times before it beats polystyrene on energy use and only 86 times before it does less damage to the air. Paper cups do more harm than polystyrene on every count except their impact on water.

The answer, says the report, is to pay more attention to the amount of energy used by dishwashers and the pollution caused by detergents. Most office-workers have another answer: allow a fine patina of old coffee to develop around the inside of the mug. It may not be hygienic, but it is good for the planet.

Questions

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1 Which is the most environmentally friendly, a china cup or a disposable cup of polystyrene or paper?

2 What would you say was the most important result of the coffee cup study?

Answers

1 It depends on how you use it. Excessive washing of your china cup would render its use less environmentally friendly than the use of disposable cups.

2 It tells us that the use stage of a product can be at least as important as the production and disposal stages from an environmental impact point of view. This study highlighted the pollution caused by energy and detergent use during normal washing-up.

Case Study 4: Product Life-Cycle Analysis

Excerpted, with permission, from Yrjö Virtanen and Sten Nilsson, *Some Environmental Policy Implications of Recycling Paper Products in Western Europe*, Laxenburg, Austria, International Institute for Applied Systems Analysis.

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Public opinion and legislators have, in response to the environmental debate, requested the introduction of mandatory recycling systems and certain minimal levels of recycling. But too narrow a focus on the recycling concept may, on implementation, generate unexpected effects that can at least partially offset the expected benefits. This is especially true for paper, which is a major component of municipal waste. Since paper has a high energy content and is a renewable resource, the issues involved in large-scale paper recycling systems can be very complex.

The objectives of a feasibility study undertaken by the International Institute for Applied Systems Analysis (IIASA) on recycling paper products in Western Europe were to evaluate the applicability of a life-cycle approach to paper recycling, to provide new insights into the complexity of introducing large-scale recycling into existing production and distribution systems and to broaden the debate with new arguments. In several respects, and up to certain levels, recycling paper seems to be beneficial. However, as often occurs in the case of complex systems with multiple interdependencies and feedback loops, simplified policy actions tend to produce counterintuitive effects.

In order to demonstrate more explicitly the consequences of alternative policies on paper recycling, two extreme scenarios and one medium scenario as regards the extent of recycling were studied: this means a maximum, a selective and a zero recycling scenario. In the latter scenario old paper is used for energy recovery. The average rate at which recycled paper fibres were used was 28 per cent for Western Europe in 1986. The reuse rates in the selective and maximum scenarios were 35 per cent and 56 per cent, respectively.

The differences between gross energy demand and the net non-renewable energy demand (i.e. fossil fuels consumed) for the different scenarios were investigated and it was found that:

- The gross energy demand is lowest for the maximum and highest for the zero recycling scenario.

- The opposite is the case for the net fossil fuel demand, i.e. the net fossil fuel derived is highest for the maximum recycling scenario.

- Thus, the maximum recycling scenario gives the highest emissions of SO_2, NO_x and net CO_2.

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Furthermore, the selective and maximum recycling scenarios show a forest utilization considerably below that estimated as a sustainable level for Western Europe. Underutilization of forest resources may lead to unsatisfactory economic conditions for the necessary forest management, resulting in fewer vital forests and higher vulnerability to natural stress and air pollutants.

The conclusions of the feasibility study, while too preliminary to permit solid quantitative comparisons, indicate that the recycling of paper in Western Europe has economic and environmental advantages. However, the renewable character and the high energy content of paper and wood seem to make energy recovery more attractive than recycling under some conditions. Therefore, a balanced mixture of recycling and energy recovery seems to be a suitable solution, since recycling minimizes the use of certain resources and emissions, while energy recovery minimizes the overall use of fossil fuels. The appropriate balance may vary from country to country in Western Europe.

There remain a number of important questions that must be investigated further before large-scale programmes for the increased recycling of paper products are introduced. These questions are connected with the fact that the environmental impacts of recycling strongly depend on how far recycling is taken and how selective it is.

Questions

1 What were the ... of the paper recycling study? Which scenarios were ...ated?

2 What is the ess... report's recommendation concerning waste paper in ... Europe? LU5

Answers

1. The objectives were to evaluate the applicability of a life-cycle approach to paper recycling, to provide new insights into the complexity of introducing large-scale recycling into existing production and distribution systems and to broaden the debate with new arguments. A maximum, a selective and a zero paper recycling scenario were investigated.

2. The report recommends a balanced mixture of recycling and energy recovery of waste paper, since recycling minimizes the use of certain resources and emissions, while energy recovery minimizes the overall use of fossil fuels.

Case Study 5: Environmental Impact Analysis

Provided by R.A. Luken, Senior Environmental Adviser, UNIDO.

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A Ministry of Power is seeking to expand the production of electric power. It has proposed a new project that would increase coal mining and construct two coal-fired power plants of 400 MW each.

Negative impacts can occur during both the construction and operation of the coal mines and power plants. Construction impacts are associated with site preparation. In addition, the large influx of construction workers can have a significant impact on local communities.

Coal mining can, depending on site-specific conditions, result in underground mine subsidence, land disturbance from surface mining, contamination of surface water, fugitive dust and noise.

Coal-fired power plants can be a major source of air emissions that can effect both local and regional air quality. The combustion of coal results in emissions of sulfur dioxide, oxides of nitrogen, carbon monoxide, carbon dioxide and particulates. The environmental degradation associated with these emissions depends on a complex interaction among the physical characteristics of the plant's stack, physical and chemical characteristics of the emissions, meteorological conditions at or near the site, topographical conditions at the plant site and surrounding areas and the type and location of the receptors (people, crops, native vegetation).

The most significant waste-water streams from a coal-fired power plant are, typically, rather clean cooling water. It can be recycled or discharged into water bodies with minimal impact on the chemical quality. Waste heat, however, can impair ambient quality, particularly for plants using once-through cooling. Other effluents from coal-fired power plants include cooling system blowdown, boiler blowdown, ash transport waste water and run-off from coal piles.

Questions

1 **Which would be the more significant pollution problem associated with a coal-fired power plant, water or air pollution? (Hint: see Learning Unit 2, Atmospheric Pollution, pages 16-18.)**

2 **Why would you advise against locating the coal-fired power plant in a valley?**

3 **Which environmental impact associated with air pollutants do you think might be ignored? (Hint: see Learning Unit 2, Acidification, pages 24-26.)**

4 What do you anticipate will be a significant barrier to introduction of Cleaner Production options in this project?

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Answers

1. Air pollution is usually the more significant pollution problem particularly if the plant recycles its cooling waters. The more significant pollutants are sulfur oxides and particulates.

2. Location in a valley could trap the emissions of air pollutants around the plant, resulting in higher than usual ambient concentrations.

3. Given the size of the total project, there will be acid deposition impacts. The power generating authority would probably commit itself to meeting ambient SO_2 standards but would ignore the potential acid deposition problems.

4. The greatest barrier to the introduction of Cleaner Production options is that most managers have already decided on specific project components before the environmental impact assessment is prepared. Consequently, alternative technologies, fuels and plant locations are not considered.

Review

Test

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The following test will help you review the material in Learning Unit 5.

1 Pollution prevention opportunities may best be identified through

a. Environmental impact assessment
b. Waste reduction audit
c. Environmental compliance audit
d. Product life-cycle analysis

2 A waste reduction audit makes a detailed analysis of plant processes and wastes with the purpose of

a. Producing waste
b. Completely eliminating waste
c. Identifying wastes
d. Hiding waste

3 A waste reduction audit is best described as

a. An input characterization
b. A material balance
c. A balanced financial statement
d. A least-cost production programme

4 A waste reducion audit usually does not include

a. Water use
b. Materials use
c. Labour use
d. Chemicals use

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5 All of the following are the four *R*'s of waste reduction except

a. Reduction
b. Reuse
c. Remanufacture
d. Recovery

6 The critical barrier to a waste reduction audit is

a. Political interference
b. Financial resources
c. Technical competence
d. Management attitudes

7 The main purpose of an environmental compliance audit is to

a. Ensure that a firm is complying with environmental norms
b. Provide information to environmental management agencies
c. Meet the requirements of the Business Charter of ICC
d. Protect environmental quality

8 Conducting an environmental compliance audit requires the commitment of

a. Top management
b. Supervisors
c. Workers
d. All of the above

9 Environmental compliance audit activities at a site require all of the following except

a. Identification of the management control system
b. Determining process inputs
c. Gathering of audit evidence
d. Evaluation of the audit findings

10 A product life-cycle analysis considers

a. Only the design of a product
b. The potential for product recycling
c. All stages of production and consumption
d. The production process

11 The most controversial step in a product life-cycle analysis is

a. Cost analysis
b. Inventory analysis
c. Impact analysis
d. Improvement analysis

12 A product life-cycle analysis is more appropriate for

a. Selection of raw materials
b. Minimizing the wastes associated with production
c. Identification of new markets
d. Major decisions on product design

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13 An environmental impact assessment predicts

a. Effects on the environment
b. Effects on production cost
c. Effects on management
d. Effects on pollutant discharge

14 Scoping for an environmental impact assessment means

a. Finding the best environmental location for a project
b. Identifying the major environmental impacts
c. Choosing the least-cost mitigation strategy
d. Finding the most qualified team of experts

15 All of the following are important principles in managing an environmental impact assessment except

a. Balancing the benefits and costs of mitigation measures
b. Involving the appropriate persons and groups
c. Linking information to decisions about the project
d. Presenting clear options for the mitigation of impacts

Answers
1-5 bcbcc
6-10 dadbc
11-15 cdaba

Some Ideas to Think About

The following are some additional questions that Cleaner Production raises. Take some time to think about them. If possible, work in a small group and try to achieve consensus.

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1 Why did Cleaner Production and waste reduction audits become prominent only in the 1980s?

2 Does Cleaner Production usually require new investments for its implementation?

3 If waste reduction audits are so profitable, why hasn't every industrial enterprise been doing them for years?

4 Why is an environmental impact assessment so political?

5 Why does even big business in the European Community fight hard to make environmental compliance audits private rather than public?

Reading Excerpts

Environmental Auditing

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Excerpted, with permission, from ICC, *Environmental Auditing*, Publication 468 (Paris, 1989), pp. 6-15.

What exactly does environmental auditing mean? Why should industrial companies in particular arrange for environmental audits? Who should be responsible for them, and to whom should they report? What sort of methodology should be applied?

This essay gives the first internationally agreed answers to these questions. The ICC defines audits as a management tool, and emphasizes that the responsibility for conducting them should be that of companies themselves. The essay has five other objectives:

- stressing the benefits of audits to management;
- emphasizing their value to regulatory authorities;
- helping to establish audits as a credible and trustworthy instrument in the minds of the work-force, local community, environmentalist associations and the general public;
- settling an agreed basis for discussion and action worldwide;
- suggesting a standard practical methodology for personnel charged with undertaking the audits.

Definition and Purpose of Audits

During recent years the concept and practice of environmental management have developed rapidly within industrial organisations. The ICC Guidelines represent one illustration of this development. The underlying objective of environmental management is to provide a structured and comprehensive mechanism for ensuring that the activities and products of an enterprise do not cause unacceptable effects in the environment. All stages are considered from initial planning and con- ception to final termination.

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Most approaches to environmental management include provision for systematic examination of performance to ensure compliance with requirements. This paper is concerned with such systematic examination of performance during the operational phase of the industrial activity. The distinction is made between this process and, for example, Environmental Impact Assessment (EIA) which considers potential environmental effects during the planning phase before an operation starts. Various terms have been used for such examination (audit, appraisal, survey, surveillance, review), leading to possible confusion. Here the term 'Environmental Audit' is adopted.

The advantages and nature of environmental audits are considered below. However, the broad purpose is to provide an indication to company management of how well environmental organisation, systems and equipment are performing. If this purpose is to be fulfilled with full cooperation and commitment of those involved, it is essential that the procedure should be seen as the responsibility of the company itself, should be voluntary and for company use only. Thus audits would not normally be used to instigate prosecutions or litigation. Accordingly, the definition of environmental auditing adopted here is as follows:

"A management tool comprising a systematic, documented, periodic and objective evaluation of how well environmental organisation, management and equipment are performing with the aim of helping to safeguard the environment by:

- facilitating management control of environmental practices;
- assessing compliance with company policies, which would include meeting regulatory requirements".

Advantages of Audits

The primary and obvious advantage of environmental auditing is to help safeguard the environment and to assist with and substantiate com- pliance with local, regional and national laws and regulations, and with company policy and standards. A related advantage is reduced exposure to litigation and regulatory risk (e.g. penalties, additional regulations). The process ensures an independent verification, identifies matters needing attention and provides timely warning to management of potential future problems.

Experience demonstrates that environmental audits can have other benefits, the importance of which may vary from situation to situation, as follows:

- facilitating comparison and interchange of information between operations or plants;
- increasing employee awareness of environmental policies and responsibilities;

- identifying potential cost-savings, including those resulting from waste minimization;
- evaluating training programmes and providing data to assist in training personnel;
- providing an information base for use in emergencies and evaluating the effectiveness of emergency response arrangements;
- assuring an adequate, up-to-date environmental data base for internal management awareness and decision-making in relation to plant modifications, new plans, etc;
- enabling management to give credit for good environmental performance;
- helping to assist relations with authorities by convincing them that complete and effective audits are being undertaken, by informing them of the type of procedure adopted;
- facilitating the obtaining of insurance coverage for environmental impairment liability.

It should be emphasized again that the major value to the operating facility is as a management tool which provides information on environmental performance in relation to goals and intentions.

Essential Elements of Environmental Audits

The practice of environmental auditing involves examining critically the operations on a site and, if necessary, identifying areas for improvement to assist the management to meet requirements. The essential steps are the collection of information, the evaluation of that information and the formulation of conclusions including identification of aspects needing improvement. Suggested procedures are described in the appendix. For environmental auditing to be effective and yield maximum benefit, the following elements are necessary:

Full Management Commitment

It is important that management from the highest levels overtly supports a purposeful and systematic environmental audit programme. Such commitment is demonstrated by for example, personal interest and concern, the adoption of high standards, the allocation of appropriate manpower and resources, and the active follow-up of recommendations.

Audit Team Objectivity

The principal members of the audit team should be sufficiently detached to ensure objectivity. How this is best arranged will depend upon the size and structure of the company concerned and the nature of the specific audit.

Professional Competence

Team members should be appropriately qualified and sufficiently senior to provide a technically sound and realistic appraisal, and to command respect. The skills required fall under the headings of general environmental affairs and policy, specific environmental expertise and operational experience and knowledge of environmental auditing.

Well-defined and Systematic Procedures

To ensure comprehensive and efficient coverage of relevant matters, considered procedures such as those outlined in the appendix should be adopted.

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Written Reports

It is self-evident that the process should be properly documented, and that a clear report should be submitted to the management appropriate to the organization of the company. This report should concentrate on factual, objective observations.

Quality Assurance

It is desirable to have some mechanism to maintain the quality of the auditing system itself, and provide assurance of consistency and reliability to the company.

Follow-up

Clearly the full value from auditing can only be obtained if there is active implementation and follow-up of matters identified.

Conclusion

The ICC supports and encourages the adoption of environmental auditing programmes by industrial organisations as one element in their environmental management systems. Just as the environmental management systems should reflect the nature of the organisation, culture and products of individual businesses, environmental auditing programmes should be individually designed and operated to best meet the specific needs and objectives of the business served.

Experience has demonstrated that the full utility of this management tool can best be achieved if its use is voluntary, and findings are for the exclusive use of company management in carrying out their responsibility to correct all deficiencies promptly.

Appendix

Suggested Basic Steps in an Environmental Audit

Introduction

This brief description of suggested basic steps in typical environmental audits summarizes key features, and highlights the well-defined and planned structure characteristic of environmental audits wherever they are conducted. There are three essential phases: preparatory pre-audit activities; a site visit normally involving interviews with personnel and inspection of facilities; and post-visit activities.

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Environmental audits may have different objectives, and be conducted in many different settings by individuals with varied backgrounds and skills, but each audit tends to contain certain common elements. During the audit, a team of individuals completes a field assignment which involves gathering basic facts, analyzing the facts, drawing conclusions concerning the status of the programmes audited with respect to specific criteria, and reporting the conclusions to appropriate management.

These activities are conducted within a formal structure in a sequence that is repeated in each location audited to provide a level of uniformity of coverage and reliability of findings that is maintained from audit to audit. On the following pages a typical audit work flow can be found. Although not all audit programmes necessarily contain each step, the design of each programme generally makes provision for each of the activities described.

Pre-Audit Activities

Preparation for each audit covers a number of activities including selecting the review site and audit team, developing an audit plan which defines the technical, geographic and time scope, and obtaining background information on the plant (for example by means of a questionnaire) and the criteria to be used in evaluating programmes. The intent of these activities is to minimize time spent at the site and to prepare the audit team to operate at maximum productivity throughout the on-site portion of the audit.

With respect to the composition of the audit team, there are both advantages and disadvantages in including a member from the site being audited. Advantages include:

- the insider's knowledge of the specifics of the plant as regards both physical installations and organizational patterns;

- associating a local employee with the audit report may make it appear more credible to the plant's workforce.

The main disadvantage is that the insider may have difficulty in taking or expressing an objective view, especially if this might be seen as criticism of his superior or immediate colleagues.

Independent consultants may provide assistance, especially to smaller companies, in the event of a lack of internal expertise.

Activities at the Site

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The audit activities at the site typically include five basic steps:

Identifying and Understanding Management Control Systems

Internal controls are incorporated in the facility's environmental management system. They include the organisational monitoring and recordkeeping procedures, formal planning documents such as plans for prevention and control of accidental release, internal inspection programmes, physical controls such as containment of released material, and a variety of other control system elements. The audit team gains information on all significant control system elements from numerous sources through use of formal questionnaires, observations and interviews.

Assessing Management Control Systems

The second step involves evaluating the effectiveness of management control systems in achieving their objectives. In some cases, regulations specify the design of the control system. For example, regulations may list specific elements to be included in plans for responding to accidental releases. More commonly, team members must rely on their own professional judgement to assess adequate control.

Gathering Audit Evidence

In this step the team gathers evidence required to verify that the controls do in practice provide the result intended. Team members follow testing sequences outlined in the audit protocol which have been modified to consider special conditions at the site. Examples of typical tests include review of a sample of effluent monitoring data to confirm compliance with limits, of training records to confirm that appropriate people have been trained, or of purchasing department records to verify that only approved waste disposal contractors have been used. All of the information gathered is recorded for ease of analysis and as a record of conditions at the time of the audit. Where a control element is in some way deficient, the condition is recorded as a 'finding'.

Evaluating Audit Findings

After the individu... controls have been tested and team members have reached conclu... ...ncerning individual elements of the control system, the team mee... ...egrate and evaluate the findings and to assess the significance of ea... ...iency or pattern of deficiencies in the overall functioning of the co... system. In evaluating the audit findings, the team confirms that ther... sufficient evidence to support the findings and summarizes related fin...s in a way that most clearly communicates their significance.

Reporting Audit Findings

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Findings are no... discussed individually with facility personnel in the course of the a... the conclusion of the audit, a formal exit meeting is held with ... management to report fully all findings and their significance in th... ...ation of the control system. The team may provide a written sum... to management which serves as an interim report prior to prepara... of the final report.

Post-Audit Activities

At the conclusion of ... on-site audit two important activities remain: preparation of the ... report and development of a corrective action programme.

Final Audit Report

The final audit rep... is generally prepared by the team leader and, after review in draft by ... in a position to evaluate its accuracy, it is provided to appropria... management.

Action Plan Preparation and Implementation

Facility personnel, ...netimes assisted by the audit team or outside experts, develop a pla... ...ddress all findings. This action plan serves as a mechanism for obt... management approval and for tracking progress toward its complet... It is imperative that this activity take place as soon as possible so that management can be assured that appropriate corrective action is planned. A primary benefit of the audit is lost, of course, if corrective action is not taken promptly.

Follow-up to ensure that the corrective action plan is carried out and all necessary corrective action is taken is an important step. This may be done by an audit team, by internal environmental experts, or by management.

Summary

Environmental audits, while they may vary in some details, have certain generic characteristics as described above. The approach is characterized by a well-defined and planned structure, careful, methodical investigations and strong emphasis on reporting to all appropriate management. These characteristics form the basis for the reputation that environmental auditing has earned for providing reliable and useful information to management in all settings where it is practiced around the world.

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Basic Steps of an Environmental Audit

Pre-Audit Activities

Select and Schedule Facility to Audit

Based on:

- Selection Criteria

Select Audit TeamMembers

- Confirm their Availability
- Make Travel and Lodging Arrangements
- Assign Audit Responsibilities

Contact Facility and Plan Audit

- Discuss Audit Programme
- Obtain Background Information
- Administer Questionnaire (if necessary)
- Define Scope
- Determine Applicable Requirements
- Note Priority Topics
- Modify or Adapt Protocols
- Determine Resource Needs

Activities at Site

Step 1: Identify and Understand Management Control Systems

- Review Background Information
- Opening Meeting
- Orientation Tour of Facility
- Review Audit Plan
- Confirm Understanding of Internal Controls

Step 2: Assess Management Control Systems

- Identify Strengths and Weaknesses of Internal Controls
- Adapt Audit Plan and Resource Allocation
- Define Testing and Verification Strategies

Step 3: Gather Audit Evidence

- Apply Testing and Verification Strategies
- Collect Data
- Ensure Protocol Steps are Completed
- Review all Findings and Observations
- Ensure that all Findings are Factual
- Conduct Further Testing if Required

Step 4: Evaluate Audit Findings

- Develop Complete List of Findings
- Assemble Working Papers and Documents
- Integrate and Summarize Findings
- Prepare Report for Closing Meeting

Step 5: Report Findings to Facility

- Present Findings at Closing Meeting

Post-Audit Activities

Issue Draft Report

- Corrected Closing Report
- Determine Distribution List
- Distribute Draft Report
- Allow Time for Corrections

Issue Final Report

- Corrected Draft Report
- Distribute Final Report
- Highlight Requirement for Action Plan
- Determine Action Plan Preparation Deadline

Action Plan Preparation and Implementation

- Based on Audit Findings in Final Report

Follow-up on Action Plan

Life-Cycle Assessment: Inventory Guidelines and Principles

Excerpted, with permission, from B.W. Vigon and others. *Life-Cycle Assessment: Inventory Guidelines and Principles*, EPA/600/R-92/036, chap. 2.

Life-Cycle Assessment Concept

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Over the past 20 years, environmental issues have gained greater public recognition. The general public has become more aware that the consumption of manufactured products and marketed services, as well as the daily activities of our society, adversely affect supplies of natural resources and the quality of the environment. These effects occur at all stages of the life cycle of a product, beginning with raw material acquisition and continuing through materials manufacture and product fabrication. They also occur during product consumption and a variety of waste management options such as landfilling, incineration, recycling, and composting. As public concern has increased, both government and industry have intensified the development and application of methods to identify and reduce the adverse environmental effects of these activities.

Life-cycle inventory is a "snapshot" of inputs to and outputs from a system. It can be used as a technical tool to identify and evaluate opportunities to reduce the environmental effects associated with a specific product, production process, package, material, or activity. This tool can also be used to evaluate the effects of resource management options designed to create sustainable systems. Life-cycle inventories may be used both internally by organizations to support decisions in implementing product, process, or activity improvements and externally to inform consumer or public policy decisions. External uses are expected to meet a higher standard of accountability in methodology application. Life-cycle assessment adopts a holistic approach by analyzing the entire life cycle of a product, process, package, material, or activity. Life-cycle stages encompass extraction and processing of raw materials; manufacturing, transportation, and distribution; use/reuse/maintenance; recycling and composting; and final disposition. It is not the intent of a life-cycle

This study was conducted in cooperation with the Office of Air Quality Planning and Standards, the Office of Solid Waste, and the Office of Pollution Prevention and Toxics.
Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Major Concepts

- Life-cycle assessment is a tool to evaluate the environmental consequences of a product or activity holistically across its entire life.
- There is a trend in many countries toward more environmentally benign products and processes.
- A complete life-cycle assessment consists of three complementary components: Inventory, Impact, and Improvement Analyses.
- Life-cycle inventories can be used both internally to an organization and externally, with external applications requiring a higher standard of accountability.
- Life-cycle inventory analyses can be used in process analysis, material selection, product evaluation, product comparison, and policy-making.

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assessment to analyze economic factors. A life-cycle assessment can be used to create scenarios upon which a cost analysis could be performed.

The three separate but interrelated components of a life-cycle assessment include:

- the identification and quantification of energy and resource use and environmental releases to air, water, and land (inventory analysis);
- the technical qualitative and quantitative characterization and assessment of the consequences on the environment (impact analysis); and
- the evaluation and implementation of opportunities to reduce environmental burdens (improvement analysis).

Some life-cycle assessment practitioners have defined a fourth component, the scoping and goal definition or initiation step, which serves to tailor the analysis to its intended use.

Life-cycle assessment is not necessarily a linear or stepwise process. Rather, information from any of the three components can complement information from the other two. Environmental benefits can be realized from each component in the process. For example, the inventory analysis alone may be used to identify opportunities for reducing emissions, energy consumption, and material use. The impact analysis addresses ecological and human health consequences and resource depletion, as well as other effects, such as habitat alteration, that cannot be analyzed in the inventory. Data definition and collection to support impact analysis may occur as part of inventory preparation. Improvement analysis helps ensure that any potential reduction strategies are optimized and that improvement programs do not produce additional, unanticipated adverse impacts to human health and the environment. This guidance document is concerned primarily with inventory analyses.

A Brief History of Life-Cycle Inventory Analysis

Life-cycle inventory analysis had its beginnings in the 1960s. Concerns over the limitations of raw materials and energy resources sparked interest in finding ways to cumulatively account for energy use and to project future resource supplies and use. In one of the first publications of its kind, Harold Smith reported his calculation of cumulative energy requirements for the production of chemical intermediates and products at the World Energy Conference in 1963.

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Later in the 1960s, global modeling studies published in *The Limits to Growth* (Meadows et al., 1972) and *A Blueprint for Survival* (Club of Rome) resulted in predictions of the effects of the world's changing population on the demand for finite raw materials and energy resources. The predictions of rapid depletion of fossil fuels and climatological changes resulting from excess waste heat stimulated more detailed calculations of energy use and output in industrial processes. During this period, about a dozen studies were performed to estimate costs and environmental implications of alternative sources of energy.

In 1969 researchers initiated a study for the Coca-Cola Company that laid the foundation for the current methods of life-cycle inventory analysis in the United States. In a comparison of different beverage containers to determine which container had the lowest releases to the environment and least affected the supply of natural resources, this study quantified the raw materials and fuels used and the environmental loadings from the manufacturing processes for each container. Other companies in both the United States and Europe performed similar comparative life-cycle inventory analyses in the early 1970s. At this time, many of the data were derived from publicly available sources such as government documents or technical papers, as specific industrial data were not available.

The process of quantifying the resource use and environmental releases of products became known as a Resource and Environmental Profile Analysis (REPA), as practiced in the United States. In Europe it was called an Eco-balance. Stimulated by the formation of public interest groups encouraging industry to ensure the accuracy of information in the public domain, and by the oil shortages in the early 1970s, approximately 15 REPAs were performed between 1970 and 1975.

Through this period, a protocol or standard research methodology for conducting these studies was developed. This multi-step methodology involves a number of assumptions. During these years, the assumptions and techniques used underwent considerable review by EPA and major industry representatives, with the result that reasonable methodologies evolved.

A Life-Cycle Assessment has Three Components

These components overlap and build on each other in the development of a complete life-cycle assessment.

- Inventory Analysis
- Impact Analysis
- Improvement Analysis

Scoping is an activity that initiates an assessment, defining its purpose, boundaries, and procedures.

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From 1975 through the early 1980s, as interest in these comprehensive studies waned because of the fading influence of the oil crisis, environmental concern shifted to issues of hazardous waste management. However, throughout this time, life-cycle inventory analyses continued to be conducted and the methodology improved through a slow stream of about two studies per year, most of which focused on energy requirements. During this time, European interest grew with the establishment of an Environment Directorate (DG XI) by the European Commission. European life-cycle assessment practitioners developed approaches parallel to those being used in the USA. Besides working to standardize pollution regulations throughout Europe, DG XI issued the Liquid Food Container Directive in 1985, which charged member companies with monitoring the energy and raw materials consumption and solid waste generation of liquid food containers.

When solid waste became a worldwide issue in 1988, the life-cycle inventory analysis technique again emerged as a tool for analyzing environmental problems. As interest in all areas affecting resources and the environment grows, the methodology for life-cycle inventory analysis is again being improved. A broad base of consultants and research institutes in North America and Europe have been further refining and expanding the methodology. With recent emphasis on recycling and composting resources found in the solid waste stream, approaches for incorporating these waste management options into the life-cycle inventory analysis have been developed. Interest in moving beyond the inventory to analyzing the impacts of environmental resource requirements and emissions brings life-cycle assessment methods to another point of evolution.

During the past two years, the Society of Environmental Toxicology and Chemistry (SETAC) has served as a focal point for technical developments in the life-cycle assessment arena. Workshops on the overall technical framework, impact analysis, and data quality were held to allow consensus building on methodology and acceptable professional practice.

Public forums and a newsletter have provided additional opportunity for input from the user community.

Over the past 20 years, most life-cycle inventories have examined different forms of product packaging such as beverage containers, food containers, fast-food packaging, and shipping containers. Many of these inventories have supported efforts to reduce the amount of packaging in the waste stream or to reduce the environmental emissions of producing the packaging.

Some studies have looked at actual consumer products, such as diapers and detergents, while others have compared alternative industrial processes for the manufacture of the same product.

Overview of Life-Cycle Assessment Methodology

Three Components

Inventory Analysis

The inventory analysis component is a technical, data-based process of quantifying energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle of a product, package, process, material, or activity. Qualitative aspects are best captured in the impact analysis, although it could be useful during the inventory to identify these issues. In the broadest sense, inventory analysis begins with raw material extraction and continues through final product consumption and disposal. Some inventories may have more restricted boundaries because of their intended use (e.g., internal industrial product formulation improvements where raw materials are identified). Inventory analysis is the only component of life-cycle analysis that is well developed. Its methodology has been evolving over a 20-year period. Refinement and enhancement continue to occur following the SETAC workshop in 1990.

Impact Analysis

The impact analysis component is a technical, quantitative, and/or qualitative process to characterize and assess the effects of the resource requirements and environmental loadings (atmospheric and waterborne emissions and solid wastes) identified in the inventory stage. Methods for impact analysis are in the early stage of development following a SETAC workshop in early 1992. The analysis should address both ecological and human health impacts, resource depletion, and possibly social welfare. Other effects, such as habitat modification and heat and noise pollution that are not easily amenable to the quantification demanded in the inventory, are also part of the impact analysis component.

The key concept in the impact analysis component is that of stressors. The stressor concept links the inventory and impact analysis by associated

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resource consumption and releases documented in the inventory with potential impacts. Thus, a stressor is a set of conditions that may lead to an impact. For example, a typical inventory will quantify the amount of SO_2 released per product unit, which then may produce acid rain and which in turn might affect the acidification in a lake. The resultant acidification might change the species composition to eventually create a loss of biodiversity.

An important distinction exists between life-cycle impact analysis and other types of impact analysis. Life-cycle impact analysis does not necessarily attempt to quantify any specific actual impacts associated with a product or process. Instead, it seeks to establish a linkage between the product or process life cycle and potential impacts. The principal methodological issue is managing the increased complexity as the stressor-impact sequence is extended. Methods for analysis of some types of impacts exist, but research is needed for others.

Improvement Analysis

The improvement analysis component of the life-cycle assessment is a systematic evaluation of the needs and opportunities to reduce the environmental burden associated with energy and raw material use and waste emissions throughout the life cycle of a product, process, or activity. This analysis may include both quantitative and qualitative measures of improvements. This component has not been widely discussed in a public forum.

Scoping or Initiation

Scoping is one of the first activities in any life-cycle assessment and is considered by some practitioners as a fourth component. During scoping, the product, process, or activity is defined for the context in which the assessment is being made. The scoping process links the goal of the analysis with the extent, or scope, of the study, i.e., what will or will not be included. For some applications, an impact analysis will be desired or essential. In these cases, the preparation of the inventory is not a stand alone activity. The scoping process will need to reflect the intent to define and collect the additional inventory data for the impact analysis.

For internal life-cycle inventories, scoping may be done informally by project staff. Scoping for external studies may require the establishment of a multi-organization group and a formal procedure for reviewing the study boundaries and methodology.

Although scoping is part of life-cycle analysis initiation, there may be valid reasons for reevaluating the scope periodically during a study. As the life-cycle inventory model is defined or as data are collected, scope modifications may be necessary.

Identifying and Setting Boundaries for Life-Cycle Stages

The quality of a life-cycle inventory depends on an accurate description of the system to be analyzed. The necessary data collection and interpretation is contingent on proper understanding of where each stage of a life cycle begins and ends.

General Scope of Each Stage

Raw Materials Acquisition

This stage of the life cycle of a product includes the removal of raw materials and energy sources from the earth, such as the harvesting of trees or the extraction of crude oil. Transport of the raw materials from the point of acquisition to the point of raw materials processing is also considered part of this stage.

Manufacturing

The manufacturing stage produces the product or package from the raw materials and delivers it to consumers. Three substages or steps are involved in this transformation: materials manufacture, product fabrication, and filling/packaging/distribution.

Materials manufacture. This step involves converting a raw material into a form that can be used to fabricate a finished product. For example, several manufacturing activities are required to produce a polyethylene resin from crude oil: The crude oil must be refined; ethylene must be produced in an olefins plant and then polymerized to produce polyethylene; transportation between manufacturing activities and to the point of product fabrication is considered part of materials manufacture.

Product fabrication. This step involves processing the manu- factured material to create a product ready to be filled or packaged, for example, blow molding a bottle, forming an aluminum can, or producing a cloth diaper.

Filling/packing/distribution. This step includes all manufacturing processes and transportation required to fill, package, and distribute a finished product. Energy and environmental wastes caused by transporting the product to retail outlets or to the consumer are accounted for in this step of a product's life cycle.

Use/Reuse/Maintenance

This is the stage consumers are most familiar with: the actual use, reuse, and maintenance of the product. Energy requirements and environmental wastes associated with product storage and consumption are included in this stage.

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Stages of a Life Cycle

- Raw Materials Acquisition
- Manufacturing
    - Materials Manufacture
    - Product Fabrication
    - Filling/Packaging Distribution
- Use/Reuse/Maintenance
- Recycle/Waste Management

Recycle/Waste Management

Energy requirements and environmental wastes associated with product disposition are included in this stage, as well as post-consumer waste management options such as recycling, composting, and incineration.

Issues that Apply to all Stages

The following general issues apply across all four life-cycle stages:

Energy and Transportation

Process and transportation energy requirements are determined for each stage of a product's life cycle. Some products are made from raw materials, such as crude oil, which are also used as sources of fuel. Use of these raw materials as inputs to products represents a decision to forego their fuel value. The energy value of such raw materials that are incorporated into products typically is included as part of the energy requirements in an inventory analysis. Energy required to acquire and process the fuels burned for process and transportation use is also included.

Environmental Waste Aspects

Three categories of environmental wastes are generated from each stage of a product's life cycle: atmospheric emissions, water-borne wastes, and solid wastes.

These environmental wastes are generated by both the actual manufacturing processes and the use of fuels in transport vehicles or process operations.

Waste Management Practices

Depending on the nature of the product, a variety of waste management alternatives may be considered: land filling, incineration, recycling, and composting.

Allocation of Waste or Energy Among Primary and Co-Products

Some processes in a product's life cycle may produce more than one product. In this event, all energy and resources entering a particular process and all wastes resulting from it are allocated among the product and co-products. Allocation is most commonly based on the mass ratios of the products, but there are exceptions to this.

Summing the Results of Each Stage

To calculate the total results for the entire life cycle of a particular product, the energy requirements and certain emission values for each stage of the product's life cycle can be summed. For example, energy requirements for each stage are converted from fuel units to million British Thermal Units (Btus) or megajoules and summed to find the total energy requirements. Solid wastes may be summed in pounds or converted to volume and summed. The current, preferred practice is to present the individual environ- mental releases into each of the environmental media on a pollutant- by-pollutant basis. Where such specificity in an external study would reveal confidential business information, exceptions should be made on a case-by-case basis. Claims for confidentiality should be made only when it is reasonable to expect that release of the information would damage the supplier's competitive position. Even then, the data inputs to an external use are legitimately expected to be independently verified. A peer review process leading to agreed-upon reporting is one possible mechanism for dealing with this issue. Other approaches for independent verification are possible.

Applications of an Inventory Analysis

An inventory conforming to the scope defined in this document will provide a quantitative catalog of energy and other resource requirements, atmospheric emissions, waterborne emissions, and solid wastes for a specific product, process, package, material, or activity. Once an inventory has been performed and is deemed as accurate as possible within the defined scope and boundaries of the system, the results can be used directly to identify areas of greater or lesser environmental burden, to support a subsequent life-cycle impact analysis, and as part of a preliminary improvements analysis. Life-cycle impact assessment can be applied to quantify the human and ecological health consequences associated with specific pollutants identified by the inventory

The following are possible applications for life-cycle inventories. These are organized according to whether the application is supportable with the inventory alone or whether some level of additional impact analysis is appropriate. The critical issue that users should keep in mind is that if an application results only in an inventory, the resulting information must not be over-interpreted. Inventories can be applied internally to an organization or externally to convey information outside of the sponsoring organization. External uses are broadly defined in this document to include any study where results will be presented or used beyond the boundaries of the sponsoring organization. Most applications will require some level of impact analysis in addition to the inventory

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To Support Broad Environmental Assessments

The results of an inventory are valuable in understanding the relative environmental burdens resulting from evolutionary changes in given processes, products, or packaging over time; in understanding the relative environmental burdens between alternative processes or materials used to make, distribute, or use the same product; and in comparing the environmental aspects of alternative products that serve the same use.

To Establish Baseline Information

A key application of a life-cycle inventory is to establish a baseline of information on an entire system given current or predicted practices in the manufacture, use, and disposition of the product or category of products. In some cases it may suffice to establish a baseline for certain processes associated with a product or package. This baseline would consist of the energy and resource requirements and the environmental loadings from the product or process systems analyzed. This baseline information is valuable for initiating improvement analysis by applying specific changes to the baseline system.

To Rank the Relative Contribution of Individual Steps or Processes

The inventory provides detailed data regarding the individual contributions of each step in the system studied to the total system. The data can provide direction to efforts for change by showing which steps require the most energy or other resources, or which steps contribute the most pollutants. This application is especially relevant for internal industry studies to support decisions on pollution prevention, resource conservation, and waste minimization opportunities.

These first three applications are supportable with the understanding that the inventory data convey no information as to the possible environmental consequences of the resource use or releases. Any interpretation beyond the "less is best" approach is subjective.

To Identify Data Gaps

The performance of life-cycle inventory analyses for a particular system reveals areas in which data for particular processes or regarding current practices are lacking or are of uncertain or questionable quality. When the inventory is to be followed by an impact analysis, this use can also identify areas where data augmentation for the impact analysis is appropriate.

To Support Policy

For the public policy maker, life-cycle inventories and impact analyses can help broaden the range of environmental issues considered in developing regulations or setting policies.

To Support Product Certification

Product certifications have tended to focus on relatively few criteria. Life-cycle inventories, only when augmented by appropriate impact analyses, can provide information on the individual, simultaneous effects of many product attributes.

To Provide Education for Use in Decision-Making

Life-cycle inventories and impact analyses can be used to educate industry, government, and consumers on the tradeoffs of alternative processes, products, materials, and/or packages. The data can give industry direction in decisions regarding production materials and processes and create a better informed public regarding environmental issues and consumer choices.

These last three applications of life-cycle inventories are the most prone to over-interpretation. This is partly due to their more probable use external to the performing organization and partly due to their implicit orientation towards assessing the environmental consequences of a product or process.

Environmental Impact Assessment: Basic Procedures for Developing Countries

Excerpted, with permission, from UNEP, Regional Office for Asia and the Pacific. *Environmental Impact Assessment: Basic Procedures for Developing Countries* (Bangkok, 1988).

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What Is Environmental Impact Assessment?

Environmental Impact Assessment, or "EIA" for short, is a formal study process used to predict the environmental consequences of a proposed major development project. Such projects may include, for example, building a hydroelectric dam or a factory, irrigating a large valley, or developing a harbour.

An EIA concentrates on problems, conflicts or natural resource constraints that could affect the viability of a project. It also examines how the project might cause harm to people, their homeland or their livelihoods, or to other nearby developments. After predicting potential problems, the EIA identifies measures to minimise the problems and outlines ways to improve the project's suitability for its proposed environment.

The aim of an EIA is to ensure that potential problems are foreseen and addressed at an early stage in the project's planning and design. To achieve this aim, the assessment's findings are communicated to all the various groups who will make decisions about the proposed project: the project developers and their investors, as well as regulators, planners and politicians. (In some countries, a report—called an Environmental Impact Statement—is prepared at the end of the EIA study, and this is submitted to a Government department as part of a permit application for the project). Having read the conclusions of an Environmental Impact Assessment, project planners and engineers can shape the project so that its benefits can be achieved and sustained without causing inadvertent problems.

The EIA is an important phase in the process of deciding about the final shape of a proposed project. It helps officials make decisions about a project and it helps the project's proponents achieve their aims more successfully:

- A project that has been designed to suit the local environment is more likely to be completed on time and within budget, and is more likely to avoid difficulties along the way.

- A project that conserves the natural resources it relies upon will continue to be sustained by the environment for years to come.
- A project that yields its benefits without causing serious problems is more likely to bring credit and recognition to its proponents.

In summary, an Environmental Impact Assessment:

- Predicts the likely environmental impacts of projects.
- Finds ways to reduce unacceptable impacts and to shape the project so that it suits the local environment.
- Presents these predictions and options to decision-makers.

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EIA Is a Management Tool

Like economic analysis and engineering feasibility studies, EIA is a management tool for officials and managers who must make important decisions about major development projects.

All developers are familiar with economic and engineering studies. These tools provide the basis for designing robust, economically-viable projects. EIA is now seen as an equally important tool in designing a viable project.

In recent years, major projects have encountered serious difficulties because insufficient account has been taken of their relationship with the surrounding environment. Some projects have been found to be unsustainable because of resource depletion. Others have been abandoned because of public opposition, become financially encumbered by unforeseen costs, held liable for damages to natural resources and even been the cause of disastrous accidents.

Given this experience, it is clearly very risky to undertake, finance, or approve a major project without first taking into account its environmental consequences—and then siting and designing the project so as to minimise adverse impacts. For instance, the following questions need to be asked about any major project:

- Can it operate safely, without serious risk of dangerous accidents or long-term health effects?
- Can the local environment cope with the additional waste and pollution it will produce?
- Will its proposed location conflict with nearby land uses, or preclude later developments in the surrounding area?
- How will it affect local fisheries, farms or industry?
- Is there sufficient infrastructure, such as roads and sewers, to support it?

- How much water, energy and other resources will it consume, and are these in adequate supply?
- What human resources will it require or replace, and what social effects may this have on the community?
- What damage may it inadvertently cause to national assets such as virgin forest, tourism areas, or historical and cultural sites?

Who Is Involved in the EIA Process?

An EIA review is normally undertaken by those responsible for the development—the "developer". In some cases, the developer is a private company; in other cases, the developer is the government authority responsible for the relevant sector (e.g., transportation or agriculture).

Increasingly, governments and international agencies are adopting regulations that legally require developers to undertake EIAs. In such cases, the EIA report may need to be submitted as part of the application to a permit-granting government department—the "competent authority". But many developers, on their own initiative, are incorporating the EIA process into their routine project cycle. They recognise that environmental problems not only lead to risks and costly liabilities, but that they also cause concern about the developer's effectiveness across the full range of its responsibilities. A prudent developer uses all the management tools available to ensure a project's success in advance.

Although the developer is usually responsible for undertaking the EIA, the "competent authority" also has a role to play:

- By providing general guidance, past EIA formats or examples to follow.
- After the EIA is done, using its results to reach a decision on the project, and later ensuring that all the mitigation measures are implemented.

The concerns and points-of-view of all the various groups interested in and affected by the project should be taken into account throughout the process. Each of these participants will have a different use for the results of the EIA:

- The *developer* needs to know where to site a project and how to reduce adverse environmental impacts.
- The *investor* needs to know how the impacts will affect the viability of the project, and what liabilities are incurred.
- The *competent authority* uses the EIA's results to decide on a response to the permit application.

- Other *government authorities* will want to know the implications of the project's adverse impacts for other projects they may wish to promote.
- The ***regulator*** needs to know the extent of environmental impacts and whether they are acceptable.
- The ***regional planner*** needs to know how the impacts will interfere with adjacent developments and land uses.
- The ***local community*** or its representatives will need to know how the project's impacts will affect their quality of life.
- The ***politician*** needs to know who is affected and in what way, and what issues should be of concern.

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EIA Should Be Integrated with the Project Cycle

Most governments are now well aware of the possibility of undesirable side-effects from large scale industrial development. In 1970, the USA became the first country to make Environmental Impact Assessment a legal requirement for major development projects

Since then, countries throughout the world have enacted similar laws, suited to their own constitutions, economies and social values. Governments of all these countries—as well as international lending agencies and organisations like the United Nations Environment Programme—are still learning how to make EIA a practical management tool. useful in day-to-day decisions about building a country's economy. The key seems to lie in the management of the EIA: by designing the process so that it provides useful information to decision-makers at just the right time in the project cycle, EIA can have a real effect on projects. In other words, EIA should enhance and augment the project planning process. Only by actually shaping projects can EIA become an important instrument for protecting the environment and ensuring sustainable economic success.

Important Principles in Managing an EIA

Principle I

Focus on the Main Issues

It is important that an Environment Impact Assessment does not try to cover too many topics in too much detail.

At an early stage, the scope of the EIA should be limited to only the most likely and most serious of the possible environmental impacts. Some EIAs have resulted in large and complex reports running to several thousand pages. Such extensive work is unnecessary, and can be counter-productive, because the EIA's findings must be readily accessible and immediately useful to decision-makers and project planners.

When mitigation measures are being suggested, it is again important to focus the study only on workable, acceptable solutions to the problems. It is easy for the study to waste time considering measures that are impractical or totally unacceptable to the developer or to the Government.

When it is time to communicate the conclusions, the EIA should provide a summary of information relevant to the needs of each group for making its decision. Supporting data should be provided separately.

Principle 2

Involve the Appropriate Persons and Groups

Just as it is important not to waste time and effort on irrelevant issues, it is also important to be selective when involving people in the EIA process. Generally, three categories of participants are needed to carry out an EIA:

- Those appointed to manage and undertake the EIA process (usually a co-ordinator and a staff of experts)
- Those who can contribute facts, ideas or concerns to the study, including scientists, economists, engineers, policy makers, and representatives of interested or affected groups
- Those who have direct authority to permit, control or alter the project that is, the decision-makers—including for example the developer, aid agency or investors, competent authorities, regulators and politicians.

Principle 3

Link Information to Decisions about the Project

An EIA should be organised so that it directly supports the many decisions that need to be taken about the proposed project. It should start early enough to provide information to improve basic designs, and should progress through the several stages of project planning. In a typical sequence:

- When the developer and investors first broach the project concept, they consider likely environmental issues.
- When the developer is looking for sites or routes, environmental considerations are used to aid the selection process.
- When the developer and investors are assessing the project's feasibility, an EIA is in progress, helping them to anticipate problems.
- When engineers are creating the project design, the EIA identifies certain standards for the design to meet.

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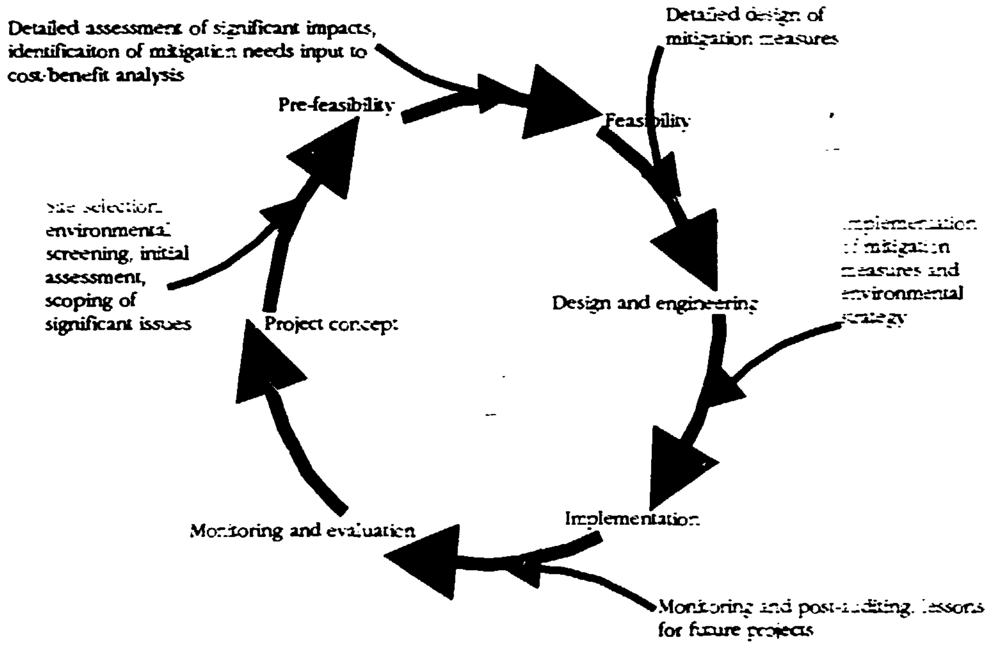
Project Cycle

Illustrated here is a generalised project cycle, showing when and how an Environmental Impact Assessment can contribute positively to the cycle's progress



- When a permit is requested, a completed EIA report is submitted. and also published for general comment.
- When the developer implements the project, monitoring or other measures provided for in the EIA are undertaken.

Principle 4

Present Clear Options for the Mitigation of Impacts and for Sound Environmental Management

To help decision-makers, the EIA must be designed so as to present clear choices on the planning and implementation of the project, and it should make clear the likely results of each option. For instance, to mitigate adverse impacts, the EIA could propose:

- Pollution control technology or design features.
- The reduction, treatment or disposal of wastes.
- Compensation or concessions to affected groups.

To enhance environmental compatibility, the EIA could suggest:

- Several alternative sites.
- Changes to the project's design and operation.

- Limitations to its initial size or growth.
- Separate programmes which contribute in a positive way to local resources or to the quality of the environment.

And to ensure that the implementation of an approved project is environmentally sound, the EIA may prescribe:

- Monitoring programmes or periodic impact reviews.
- Contingency plans for regulatory action.
- The involvement of the local community in later decisions

Principle 5

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Provide Information in a Form Useful to the Decision-Makers

The objective of an EIA is to ensure that environmental problems are foreseen and addressed by decision-makers. To achieve this, decision-makers must fully understand the EIA's conclusions. Most decision-makers are unlikely to use information, no matter how important it is, unless it is presented in terms and formats immediately meaningful:

- Briefly present "hard" facts and predictions about impacts, comment on the reliability of this information, and summarise the consequences of each of the proposed options.
- Write in the terminology and vocabulary that is used by the decision-makers and the community affected by the project.
- Present the essential findings in a concise document, supported by separate background materials where necessary.
- Make the document easy to use, providing visuals whenever possible.

The Environmental Impact Assessment Process

Before Starting the EIA

Despite its usefulness in finding ways to make projects more successful, the full EIA process is not necessary for every kind of development project. For a major project an EIA may use considerable resources and expertise. If a detailed EIA [illegible] needed, these resources can be put to better use elsewhere.

There are two "tiers" of assessment which should be applied to the project before proceeding with a full EIA: *screening* and *preliminary assessment*. Where these first tiers of assessment are a regulatory requirement, the developer normally does the work and submits the results to the regulatory agency. The agency may then decide:

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- There is nothing to be concerned about, or
- The evaluation should proceed to the next tier.

The advantage of a tier approach is that the extent of the inquiry expands with the advancing development of the project plans. *"Screening"* is appropriate when the project is only a rough concept. Later, when the project is under more general discussion, a *"preliminary assessment"* can look deeper into possible sites and potential impacts. Then, just before the preliminary stages of feasibility and design work get underway, a full "EIA study" can commence, so that it can influence the detailed decisions to come. This tier approach also ensures that impacts are examined at a very early stage in the project planning, and not later when sites or designs are already decided by other factors.

Screening

Screening is the first and simplest tier of project evaluation. Screening helps to clear types of projects which in past experience are not likely to cause serious environmental problems. The exercise may take one of several forms:

- Measuring environmental impact against simple criteria such as size or location.
- Comparing the proposal with lists of project types rarely needing an EIA (e.g., schools) or definitely needing one (e.g., coal mines).
- Estimating general impacts (e.g., increased infrastructure needed) and comparing these impacts against set thresholds.
- Doing complex analyses, but using readily available data.

Preliminary Assessment

If screening does not automatically clear a project, the developer may be asked to undertake a *preliminary assessment.* This involves sufficient research and expert advice to:

- Identify the project's key impacts on the local environment
- Generally describe and predict the extent of the impacts
- Briefly evaluate their importance to decision-makers.

The preliminary assessment can be used to assist early project planning, for instance to narrow the discussion of possible site—and it can serve as an early warning that the project may have serious environmental difficulties. It is in the developer's interest to do a preliminary assessment, since in practice, this step can clear projects of the need for a full EIA.

Organisation

If after reviewing a preliminary assessment the competent authority deems that a full EIA is needed, the next step for the project developer is the *organisation* of the EIA study. This entails:

- Commissioning and briefing an independent co-ordinator and expert study team (the disciplines that will be represented are decided after the "scoping" stage, but the team always includes a communications expert).
- Identifying the key decision-makers who will plan, finance, permit and control the proposed project, so as to characterise the audience for the EIA.
- Researching laws and regulations that will affect these decisions.
- Making contact with each of the various decision-makers.
- Determining how and when the EIA's findings will be communicated.

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Scoping

The first task of the EIA study team is "scoping" the EIA. The aim of scoping is to ensure that the study addresses all the issues of importance to the decision-makers. First the study team's outlook is broadened—by discussions with the project developers, decision-makers, the regulatory agency, scientific institutions, local community leaders, and others—to include all the possible issues and concerns raised by these various groups. Then the study team selects primary impacts for the EIA to focus on, choosing on the basis of magnitude, geographical extent, significance to decision-makers, or because of special local sensitivities (e.g., soil erosion, the presence of an endangered species, or a nearby historical site).

The EIA Study

After "scoping," the EIA study itself begins. Simply put, the EIA study attempts to answer five questions:

- *What will happen as a result of the project?*
- *What will be the extent of the changes?*
- *Do the changes matter?*
- *What can be done about them?*
- *How can decision-makers be informed of what needs to be done?*

After controls on the project's impacts are proposed in answer to the fourth question, the study team may again ask: *"What will happen as a result of the (now revised) project?"* Thus the EIA often becomes a cyclical process of asking and re-asking the first four questions, until decision-makers can be offered workable solutions.

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Identification

The answer to the first question—"*What will happen as a result of the project?*" has already been partly addressed, but only in general terms: if a "preliminary assessment" has been done, it will have broadly reviewed the project's effects; also, "scoping" will have focused the study on the most important issues for decision-makers. Taking these findings into account, the full EIA study now formally identifies those impacts which should be assessed in detail. This *identification* phase of the study may use these or other methods:

- Compile a candidate list of key impacts—such as changes in air quality, noise levels, wildlife habitats, species diversity, landscape views, social and cultural systems, settlement patterns and employment levels—from other EIAs for similar projects. This should draw on as many examples of similar projects as possible.

- Name all the project's "sources" of impacts (e.g., smoke emissions, water consumption. construction jobs) using check lists or questionnaires; then list possible "receptors" in the environment (e.g. crops, communities using the same water for drinking, migrant labourers) by surveying the existing environment and consulting with interested parties. Where the "sources" may affect the "receptors", a potential impact is suspected.

- Identify impacts themselves through the use of checklists, matrices, networks, overlays, models and simulations.

Prediction

The next step, called *Prediction*, answers the EIA's second question—"*What will be the extent of the changes?*" As far as is practicable, prediction scientifically characterises the impact's causes and effects, and its secondary and synergistic consequences for the environment and the local community. Prediction follows an impact within a single environmental parameter (e.g., a toxic liquid effluent) into its subsequent effects in many disciplines (e.g., reduced water quality, adverse impacts on fisheries, economic effects on fishing villages, and resulting socio-cultural changes). Prediction draws on physical, biological, socio-economic, and anthropological data and techniques In quantifying impacts, it may employ mathematical models, photomontages, physical models, socio-cultural models, economic models, experiments or expert judgements.

To prevent unnecessary expense, the sophistication of the prediction methods used should be kept in proportion to the "scope" of the EIA. For instance, a complex mathematical model of atmospheric dispersion should not be used if only a small amount of relatively harmless pollutant is emitted. Simpler models are available and are sufficient for the purpose. Also, it is unnecessary to undertake expensive analyses if they're not required by the decision-makers for whom the EIA is being done.

All prediction techniques, by their nature, involve some degree of uncertainty. So along with each attempt to quantify an impact, the study team should also quantify the prediction's uncertainty in terms of probabilities or "margins of error".

It has been a shortcoming of many EIAs that social and cultural impacts are not given the prominence they deserve in describing the extent of changes expected to result from a major development project. This has probably been due to the bias of physical and biological scientists against the comparatively younger disciplines of cultural anthropology and sociology. This is an unfortunate bias, since socio-cultural impacts are the ones that the local community will feel most acutely in their everyday lives. A consideration of socio-cultural impacts should be integrated, wherever possible, into every discussion of physical/biological change, and not just treated separately in a minor chapter or appendix. LU5

Evaluation

The third question addressed by the EIA—"*Do the changes matter?*"—is answered in the next step, *evaluation*, so called because it evaluates the predicted adverse impacts to determine whether they are significant enough to warrant mitigation. This judgement of significance can be based on one or more of the following:

- Comparison with laws, regulations or accepted standards.
- Consultation with the relevant decision-makers.
- Reference to pre-set criteria such as protected sites, features or species.
- Consistency with government policy objectives.
- Acceptability to the local community or the general public.

Mitigation

If the answer to the third question is *"Yes, the changes do matter"*, then the EIA proceeds to answer the fourth question—*"What can be done about them?"* In this phase, the study team formally analyses *Mitigation*. A wide range of measures are proposed to prevent, reduce, remedy or compensate for each of the adverse impacts "evaluated" as significant. Possible mitigation measures include:

- Changing project sites, routes, processes, raw materials, operating methods, disposal routes or locations, timing, or engineering designs.
- Introducing pollution controls, waste treatment, monitoring, phased implementation, landscaping, personnel training, special social services or public education.

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- Offering (as compensation) restoration of damaged resources, money to affected persons, concessions on other issues, or off-site programmes to enhance some other aspect of the environment or quality of life for the community.

All mitigation measures cost something, and this cost must be quantified too.

These various measures are then compared, trade-offs between alternative measures are weighed, and the EIA study team proposes one or more "action plans", usually combining a number of measures. The action plan may include technical control measures, an integrated management scheme (for a major project), monitoring, contingency plans, operating practices, project scheduling, or even joint management (with affected groups). The study team should explicitly analyse the implications of adopting different alternatives, to help make the choices clearer for decision-makers. Several analytical techniques are available for this purpose:

- Cost/benefit analysis, in which all quantifiable factors are converted to monetary values, and actions are assessed for their effect on project costs and benefits (Be cautioned, however, that the unquantifiable and qualitative aspects can be equally important, and often need to be taken into account in the decision-making process).
- Explaining what course of action would follow from various broad "value judgements" (e.g., that social impacts are more important than resources).
- A simple matrix of environmental parameters versus mitigation measures, containing brief descriptions of the effects of each measure.
- Pairwise comparisons, whereby the effects of an action are briefly compared with the effects of each of the alternative actions, one pair at a time.

Documentation

The last step in the EIA process, which responds to the last question—*"How can decision-makers be informed of what needs to be done?"*—is the *documentation* of the process and the conclusions. Recall that the purpose of an EIA is to ensure that potential problems are foreseen and addressed in the project's design. Many technically first-rate EIA studies fail to exert their importance and usefulness because of poor documentation. The EIA can achieve its purpose only if its findings are well communicated to decision-makers.

Generally, to produce effective communications, one must identify the target audience or audiences, and then shape and style the publication to meet their specific needs. In documenting an EIA, this means identifying the key decision-makers, perceiving the questions they will be asking, and providing them with straightforward answers, formatted for easy interpretation in relation to their decision-making (e.g., tables, graphs, summary points). Successful EIA documentation is more readily produced if the audience and their needs are established at the start of the EIA, and then made to affect how the research is focused and reported. It is the job of the study team's communications expert to make this happen.

So that decision-makers can look more deeply into particular issues, the EIA report should also include a record of the EIA process and the judgements made by the study team. An EIA report typically contains:

- An executive summary of the EIA findings.
- A description of the proposed development project.
- The major environmental and natural resource issues that needed clarification and elaboration.
- The project's impacts on the environment (in comparison with a baseline environment as it would be without the project), and how these impacts were identified and predicted.
- A discussion of options for mitigating adverse impacts and for shaping the project to suit its proposed environment, and an analysis of the trade-offs involved in choosing between alternative action.
- An overview of gaps or uncertainties in the information.
- A summary of the EIA for the general public.

All of this should be contained in a very concise, easy-to-read document, with cross references to background documentation, which is provided in an appendix. (The short document is sometimes called an "Environmental Impact Statement", especially when it is submitted as part of a permit application.)

Using the Results

Decisions based on the EIA are usually made by persons who have not been closely involved with the day-to-day progress of the EIA study. Their first consideration of the project's environmental impact may well be the moment they pick up and skim through the EIA report. The EIA will hopefully tell them all they need to know about "what will happen as a result of the project", "the extent of the changes", "whether the changes matter", and "what can be done about them". But the decision-makers themselves must also consider political realities when selecting a course of action. Only decision-makers are in a position to balance the project's needs and problems with the other needs and problems over which they have jurisdiction. They must take into account not only the facts of the situation, but also people's perceptions.

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If the project is accepted, perhaps with recommended modifications, then the decision-maker may need to take two further actions:

- Prepare a plan for reducing conflicts about the project; this may include public participation in planning, public education, and actions to compensate affected groups
- Allocate institutional responsibilities for overseeing the developer's adherence to its environmental requirements, for incorporating environmental management into further planning, and for enforcing any restrictions or carrying out any monitoring.

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Sometimes, the competent authority sends the EIA to a review panel for comment on its adequacy and quality, before reaching its decision. The decision-maker may call for further study to answer additional questions about the project. The decision-maker may also ask that an opportunity be provided for public review and involvement. The competent authority simply places copies of the report on public display, and invites the public to comment. The EIA team may then be asked to re-draft the EIA to take account of the comments made, before a decision is taken. In cases where the decision-maker chooses to reject the proposed project altogether, there should be an appeal process open to the project developers.

The EIA's usefulness does not end with the decision on a course of action about the project. It still has several further contributions to make to the project's success:

- If the project goes ahead with recommended changes, the EIA's findings should be used to help shape the project to suit the environment, by influencing engineering designs.
- Decisions that need to be made in the latter phases of project planning, such as precisely where to route supporting road or rail links, should be based on the EIA.
- The EIA's precautions on environmental impacts can be part of the brief for tendering on contracts, and should be re-drafted as environmental safety guidance for workers.

Lastly, after the project is completed, a "post audit" can be done to determine how close the EIA's predictions were to the project's real impacts. This forms a valuable record for others doing EIAs on similar projects in the future.

Resources Needed for an EIA

Because of the EIA's acknowledged importance in planning a country's sustainable economic growth, EIAs are now undertaken throughout the world, even in places with very few resources to give to planning initiatives. There are, however, certain minimum resources needed to perform EIAs that can successfully shape major projects:

Qualified multi-disciplinary staff. This includes a skilled manager (to co-ordinate the activities, communicate with decision-makers, and motivate the study team), trained specialists (in fields such as environmental science, rural and urban planning, economics, waste and pollution control, process engineering, landscape design, sociology and cultural anthropology), and a communications expert.

Technical guidelines, agreed with the competent authority, for carrying out the various phases of the EIA process, especially screening, scoping, prediction, evaluation and mitigation.

Information about the environment (especially relating to the impacts being considered after "scoping") which can be sorted and evaluated.

Analytical capabilities for doing field work, laboratory testing, library research, data processing, photomontage, surveys and predictive modelling.

Administrative resources for the day-to-day running of the EIA process, including office staff, meeting rooms and support, communications facilities and records management.

Institutional arrangements, including a formal procedure for consultation with the decision-makers and other interested groups, the authority to obtain the necessary information of the proposed project, and a formal process for integrating the EIA into decision-making about projects.

Review, monitoring and enforcement powers, to ensure that accepted mitigation measures are included in the development.

Among the resources needed to perform an EIA, not least are money and time. As concerns time, the following are averages for a sampling of recent EIAs: preliminary assessments take between two and 10 weeks to complete: full EIAs may last between three months and two years. Regarding costs, officials often balk at some of the figures they hear, but developers and investors will realise that they represent but a very small percentage of the costs of any major development project—nearly always less than 1%. Indeed, it is a relatively small price to pay to prevent costly unforeseen problems, to promote development that can be sustained, to help prevent potentially ruinous environmental catastrophes, and to obtain approval and acceptance. EIAs mean better, more successful projects; they are a good investment in the future, for both the developer and the economy as a whole.

What To Do Next

If you want to know more about Environmental Impact Assessments done in your own country, consult these likely sources:

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- The Ministry in charge of environmental protection.
- Authorities empowered to grant building or other permits.
- Environmental research centres.
- Universities and related research establishments.

To find out more about how to do an Environmental Impact Assessment, contact the United Nations Environment Programme (UNEP) at one of the following addresses:

- **United Nations Environment Programme**
  Regional Office for Asia and the Pacific
  The United Nations Building, Rajadamnern Avenue, Bangkok 10200, Thailand
- **United Nations Environment Programme**
  Industry and Environment Office
  Tour Mirabeau
  39-43, Quai André Citröen
  75739 Paris Cedex 15, France
- **United Nations Environment Programme Headquarters**
  PO Box 30552
  Nairobi, Kenya

UNEP can provide guidelines on the EIA process, examples of EIAs done throughout the world, reference materials on EIA techniques, and assistance finding the necessary resources, including expert advice.

The Governing Council of UNEP has adopted "Goals and Principles of Environmental Impact Assessment". In brief, the goals are:

- To take environmental effects into account in decisions by competent authorities.
- To promote beneficial EIA procedures in all countries.
- To encourage consultation between States on projects involving impacts across national boundaries.

First among UNEP's principles for EIA is that environmental effects should be considered before doing any project, and that EIAs should be done when significant effects are expected. The other principles cover many of the points about the EIA process which are discussed in this essay: who to involve, how to focus the process, and how to integrate it with decision-making about the proposed project.