ENVIRONMENTAL MANAGEMENT TOOLS AND THEIR APPLICATION – A REVIEW WITH REFERENCES TO CASE STUDIES

BY

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ABSTRACT

This paper is an attempt to classify environmental impact reduction efforts, present different methodologies for environmental performance improvements in an appropriate framework, and see these in combination with Systems Engineering principles. The main goal of the present work is to apply Systems Engineering methodology in order to evaluate and improve environmental life cycle performances in industrial systems. The paper also presents case studies from the furniture industry and the shipbuilding and shipping industry in Norway. These case studies exemplify and demonstrate the methods in use, and show how companies move from one level of environmental performance to a higher level through the work with environmental related problems. The conclusion is that by using Systems Engineering, appropriate tools, or parts of them, may be taken into use while needed. Finally, Systems Engineering is introduced as a method for Industrial Ecology.

1 INTRODUCTION

Industrial companies are to an increasing extent faced with requirements for better environmental performance. These requirements have traditionally originated from governmental and international authorities as well as consumers. We now see a growing awareness by investment and insurance companies in the sense that environmental performance is becoming an important part of their policies. On this background environmental performance requirements are becoming important decision parameters in the industry. However, industrial companies may have difficulties in finding the most appropriate tools in order to analyse, evaluate and document their environmental performance. There are several environmental management tools on the “market place”. Especially for small and medium sized enterprises there is a need for finding ways of systematising and simplify them for use as appropriate. This paper is an attempt to demonstrate how this can be done. It will be illustrated by case studies from industries in Norway.

2 CLASSIFICATION OF ENVIRONMENTAL PERFORMANCE LEVELS AMONG COMPANIES

The future focus of environmental concerns seems to change from site specific towards the life cycle perspective. This means that the holistic perspective must be taken into consideration when an industry wants to improve its environmental performance. A company’s environmental performance is not only a measure of the impacts caused by the production processes, it is also a total measure of the environmental impacts caused by the
processes, the products and the activities, idealistically viewed in a life cycle perspective. The goal must be to reduce the environmental impact in every phase of the life cycle. To reach this goal, appropriate methods for evaluating and improving the environmental performance must be taken into use. This paper introduces some methods and classifies them in accordance with the levels of environmental performances within a company. A model of the levels of environmental performances is shown in Figure 1. The first axis is the time axis, the product’s lifetime with its phases in planning, manufacturing, use and disposal, human lifetime and the civilisation span. The second axis indicates the scope of the environmental concern, ranging from a single product life cycle, to x products within one manufacturer and towards x manufacturers and the society. The areas in Figure 1 represent environmental performance efforts at different levels:

1. Environmental Engineering.
2. Pollution Prevention.
5. Sustainable Development.

![Figure 1: Classification of environmental performance levels. Modified after Bras (1996).](image)

Environmental Engineering can be understood in different ways. In this context it includes various types of engineering and production. Pollution Prevention takes system thinking into account, and the planning process is essential. The other concepts, Environmental Conscious Design and Manufacturing are related to product design and improvement of products concerning the manufacturing process, the distribution, the use and final disposal of the products. Both Sustainable Development and Industrial Ecology are concepts for the macro (and meso) level, taking environmental, economic and social issues into consideration. Companies may find themselves within these areas. A shift or movement from one area to the next area represents a change towards more holistic thinking and focus on the life cycle performance. A change in level is not necessarily equivalent with an improvement in environmental performance, but it is often noticed that it leads to improvement. The environmental performance improvements of companies must be evaluated relative to the level of environmental performance efforts of the firm.
3 CLASSIFICATION OF METHODS AND TOOLS FOR ENVIRONMENTAL PERFORMANCE IMPROVEMENTS

The best-known environmental management and environmental performance improvement tools are:

- Cleaner Production (CP)
- Environmental Accounting (EAc)
- Life Cycle Assessment (LCA)
- Life Cycle Screening (LCS)
- Life Cycle Costing (LCC)
- Material, Energy and Toxic-analysis (MET)
- Material Input per Service Unit (MIPS)
- Design for the Environment (DfE)
- Environmental Auditing (EA)
- Environmental Performance Evaluation (EPE)
- Environmental Management Systems (EMS)

A first classification of these is illustrated in Table 1, a classification relative to macro, meso and micro levels. There are no stringent boundaries between these levels, and tools placed at one level may be appropriate at other levels as well. The range is from macro to micro scale, and CP is summarised as precaution, prevention and integration.

Table 1: A classification of methods and tools for improvement of environmental performance at different levels.

<table>
<thead>
<tr>
<th>Levels</th>
<th>Appropriate tools</th>
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<tbody>
<tr>
<td>Macro - level (society - level)</td>
<td>• Montreal Protocol, Kyoto Agreement, Agenda 21, policy frameworks.</td>
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<tr>
<td>Meso - level (industry - level) (company - level)</td>
<td>• CP policies in a broad sense, international protocols.</td>
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<tr>
<td>Micro/meso – level (product - level)</td>
<td>• EMS, EA, EPE.</td>
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<tr>
<td>Micro - level (process - level)</td>
<td>• LCA, LCS, MET, MIPS, LCC, DfE, CP related to products</td>
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</table>

The following section describes the tools for the environmental performance improvements related to an organisation’s processes, products and management in general. The tools will then be classified within a similar framework as shown in Figure 1.

3.1 Process oriented tools

To calculate and evaluate the environmental impact caused by the production processes, Environmental Accounting (EAc) and Cleaner Production (CP) are frequently used. The CP methodology is quite similar to the guidelines for Environmental Accounting (EPA, 1992). This outlines procedures for conducting a preliminary assessment to identify opportunities for waste reduction or elimination. Further it describes how to use the results of this pre-assessment to give priority to areas for detailed assessment, how to use the detailed assessment to develop pollution prevention options, recycling and recovery, and how to implement those options that withstand feasibility analyses. However, there are no environmental impact assessment evaluations built into this method.
3.2 Product oriented tools

There are several methods for drawing up a list of a product’s specific environmental aspects taking the whole product chain into consideration. A few are described briefly below.

Environmental Life Cycle Assessment (LCA). The LCA-methodology is the most extensive method for studying environmental impacts throughout a product’s life cycle. It is now being standardised by the International Organisation of Standardisation\(^1\). The main steps are Goal and scope definition, Inventory analysis, Impact assessment and Interpretation. According to goal and scope definition the application, depth and subject of the study, the functional unit and the system boundaries must be defined. In line with the defined goal and scope, interpretation is the phase of an LCA in which a synthesis is drawn from the findings of either the inventory analysis or the impact assessment, or both. The findings of this interpretation may form conclusions and recommendations to decision makers.

Life Cycle Screening (LCS) and the MET-matrix. When the intention is to identify key issues for further investigations, e.g. identify parts of a life cycle that needs further research, an LCS should be carried out. An LCS is a simplification of an LCA, but it can never claim to substitute a full LCA. Similarly, the MET-matrix is a tool that helps to quickly draw up a list of a product’s main environmental aspects. It is a simple input-output model combined with the product’s life cycle, Brezet (1995). Three categories of environmental aspects, material cycle, energy consumption, and toxic emissions, are distinguished in this input-output model (therefore the name MET-matrix).

Material Input per Service unit (MIPS). The MIPS-concept, Liedtke (1994), Schmidt-Bleek (1993), is a life cycle tool for analysing material inputs per service unit. In this concept, the product is conceived as the “service delivery machine”, or “service machines”, and it focuses on the use of resources and less on waste streams. By calculating material and energy flows and the number of products produced, it is possible to calculate the material intensity related to the function of a particular product. Thereby a picture of the environmental performance related to that product is achieved. The concept is based on the philosophy that a better utilisation of materials and resources is needed to achieve a sustainable development.

Life Cycle Costing (LCC). The economic issues are the driving forces in the industry, and the results from an LCA-study are very often linked to LCC information. Traditionally cost effectiveness implies “most performance for least cost”. LCC does normally not focus on environmental issues. However, a cost examination tool that takes environmental issues into account is the Value Added Analysis (VAA), Liedtke (1994). This is related to the MIPS-concept and by VAA the sale opportunities of different products and their constituents can be estimated from both an ecological and an economic point of view.

Product Development and Design for Environment (DfE). Based on information drawn from environmental life cycle assessment studies, the traditional list of product design criteria should be supplemented with environmental conscious design requirements. There are several models for stepwise product development, and perhaps the life cycle design approach developed by the US Environmental Protection Agency, is the most comprehensive (EPA,

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\(^1\) Environmental management-Life cycle assessment -standards:
ISO 14040: Principles and framework
ISO/DIS 14041: Goal and scope definition and inventory analysis
ISO/CD 14042.3: Life cycle impact assessment
ISO/CD 14043-2: Life cycle Interpretation
The main activities are **needs analysis**, **statement of requirements**, **design** and **implementation**.

Eco Labelling (EL). Eco-labels are used to provide information about the environmental impact of a product. Eco-labels must take life cycle considerations into account. In environmental claims it is important that verification is properly conducted.

### 3.3 Environmental conscious management tools

Companies adopting CP, LCA, DfE etc., normally improve their overall environmental performance because of better housekeeping and better products. To achieve continuous improvement, their management systems should build on principles of environmental consciousness. Formal Environmental Management Systems\(^2\) (EMS), Environmental Auditing\(^3\) (EA), or Environmental Performance Evaluation\(^4\) (EPE) in accordance to given standards, help companies in this work.

**Environmental Management Systems (EMS) and Environmental Auditing (EA).** An EMS includes procedures for understanding environmental aspects, setting objectives and targets, establishing programs to achieve those objectives and targets, and reviewing performance versus those objectives and targets. EMS is that part of the overall management system which includes the organisational structure, responsibilities, practice, procedures, processes and resources for determining and implementing the environmental policy. When an environmental policy is adopted, the environmental management program should follow a continuous improvement cycle. EA is included as a systematic, documented verification process to measure if the objectives are obtained or conform to audit criteria.

Another environmental management instrument is the Resource Management (RM), a management system to combine eco- and cost-efficiency, Liedtke (1994). This includes material flow management, product management and eco-design. By such resource management the material flows can be reduced and in many cases the de-materialisation factor is expected to be 5 to 10, Schmidt-Bleek (1995). This system is built upon the same principles as the MIPS concept.

**Environmental Performance Evaluation (EPE).** EPE is the process that organisations can use to measure, analyse and assess their environmental performance against a set of criteria. EPE helps to understand what their environmental aspects are, and determines what their significant environmental aspects may be. This lets the organisation form a baseline from which objectives and targets for improvements can be derived. Therefore EPE is central to improvements of environmental performance and to compare an organisation’s performance against another similar organisation (benchmarking). An organisation that is committed to improving its environmental performance needs to be able to measure its performance level. By means of Environmental Performance Indicators (EPIs) a company will be able to do so. An EPI must reflect changes over a period of time, be reliable and reproducible, and be calibrated in the same terms as the policy goals or targets they are linked to.

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\(^2\) Eco Management and Audit Scheme – EMAS or ISO 14001: Environmental Management Systems
\(^3\) ISO 14010: Guidelines for environmental auditing – general principles
\(^4\) ISO 14031: Environmental performance evaluation - Guidelines
4 NORWEGIAN CASE STUDIES

The tools that are presented have been used more or less systematically in industry in several countries. Large companies with international trade adopted these early, medium sized and smaller companies are now taking CP, DfE and EMS into practice. A few examples are presented from the furniture industry and from the ship industry in Norway.

4.1 Examples from the Furniture Industry

The furniture industry in Norway consists mainly of small and a few medium sized enterprises. A cluster of producers and suppliers is located in the north west countryside of Norway. During a period of three-four years some companies have conducted environmental related projects.

Several CP- and EAc-projects have been performed in companies, e.g. producers of the wood work for furniture, steel parts, foam, leather producers and for the furniture assembling processes. The results of these projects were improvements within each company, and also improvement between companies such as better logistics, packaging and transportation. LCA has been adopted in a few furniture companies. The results from the LCA were used to improve the products that were analysed. Thus, LCA proved to become the start of the implementation of environmental conscious product development within these companies. However, the driving mechanisms were a better image for marketing purposes. A project involving five different furniture companies resulted in the implementation of formal environmental management systems in the respective companies within one year after kick-off. They were all EMAS-registered.

The results from these projects have demonstrated that the CP- and EAc-project that focused on economic benefits as well as environmental improvements, motivated the companies to build environmental consciousness into their management strategies.

4.2 Examples from the Ship Industry

Approximately 2/3 of the shipbuilders and producers of ship equipment are located in the north-western part of Norway. Also a few shipping companies (pipeline supply vessels for the oil industry and fishery) have their location in this part of the country. A comprehensive program has been carried out in a number of shipyards and shipping companies. This program included the total life cycle of a ship. The program was headed by Moere Research and Aalesund College, and involved at least twenty researchers over a four-year period, see Figure 2.

It started with a comprehensive CP-program where all kinds of emissions and releases from surface protection, cleaning and re-coating, repair or rebuilding of ships were measured, Fet et a (1994). Each yard made up a priority list of actions for the reduction of environmental impacts. The reduction was calculated, and so was the economic profits related to each of the measures. The findings and priorities in project 1 gave rise to new projects aiming to solve urgent environmental problems at shipyards. Key issues in these projects were cleaning and recovery of solvent, wastewater treatment systems for dry-docks, high-pressure water cleaning systems for painted areas, systems for protection under outdoor sandblasting and painting, and waste handling systems.
Project 1 also revealed a need for taking the total System Life Cycle of a ship into account when calculating environmental impacts and determining priorities. The system had to be properly defined in order to understand its structure as well as the interactions of systems and their impact on the natural environment. Based on this analysis a program called “Environmental management in a life cycle perspective” was conducted. In this program an activity based LCC-analysis and an LCA-study for a platform supply vessel was carried out. Prior to detailed calculations, an LCS was carried out to identify key issues for further investigations.

Parallel to this, another project focused on the implementation of EMS at shipyards. Each company described their environmental policy, objectives and targets for improvements were set and programs for attaining these targets were established. EPIs for EPE in the shipbuilding industry in Norway were also developed. Especially the methodology of selecting appropriate EPIs was tested and evaluated. This project was also a part of collaboration between Nordic companies representing a diversity of industries.


![Figure 2: Environmental projects carried out in the ship industry, Fet (1997).](image)

5 SYSTEMATIC APPLICATION OF THE METHODS

The presented methods are further on systematised into a framework similar to the one shown in Figure 1, see Figure 3. Area 1 is related to manufacturing processes, and appropriate tools are CP (in the narrow sense) and EAc. The next area is related to products and their life cycles. Appropriate tools are LCS, LCA, LCC, MET, MIPS and DfE for the purpose of environmental conscious product development. Area 3 represents one company, EMS, EA and EPE are important here. At society and global system level, policy programs and international
regulations are drawing up the guidelines for how to improve environmental performance in a broader term perspective.

5.1 The systems engineering method

For a company that has committed itself to an overall environmentally sound strategy, each one of the methods introduced earlier may be of assistance for the improvement of its environmental performance. It is, however, time consuming and expensive to use one method for the improvement of the production processes, one method for the improvement of their products and another method for the management, the environmental performance evaluation, the auditing process etc. Therefore a working-method that takes into consideration the various aspects of the respective methods when needed, is introduced by a six-step methodology, see Figure 4. This methodology is a simplification of Systems Engineering (SE), Fet (1997). In literature several models of SE are presented, Blanchard (1990), Blanchard (1991), Asbjørnsen (1992).
Step 1: Identify Needs. In the first step the needs for environmental related “information” must be identified. The most important interested parties within the system’s life cycle, their roles and requirements must be identified. Customers, authorities, banks and insurance companies, neighbours and own employees often ask for this kind of information.

Step 2: Define Requirements. Based on the identified needs, the requirements for the environmental information and better environmental performance must be defined. This may for example be environmental accounts for the company’s activities, eco-documentation of products or insight into the company’s environmental impacts on the local neighbourhood.

Step 3: Specify Performances. As soon as the requirements have been defined, the environmental performance must be described either for a selected product, for a process or an activity. It is important to consider the most significant environmental aspects of an organisation’s activities and products. To do this an inventory analysis is required. Especially elements from CP, EAc, LCA and EPE are useful here. The environmental performances can be expressed by means of EPIs.

Step 4: Analyse and Optimise. The environmental performance must be analysed. This requires good insight into how the extractions of natural resources affect the environment and how different kinds of emissions and outlets impact the environment. The data from the inventory must be classified according to their potential environmental impact. The impact of the various issues should be analysed relative to local, regional and global effects. To evaluate the environmental impacts, comprehensive knowledge about the condition of the environment is needed. Based on the analyses representative scenarios of improvements may be selected, analysed and optimised. Very often multi variable problems occur. Normally in multi-variate analyses several analytical methods can be applied. EPIs may be used as evaluation parameters.

Step 5: Design, Solve and Improve. In this step alternative improvements must be introduced. The findings arrived at through the previous steps, must be interesting information to the product designer who wants to improve his design. The design description must include all information necessary to produce, use, maintain and dismantle a product in the most optimal
way in accordance with the environmental performance requirements initially formulated. Changes may be introduced according to “cleaner technology” principles. To achieve continuous improvements it is recommended to establish an EMS.

**Step 6: Verify, Test and Report.** It is necessary to test, evaluate and verify whether or not the initial needs and requirements are met. Thus, considerations for tests and evaluation are innate from the beginning. A test program in this area may constitute a series of individual tests, tailored to the needs and requirements. Improvements of environmental performance should be verified e.g. by environmental audits. It is also important to document and report how changes have led to improvements. Different types of eco-labelling of products are useful, and these are in fact a report on the environmental performance of the products.

5.2 Similarities between the methods introduced earlier and the SE-method.

SE is a management tool where a company can adopt parts of other methods when appropriate. It is not necessary to perform e.g. an LCA to its full extent if only the analysis and evaluation part of the method is needed. Likewise, it is not necessary to perform a total environmental auditing if only a part of a production process is to be evaluated against a set of defined criterions. Table 2 shows how the different working steps of the tools and methods presented fit into the SE-methodology.

6 DISCUSSION AND CONCLUSION

I have classified the methods relative to processes, products and management intended use. Further the methods are systematised in accordance with the classification model of different environmental performance levels, see Figure 1. By using the tools relative to the manufacturing process, or to a product’s entire life cycle, as shown in, a company will most likely be in a position to achieve a better environmental performance. Thus focus is changed from process to product, to environmental conscious design and product development. In most cases this will result in a higher level of competence and knowledge of environmental issues among employees. The development has often unpredictable patterns. A company that starts with the goal of optimising a few processes with the purpose of reducing pollution, may end up with improved products and environmental management systems like in the examples from the furniture industry. Similarly, as shown through the projects in the ship industry, the work started with waste minimisation techniques and continued through system analysis, product improvement and implementation of EMS. Such programs have shown that the companies have moved to a higher level of environmental performance over time.

However, the case studies have shown that the methods of EAc, CP, LCA, LCC, etc. have not been fully adhered to. Parts of them have been adopted while needed, and this is in accordance with the pattern introduced through the SE-method. That work pattern requires sufficient knowledge in the organisation about environmental issues and possibilities of achieving improvements. To increase the knowledge on environmental issues in general is therefore an important challenge.

Even though the intention of this paper is to classify, systematise and simplify the methods for use and demonstrate this by selected examples, it is also of interest to introduce SE as an appropriate method for Industrial Ecology (IE). IE is a connecting link between different fields of system thinking - bringing system thinking in ecology together with systems engineering and economics. It is said that the methods in IE are poorly defined, O’Rourke
(1995). IE is brought up as an important challenge in the effort toward environmental improvements in society and among companies. Hence there is an urgent need for a method capable of handling complexity, multi-variable problems and optimisation techniques. For this purpose the SE-method is most probably appropriate. It is introduced as a methodology that is embracing the others, see Figure 3.

As a spin off from the activities referred to in the case studies, the community where several of the companies are located, have launched an initiative for Local Agenda 21. The said companies have now entered into co-operation with the local authorities and other companies in the community that previously have not been engaged in systematic environmental improvements. Thus, there will be companies on different environmental performance levels working together with a common goal. For the purpose of reaching the desired goals, the SE-method can be adopted for any company or organisation since the efforts will be related to the needs and requirements defined by each company themselves. They will most likely work according to the principles of IE. The co-operation is based on networking and value chain principles. In this case the SE-methodology will be tested as a working method. However, this work has recently started, and it requires research and most probably some modification.

This paper has demonstrated the application of SE as a method that combines the various methods for environmental assessment and management. Such combinations have not been demonstrated in this field earlier. Thus, I conclude that the SE method has proved to be a systematic tool for this purpose. It is built upon a holistic view and the life cycle perspective. SE is easy to combine with other methods as appropriate, it is a comprehensive tool for environmental life cycle studies, and it helps to establish environmental performance improvement requirements. Additional work remains for the improvement of the analytical part of analysing multivariate environmental problems.
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<tr>
<th>SE</th>
<th>CP</th>
<th>LCA</th>
<th>DIE</th>
<th>EMS</th>
<th>EPE</th>
<th>EA</th>
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<td>1. IDENTIFY NEEDS</td>
<td>1. PLANNING AND ORGANISING</td>
<td>1. GOAL AND SCOPE DEFINITION</td>
<td>NEEDS ANALYSIS</td>
<td>1. ENVIRONMENTAL POLICY</td>
<td>1. COMMITMENT</td>
<td>1. INITIATING THE AUDIT</td>
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<td></td>
<td>● Get management’s commitment</td>
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<td>● Audit scope</td>
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<td>● Set assessment program goals</td>
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<td>● Preliminary document review</td>
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<td>● Organise assessment program task force</td>
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<td>• Preliminary document review</td>
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<td>2. DEFINE REQUIREMENTS</td>
<td>2. ASSESSMENT AND PREPARATION</td>
<td>2. INVENTORY ANALYSIS</td>
<td>REQUIREMENTS</td>
<td>2. INITIAL PLANNING</td>
<td>2. PLANNING</td>
<td>2. PREPARING THE AUDIT</td>
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<td></td>
<td>● Identify and track waste streams</td>
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<td>● Management consideration</td>
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<td></td>
<td>● Compile process and facility data</td>
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<td>● Selecting indicators</td>
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<td>• Audit team assignments</td>
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<td>● Prioritise and select assessment targets</td>
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<td>• Working documents</td>
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<td></td>
<td>● Select people for assessment teams</td>
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<td>• Working documents</td>
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<td></td>
<td>● Inspect site</td>
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<td>● Env. aspects, requirements, objectives and target</td>
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<td>• Opening meeting</td>
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<td></td>
<td>● Generate options, screen and rank these</td>
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<td>● Env. management program</td>
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<td>• Collecting audit evidence</td>
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<td>● Select options for a feasibility study</td>
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<td>● Implementing strategies</td>
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<td>4. FEASIBILITY ANALYSIS STEP</td>
<td>4. INTERPRETATION</td>
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<td>● Technical and economic evaluation</td>
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<td>● Training and competence</td>
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<td>● Select options for implementation</td>
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<td>• Audit findings</td>
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<td>4. ANALYSE AND OPTIMISE</td>
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<td>• Audit findings</td>
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<td>5. DESIGN, SOLVE AND IMPROVE</td>
<td>5. REPORTING</td>
<td>(APPLICATION OF LCA- RESULTS)</td>
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<td>6. IMPLEMENTATION</td>
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<td>● Justify projects</td>
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<td>• Audit reports and document retention</td>
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<td></td>
<td>● Install or modify equipment</td>
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<td>• Distribution of audit report</td>
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<td>● Implement new procedure</td>
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<td>6. VERIFY AND REPORT</td>
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