Chapter- VII

ENVIRONMENTAL MANAGEMENT SYSTEM

7.1 Life Cycle Assessment

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.

These products cause environmental impact from in different stage like production, operation and disposal. Different products fulfill the same need may cause different environmental impacts. 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).

The entire life cycle for a manmade product goes from obtaining everything needed to make the product, through manufacturing it, using it, and then deciding what to do with it once it is no longer being used. As such, this kind of view is often called a "**cradle to grave**" view of a product, where the cradle represents the birthplace of the product and the grave represents what happens to it when we are done with it – often to be disposed in a landfill site.

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

The goal of LCA is to analyse the energy, resource and water consumption and minimize the environmental 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;

7.1.1 Stages in Life Cycle Assessment

An LCA study consists of four stages:

Stage 1: Goal and scope aims to define how big a part of product life cycle will be taken in assessment and to what end will assessment be serving. The criteria serving to system comparison and specific times are described in this step.

Stage 2: In this step, **inventory analysis** gives a description of material and energy flows within the product system and especially its interaction with environment, consumed raw materials, and emissions to the environment. All-important processes and subsidiary energy and material flows are described later.

Stage 3: Details from inventory analysis serve for **impact assessment**. The indicator results of all impact categories are detailed in this step; the importance of every impact category is assessed by normalization and eventually also by weighting.

Stage 4: Interpretation of a life cycle involves critical review, determination of data sensitivity, and result presentation.

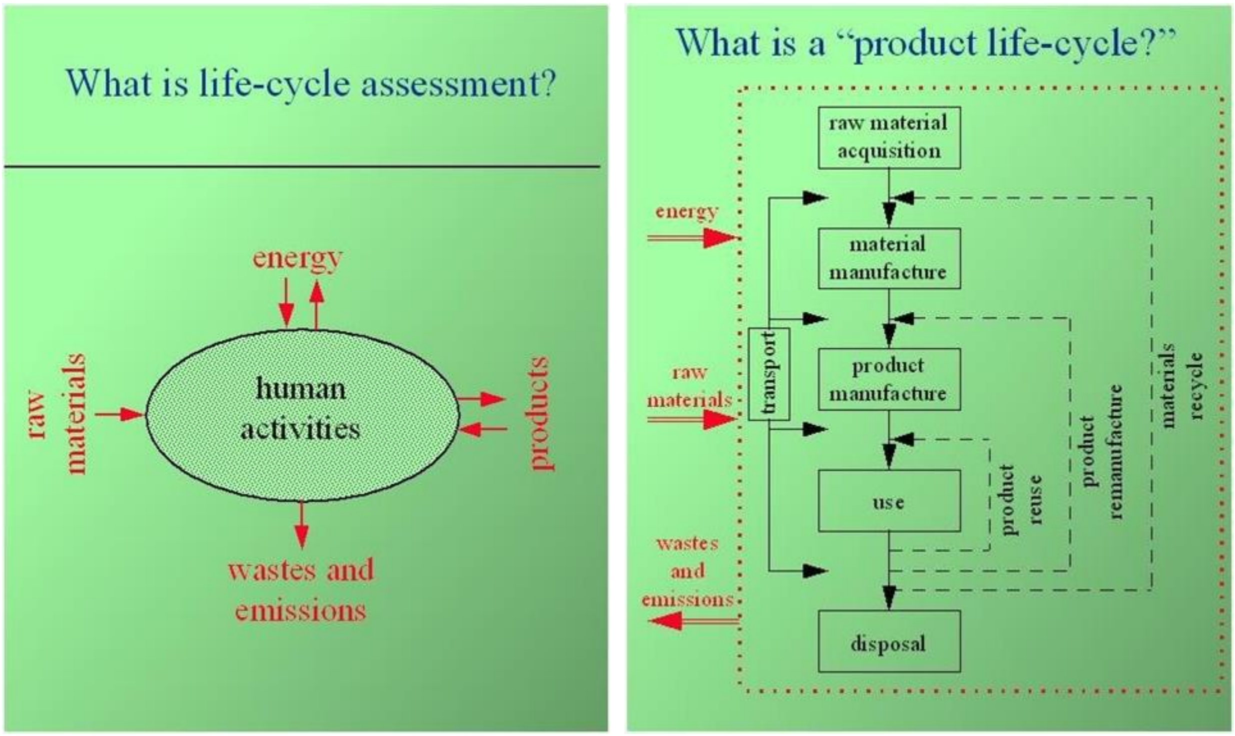

Fig 1. LCA and product life cycle assessment

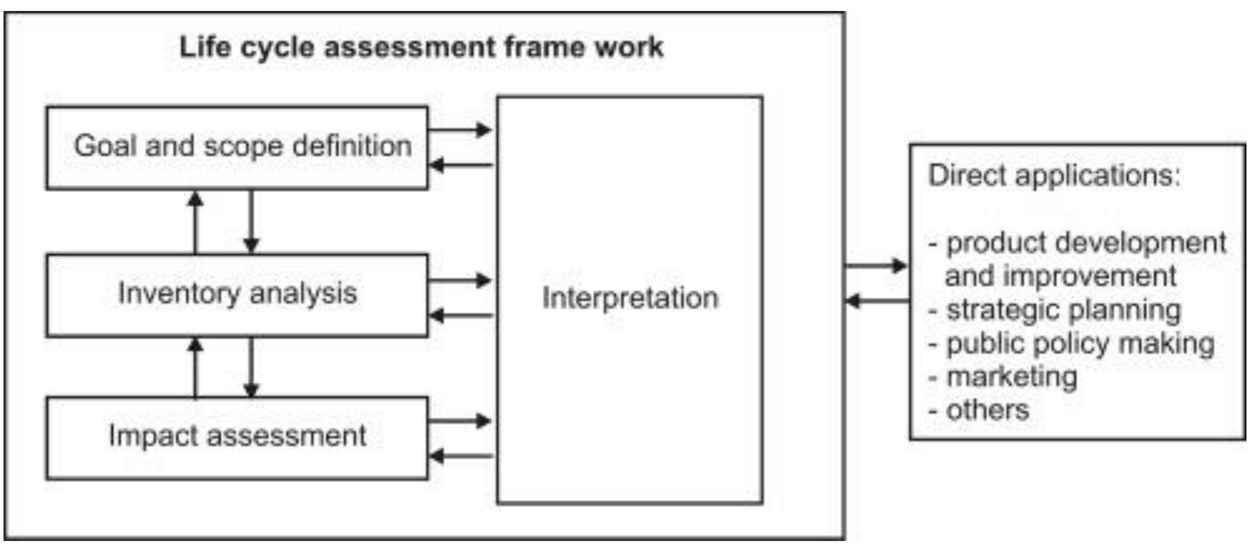

Fig 2: Four stages of LCA (ISO 14040).

Example: A car is put together from components at a factory. It is then delivered to a dealer, purchased by a consumer, and driven for a number of years. At some point the owner decides to get rid of the car – perhaps selling it to another driver who uses it for several years. Eventually the owner finds no sufficient value for it, and it will likely be shredded into small pieces and useful materials reclaimed.

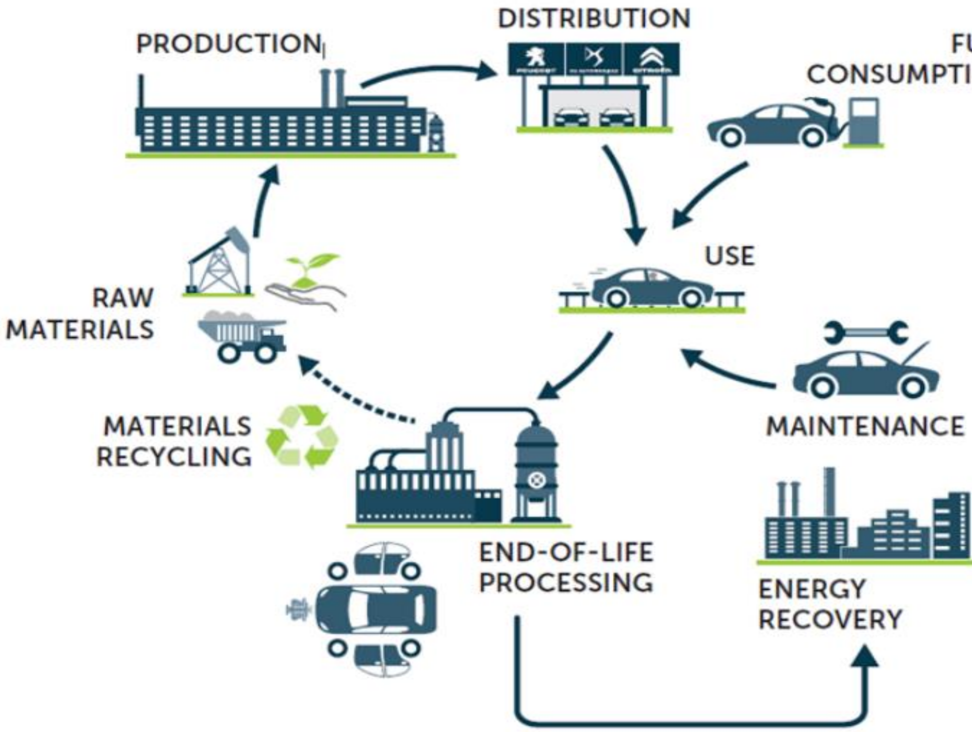

Fig 3: Vehicle Life Cycle

7.1.2 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: 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

7.2 Environmental Impact Assessment

EIA is a major instrument applied with the goal of making economic development projects environmentally sound and sustainable.

EIA is used to organize, collect and analyze information on the environmental effects of a particular project. In this process, EIA performs the following functions:

- Identifies potential environmental consequences
- Examines the significance of environmental implications
- assesses whether impacts can be mitigated and if so,
- recommends preventive and corrective measures,
- informs decision-makers and concerned parties about environmental implications,
- advises whether or not the proposed development should proceed.

An application of EIA aims to:

- provides decision-makers with complete and balanced information,
- assesses intangible, unquantifiable effects that are not addressed by other technical reports,
- provides a source of information on a proposal to the public,
- formalizes the consideration of alternatives to a proposal being considered, and
- improves the design of development and safeguards the environment
- through the application of mitigation and avoidance measures.

The application of EIA benefits the projects in

- lower project costs in the long term,
- plan for and implement avoidance or remedial measures in time to minimize adverse impacts,
- protect the environment,
- provide an opportunity for the public to get involved and participate,
- enhance public confidence, and
- foster good public relations

7.2.1 EIA and Project Cycle

To meet the objective of environmental soundness, the EIA should be initiated at the beginning of the project cycle and continue throughout the life of a project in a proactive manner

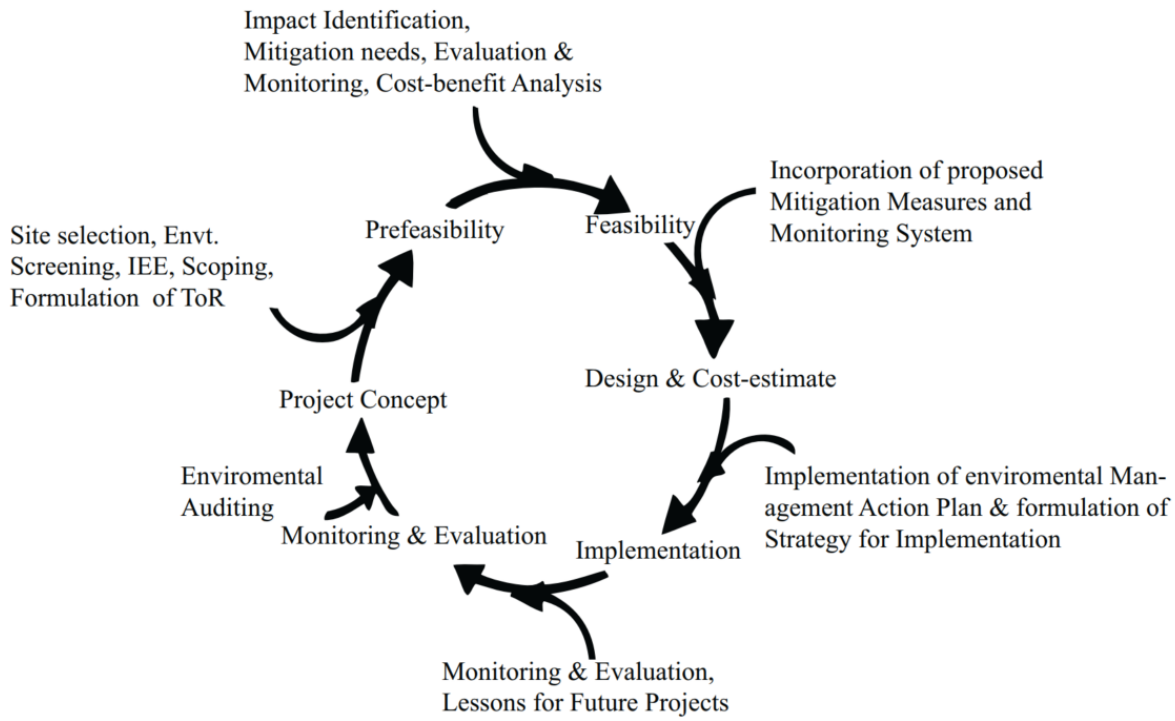

Figure 4 Project Cycle

7.3 Green Engineering

Green engineering is the design, discovery, and implementation of engineering solutions with an awareness of potential benefits and problems in terms of the environment, the economy, the society throughout the lifetime of the design. The green engineering approach is scalable and applies across molecular, product, process, and system design. This approach is as broad as the disciplines of engineering themselves and relies on the traditions of innovation, creativity, and brilliance that engineers use to find new solutions to any challenge. The goal of green engineering is to minimize adverse impacts while simultaneously maximizing benefits to the economy, society, and environment.

7.3.1 Principles of Green Engineering

The Twelve Principles of Green Engineering provide a framework for understanding green engineering. They also represent the techniques that can be used to make engineered solutions more sustainable. The 12 principles should be thought of not as rules, laws, or inviolable standards. They are instead a set of guidelines for thinking in-terms of sustainable design criteria. The Twelve Principles are:

I. **Inherent Rather Than Circumstantial:** Designers need to strive to ensure that all materials and energy inputs and outputs are as inherently nonhazardous as possible.
II. **Prevention Instead of Treatment:** It is better to prevent waste than to treat or clean up waste after it is formed.
III. **Design for Separation:** Separation and purification operations should be designed to minimize energy consumption and materials use.
IV. **Maximize Efficiency:** Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.

V. **Output-Pulled Versus Input-Pushed:** Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.

VI. **Conserve Complexity:** Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.

VII. Durability Rather Than Immortality: Targeted durability, not immortality, should be a design goal.

VIII. **Meet Need, Minimize Excess:** Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.

IX. **Minimize Material Diversity:** Material diversity in multicomponent products should be minimized to promote disassembly and value retention.

X. **Integrate Material and Energy Flows:** Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.

XI. **Design for Commercial "After life":** Products, processes, and systems should be designed for performance in a commercial “afterlife."

XII. **Renewable Rather Than Depleting:** Material and energy inputs should be renewable rather than depleting.

7.4 Sustainable Design

Embedded in the discussion of green engineering is the word ‘Design’. Design is the engineering stage where the greatest influence can be achieved in terms of sustainable outcomes. At the design stage, engineers are able to select and evaluate the properties of the final outcome. This can include material, chemical, and energy inputs; effectiveness and efficiency; aesthetics and form; and intended specifications such as quality, safety, and performance.

The design also represents the time for innovation, brainstorming, and creativity, offering an occasion to integrate sustainability goals into the specifications of the product, process, or system. Sustainability should not be viewed as a design constraint. It should be utilized as an opportunity to leapfrog existing ideas or designs and drive innovative solutions that consider systematic benefits and impacts over the life-time of the design.

For a given investment (time, energy, resources, capital) potential benefits can be realized. These benefits include increased market share, reduced environmental impact, minimized harm to human health, and improved quality of life. In the case where constraints require merely optimizing the existing solutions or making incremental improvements, some modest gains can be achieved. However, if the degrees of freedom within the design space can be increased, more benefits can be realized. This is because the engineer has an opportunity to design a new solution that may appear very different in form but provides the same service. This may pose challenges if the new design is too embedded into an existing and constrained system. Ultimately, the most benefits can be achieved when the engineer designs with the most degrees of freedom- at the highest system scale – to ensure that each component within the system is sustainable, performs with the other system components, and meets the overall intended propose.

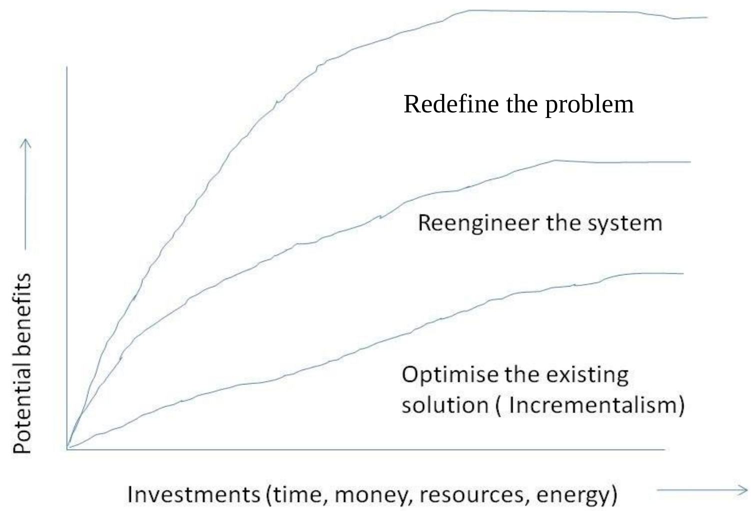

Fig. 5: Increasing Potential Benefits with Increasing Degrees of Design Freedom for a Given Investment (Allowing an increased number of degrees of freedom to solve a problem frees up more design space to innovate and generate sustainable solutions)

References

[1] "Environmental Management - Life Cycle Assessment - Principles and Framework," ISO 14040:2006, International Organisation for Standardization, 30 Jun 06.

[2] C. Hendrickson *et al.*, "Economic Input-Output Models for Environmental Life-Cycle Assessment," Env. Sci. Tech. Policy Analysis **32**, 184A (1998).

[3] G. Finnveden *et al.*, "Recent Developments in Life Cycle Assessment," J. Env. Management **91**, 1 (2009).

[4] T. Ekvall and G. Finnveden, "Allocation in ISO 14041 - A Critical Review," J. Cleaner Prod. **9**, 197 (2001).

[5] M. Marsmann, "The ISO 14040 Family, " Int. J. Life Cycle Assessment **5**, 317 (2000).

[6] C. I. Jones and G. P. Hammond, "Embodied Energy and Carbon in Construction Materials," Proc. ICE - Energy **161**, 87 (2008).