Chapter- VI

ENVIRONMENTAL MANAGEMENT SYSTEM

6.1 **Product Life Cycle Assessment**

Products play a key role in the attempts to reduce the total environmental impact of human activities. This is because every human activity – and consequently its impacts on the environment- can be related to specific needs and the fulfillment of these needs by material or non-material products. Different products, causing different environmental impacts may fulfill the same need. Thus, environmental impacts may be reduced by substituting between products. The purpose of life cycle assessment is to assess the possible environmental impacts of such product substitutions, i.e. the choice of one product instead of another (or the choice of a specific product instead of refraining from this product).

All products are produced to perform one or more functions, providing one or more services, fulfilling one or more customer requirements. For example the function of an office chair can be expressed in terms of “seating support for one computer workstation for one year” with some additional minimum requirements with respect to durability, strength, stability, safety and comfort, including adjustments of seat and backrest, arm rests etc.

Life-cycle assessment is performed to:
- Minimize the magnitude of pollution
- Conserve non-renewable resources
- Conserve ecological systems
- Develop and utilize cleaner technologies
- Maximize recycling of materials and waste
- Apply the most appropriate pollution prevention and or abatement technologies

A great deal of waste is generated through human activities -- approximately 40 tons/year per person in the United States. This represents lost resources as well as results in environmental degradation.

The most important goal of LCA, according to a survey of organizations actively involved in LCA, is to minimize the magnitude of pollution. Some of the other goals: conserve non-renewable resources, including energy; ensure that every effort is being made to conserve ecological systems, especially in areas subject to a critical balance of supplies; develop alternatives to maximize the recycling and reuse of materials and waste; and apply the most appropriate pollution prevention and/or abatement techniques;

Life cycle assessment has been applied in many ways in both the public and private sectors. This is a list of some of the uses manufacturers have for LCA. Product comparisons have received the most attention from the press but according to the Swedish survey the most important uses for manufacturers are 1) to identify processes, ingredients, and systems that are major contributors to environmental impacts, 2) to compare different options within a particular process with the objective of minimizing environmental impacts, and 3) to provide guidance in long-term strategic planning concerning trends in product design and materials.

LCA is also used in the public sector. Some of the most visible of the applications of life-cycle assessments are environmental or eco-labels. Examples of ecolabels from around the world are shown here. Besides environmental labeling programs, public sector uses of life-cycle methodologies include use as a tool for making procurement decisions and developing regulations. Policymakers report that the most important uses of LCA are in 1) helping to develop long-term policy regarding overall material use, resource conservation and reduction of environmental impacts and risks posed by materials and processes throughout the product life-cycle, 2) evaluating resource effects associated with source reduction and alternative waste management techniques, and 3) providing information to the public about the resource characteristics of products or materials.

Opportunities for reducing waste outputs and energy and raw material requirements in this system can be analyzed from several perspectives. For example, studies of wastes and emissions at a large scale can show the industries and regions where large volumes of waste or highly toxic wastes are generated. In the field of industrial ecology, the fate of materials as they move through processes and into products and wastes are studied. Life-cycle assessment looks at this system from the perspective of products.

In LCA, the processes required to make, use, and dispose of a product are analyzed to determine the raw materials, energy requirements, wastes, and emissions associated with the product's life cycle.

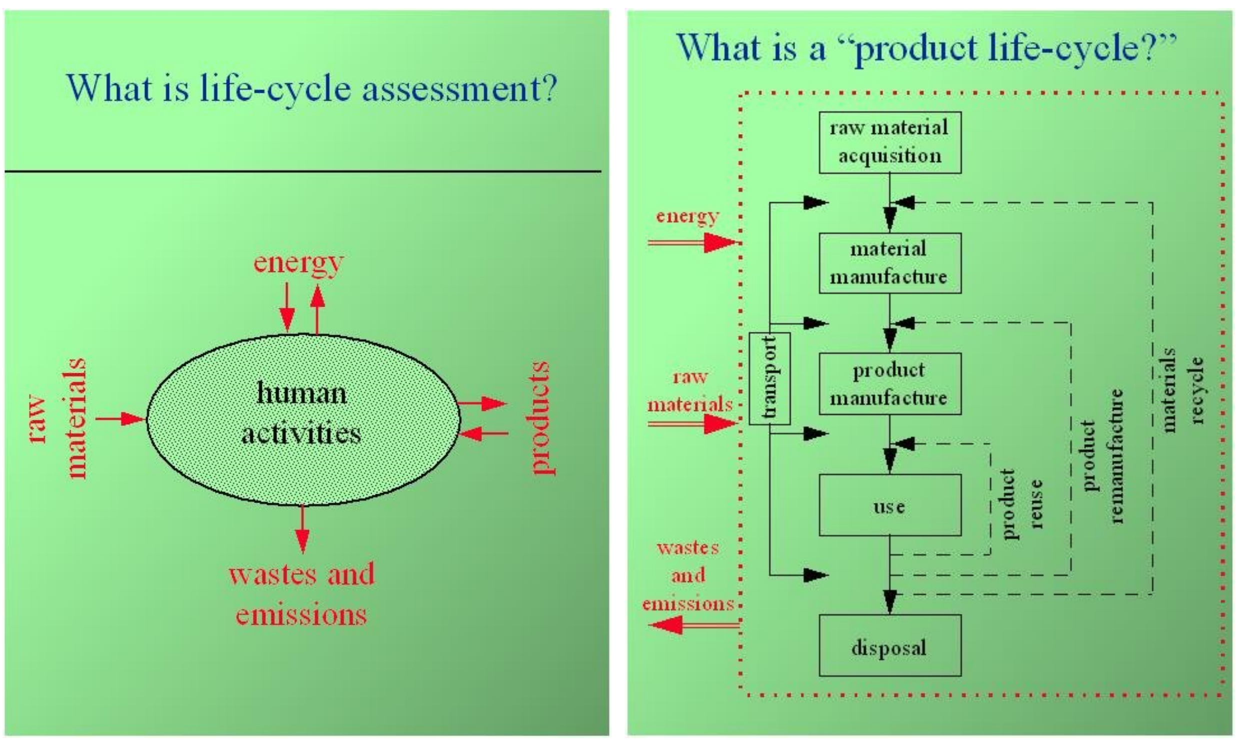

Fig. 1 : LCA and product life cycle assessment

There are three main steps in a life-cycle assessment:

1) Determine the emissions that occur and the raw materials and energy that are used during the life-cycle of a product. This is called a life-cycle inventory.

2) Assess what the impacts of these emissions and raw material depletions are. This is called a life-cycle impact assessment.
3) Interpret the results of the impact assessment in order to suggest improvements. When LCA is conducted to compare products this step may consist of recommending the most environmentally desirable product. This is called an improvement analysis.

6.2 **Functional Unit**

A Functional Unit is a quantified description of the performance of the product systems, for use as a reference unit. Tea can be stored in many different ways while it is drunk, the hair can be made in different ways and there are different ways of mowing a lawn. To ensure that the different ways of providing a service are comparable, the service must be defined and quantified. Functional Unit serves this purpose. When alternatives products are compared, FU is the fixed reference point for the environmental assessment.

Illustrations of FU:

(1) The Fast Food Center in KU uses melamine plates to serve lunch. They can be replaced by steel plates or Expandable Polystyrene (EPS) plates. Melamine plates can be used for 1,500 times on an average. Steel plates can be used for 5000 times on an average. EPS plates can be used for one time only. 100 students and 25 faculties eat in the Center every day.

FU in this case could be the requirements of plate to serve food in the Center for a period of one year.

Total number of serve per year = 125 serves per day * 6 days / week * 4 week / month * 4 month/semester * 2 semester /year = 24,000 servings per year.

Number of plates required to serve the FU can be found as:
Melamine plates = (24,000 servings / yr) / (1500 servings per unit) = 16 unit
Steel plates = (24000 servings / yr) / (5000 servings per unit) = 5 Units
EPS plates = 24, 000 units

(2) Three examples of functional units for various products are shown in Table 6.1.

Table 6.1 : Examplese of functional units for various products

Product	Quantity	Duration	Qualities
Television	Reception of TV program in color on a 21 inch screen	6 hours per day for 10 years	Sharpness of image, quality of sound, no of channels and remote control facility
Refrigerator	200 L volume capacity cooled to 5° C at an ambient temperature of 25°C	13 Years	Accuracy in temperature control, Re-evaporation of melt water from defrosting, shelves boxes
Paint	Protection of 1 m^2 metal surface on an outdoor façade, facing west and exposed to sun and rain	10 years	Non-dripping, color and durability

The functional unit determines equivalence between systems. Choosing a functional unit is not always straightforward and can have a profound impact on the results of the study. For example, if paper and plastic grocery sacks are to be compared in an LCA, the functional unit would be a given volume of groceries. Because fewer groceries, in general, are placed in plastic sacks than in paper sacks, the sacks would not be compared on a 1 to 1 basis. Instead, two plastic sacks might be determined as having the equivalent function of one paper sack.

6.3 **Product Properties**

There are three major groups of product properties.

An obligatory property refers to an attribute of the product which is a must to be at all considered as an object of product substitution. Example : A beverage container must not leak.

A positioning property is a property that is considered nice to have by the customers preferences and therefore does not affect product substitutability, but may influence the reference flow. As of this property the product is positioned more favorably with the customer relatively to other products with the same obligatory properties. Example: A beverage container may be more or less easy to handle.

Market-irrelevant properties that do not play a role for the customer’s preferences. Example: A (refillable) beverage container may be more or less easy to clean.

Properties may be related to:

- Functionality, related to the main function of the product
- Technical quality, such as stability, durability, ease of maintenance
- Additional services rendered during use and disposal
- Aesthetics, such as appearance and design
- Image (of the product or the producer)
- Costs related to purchase, use and disposal
- Specific environmental properties

A survey of office chairs in the market revealed the following information. The labour’s chair is intended for labourer, who is sitting on the chair at intervals only and not for many hours at the time, and who has intermittent standing or walking working positions. The computer workstation chair is intended for the worker, who is primarily sitting, and who is working behing a visual display unit, e.g. a computer, for a significant part of the day (at least two hours a day). The manager’s chair is intended for the design-oriented person. This person is not working much on computer, writing or drawing, but rather reading, talking on the telephone and the like. This chair could typically be for the employer or senior employee, to whom design, aesthetic, and image/representativity to customers are important issues.

Table 3 : Selected technical properties of office chairs (O – obligatory, P – positioning)

Property	Market Segment		
	Laborer’s chair	Computer workstation chair	Manager’s chair
Seat height adjustable	O	O	O

Back rest adjustable	O	O	
Back rest inclination adjustable	O	O	P
Seat inclination adjustable		O	P
Arm rest available	P	O	O
Arm rest adjustable	P	P	P
Roller brakes and choice of soft and hard rollers	P	P	P
Angle between seat and back rest adjustable		P	P
Sophistication of chair movement		P	P
Seat depth adjustable and position lockable		P	

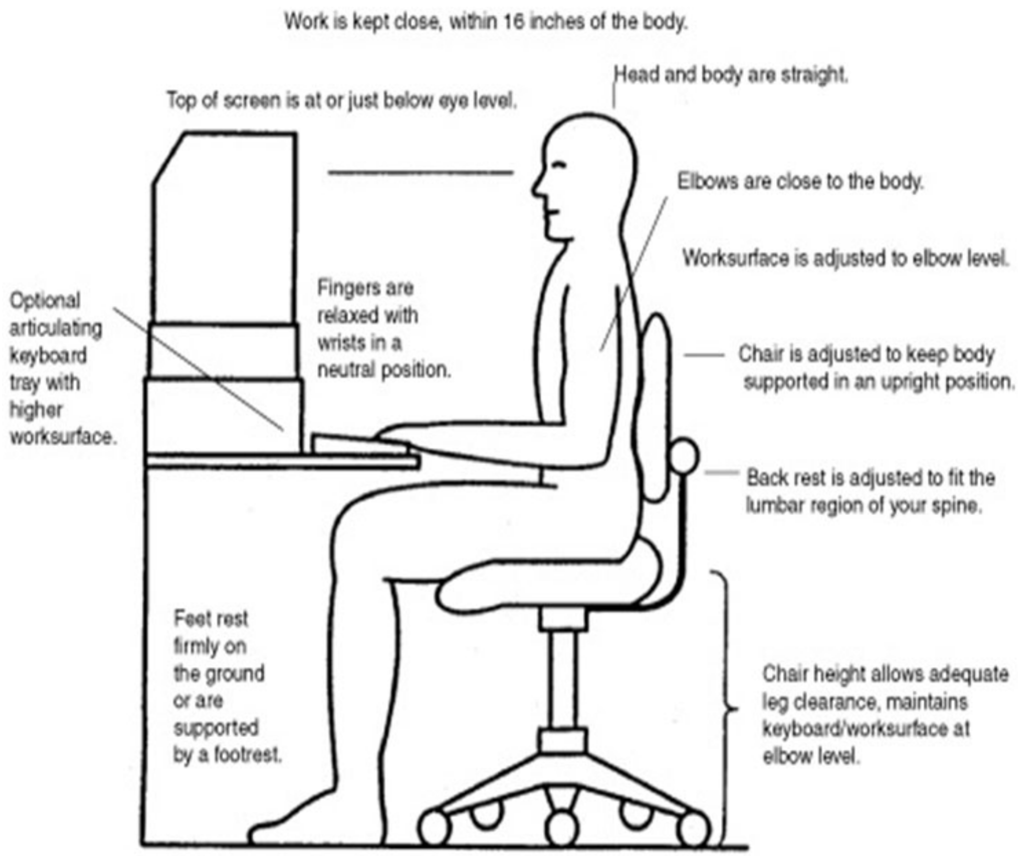

Fig. 2 : Requirements of a workstation chair

6.4 **Activities**

6.4.1 Products properties and functions

Select one of the following products and identify

1. Function of the product
2. Obligatory properties of the product
3. Positioning properties of the product
4. Other products which could provide the same or similar service to the user
5. Discuss which product can deliver the service with least environmental impact

Products : Book, Toilet soap, Plastic bottle, Chair, Hand towel, Light bulb, Food-box, Fire extinguisher, cup, dictionary, chalk

You may wish to put those in a Table given below.

Table 6.1 : The service provided by the product

Product name	
Function	
Obligatory properties	
Positioning properties	
Other products which provide the same services to the user	

6.4.2 Inventory

Exercise about the unit process

Assume that you are involved in a LCA study of food products, and that you have just returned from an interview about baking bread in private household. Your notes can be found below.

- The interviewed person normally bakes two bread at athe time (weight is 0.9-1.1 kg each)
- The main ingredients are: 1.3 – 1.5 kg flour, 1 liter of water (+ /- 10 %) and two eggs (40-60 g each).
- Baking : normally takes 50-70 minutes in the oven (effect 1000 W)
- For washing, about one liter of water is used (heated from 10 -60 degrees C)
- Approximately 2% of the dough is washed out during washing
- Approximately 100 gram of paper packaging and 10 g of PE packaging is thrown away after baking

Based on the above information about bread baking

(1) Define a reasonable key unit for the process
(2) Determine the environmental exchanges associate with the process (see process chart)

6.4.3 Life cycle check of a whiteboard marker

0. Introduction

Whiteboard markers are used frequently for writing and drawing on the white board during teaching, workshops, seminars etc. The whiteboard markers are available in different colors and can be made of different materials.

An imaginary producer of white board markes is aware of the increasing demand for environmentally sound products and wants to have an "LCA – Check" of one his pens in order to find environmental improvement options. The white board marker being used in KU can be examined during assignment. The composition is listed in Table 1.

Table 1 : Composition of the white board marker

(**To be continued.**)

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Table 1 : Composition of the white board marker

Compound	Material	Weight, g	Production process
Casing	Aluminium	4.2	Dye casting
Cap	PE – plastic	2.0	Injection moulding
Connection	PE- Plastic	1.4	Injection moulding
Ring (transparent)	PE-Plastic	0.2	Injection moulding
Sponge	PA-Plastic	3.0	?
Tip	PA-Plastic	0.6	?
Solvent	Solvent	4.3	From crude oil

1. Definition of the service provided by the product
   1.1 Define and describe the services provided by the whiteboard marker.
   1.2 Identify properties of the product and consider which are obligatory and which are positioning (See Chart 1). Find help in the text on the marker.
   1.3 Identify potential secondary services provided by the whiteboard marker.
   1.4 Define a functional unit for the whiteboard marker.
   1.5 Identify other products, which could provide a similar service to the user.

2. Determination of the products life cycle
   2.1 Make a flow diagram of the whiteboard markers life cycle.
   2.2 Assess how many markers are required to provide the functional unit.
   2.3 Make a component list for the whiteboard marker (Chart 2)
   2.4 Make an end life scenario for a whiteboard marker used in Nepal and calculate masses of saved and lost material per functional unit (Chart 3)
   2.5 Make a conservative transportation scenario and calculate the maximum transportation work in kgkm and MJ per functional unit (Chart 4)

3. Assessment according to the MECO principle

Take a look into the MECO-Chart (Chart 5) and enter all relevant information about materials, energy, chemicals and others in the products life cycle. Use the following the input as inspiration.

Materials

- Enter for each life cycle stage the use of resources (assume that the resource content of one kg plastic is one kg of oil).
- Calculate the resource use in terms of person reserve (PR)
- Enter the amounts and types of waste in the disposal stage (Including slag and ashes from eventual incineration)
- Enter resource savings due to potential recycling in the disposal stage

Energy

- Enter energy use/production in MJ in each life cycle phase
- Recalculate the total energy use/production in each phase into oil equivalents
- Recalculate the oil equivalents into person reserves (PR)
- Evaluate whether energy use from transportation is important compared with other energy consuming processes

Chemicals

- Identify emissions of chemicals in each life cycle phase
- Pay special attention to ethanol emissions to soil (landfill) and the atmoshphere
- In Denmark, the limit of oil products in drinking water is 10 mg/m^3 per functional unit, how much groundwater can be polluted to this limit due to disposal of ethanol at landfills (provided that all disposed ethanol percolates into the groundwater)
- According to the United States Department of Labour, the limits for ethanol in air in the working environment is 1900 mg/m^3. Calculate the amount of air, which can be polluted to this limit by one white board marker, and evaluate potential problems in the working environment.

Others:

Identify other impacts by the product in each life cycle stage which have not been dealt with in the above. Examples : use of land, impacts on the working environment, noise, dust, smell and hygiene.

4. Interpretation and environmental optimization

Interpretation

The above analysis of the white board marker provides an overview of the products environmental profile and it is now time to interpret the results and look for environmental improvement options.

4.1 Which processes and materials turned out to be the most important for the overall environmental properties of the product (resource use, energy use, emissions of chemicals and others) ?

4.2 Which process and materials turned out to be of less importance?

Environmental improvement of the product

Now that the environmental properties of the whiteboard marker have become clear, it is time to look for environmental improvement options. This is a creative process, which requires an open mind and a good portion of creativity.

4.3 Make a “brainstorm” in your group and make list of all the ideas that you can think of. Include changes directly related to the product as well as changes at society level.
4.4 Select one idea, and analyze to what extent a revised product provide the obligatory and positioning properties as defined earlier.
4.5 If you believe that the new idea for the product has a market potential, analyse the revised products environmental improvements/reductions relative to the existing product.

Chart 1 : Obligatory and positioning properties

Obligatory properties	Positioning properties

Chart 2 : Component list

Component			Material		
No.	Number of items	Name	Name	Mass per unit gram	Mass per functional unit
1					
2					
3					

Chart 3 : End of life scenario

Material name	Mass g	Process	Fraction %	Mass g	Saved material g	Lost material g
Aluminium		Recycling				
		Incineration				
		Landfill				
		Total				
PE-plastic		Recycling				
		Incineration				
		Landfill				
		Total				
PA -plastic		Recycling				
		Incineration				
		Landfill				
		Total				
Ethanol		Recycling				
		Incineration				
		Landfill				
		Total				

Chart 4 : Conservative transportation scenario

Material / component	From	To	Distance km	Weight kg	Transport work kgkm	Transport type	Energy use MJ

Conservative estimate of the total energy use for transportation process: ……………MJ

Chart 5 : MECO Matrix

	Material phase	Production phase	Use phase	Disposal phase
Materials				
Energy				
Chemicals				
Others				