REVIEW OF PAPER AND PULP INDUSTRY IN BANGLADESH: MATERIAL FLOW MANAGEMENT APPROACH

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ABSTRACT

Industrialization brings a lot of environmental problems. Imprudent intensity of materials use and untreated discharge of unwanted materials are responsible for environmental degradation. Paper and pulp industry is among the top-ranked polluting industries in Bangladesh. Industrial Material Flow Management is a way to motivate the producers to go in an environmental way. Industrial Material Flow Management exercises reduce-reuse-recycle concept and thereby reduces emissions, wastes and energy consumptions. By utilizing the concept, paper and pulp producers can benefit from chlorine-free production, cost saving as well as low emissions and waste; it enhances image too as 'green producer'. Various tools, namely - Life Cycle Assessment, Material Flow Accounting, Eco-efficiency, Input-Output Analysis etc. are used as tools for resourceful industrial material flow management practice. Implementing material flow management techniques requires connoisseur knowledge; a well-balanced team of experts of different disciplines; and a sequential process of activities.

Keywords: Material Flow Management, Paper and Pulp, Waste, Emission

INTRODUCTION

1.1 Description of the Problem

Decoupling growth and environmental protection is the primary focus for a better sustainable world so that the future generation is not worse off. Environment remains vulnerable to production processes if unwanted outputs from the process are just thrown to the earth surface. In addition to throwing the waste and unwanted output to the earth surface, industrialization has become the root cause of consuming fossil energy. Raw materials are different for each and every product or service people consumes, *except energy*. Energy in any form is the only common input for production of goods and services to satisfy human needs. Through this huge consumption practice, not only the earth's resources are depleting, but also climate is changing with the emissions from different steps of production. The study of Goddard Institute for Space Studies (GISS), NASA, USA (2006) shows that over the past 30 years the earth has warmed by about 0.6 degree centigrade (equivalent 1.08° Fahrenheit). Since 1850, global temperature was higher (than any other years) for eleven years in a twelve years period starting from 1995 to 2006 (IPCC 2007:30).

Bangladesh has some remarkable achievements in social and economic areas, but still lack far behind environmental issues. One reason for this falling behind is the lack of proper care of environmental issues while developing economic and social planning. Material flow of industrial processes in Bangladesh is not observed meticulously and the sources of environmental degradations are unnoticed. As the proper care for energy and waste issues facilitates economic benefit in the long run, material flow management of particular industry will benefit the whole industry both in achieving environmental standard and economic gain. Simultaneous mastery in both environmental and economic issues will lead the industry go beyond the regional or local market to global market. Even with huge potential for saving production cost and thereby gaining higher profit margin, the industries in Bangladesh are not practicing industrial material flow management. Some specific pollution prevention or end-of-pipe system have been utilized in a case-to-case basis, but wide range material flow management practice still need to be explored.

As a polluter, paper and pulp industry in Bangladesh is among the top. The sector is contributing substantially in Gross Domestic Product (GDP). In addition to massive energy consumption, level of emission and volume of untreated waste and waste water are high. Even with government initiatives, close monitoring is difficult if the producers themselves are not enthusiastic to go environment-friendly way; it is difficult to force to implement.

1.2 Purposes and Methodology of the Study

Industrial Material Flow Management (MFM) is the way by which producers become interested and willing to produce in an environmental way. Industrial MFM strategies bring financial benefit too, which is the prime concern of the entrepreneurs; hence easy to motivate the key stakeholders to play active role in eco-friendly production process. Implementation of corporate material flow management strategies will lead to a sound industrial process, where energy consumption will be reduced (also energy outsourcing); opportunities for energy generation from own sources will be developed; waste volume will go down and emission level will be in line with local and global standards. Under the system, wastes will be used as resources; ultimate disposal will go down, so that land filling requirement will be reduced. The specific objectives of the paper are as follows:

- To find the problems for implementing techniques and tools of material flow management in paper and pulp industry of Bangladesh,
- To find the causes that hinders implementation of material flow management concept,
- To find out the opportunities where MFM tools can be applied and how,
- To provide some guidelines to the focused industry sector for implementing MFM tools and techniques.

As the information technology is not good enough in developing country strong production database is not available; in addition, there are not substantial research works on

Bangladeshi paper and pulp industry, so, the good practice has been considered in few cases to find the opportunities and to suggest how industrial MFM can be applied.

A literature review has been done on the basis of literature available. Firstly, the basic concepts of the term MFM are explored and activities of MFM that are covered under industrial MFM. Secondly, current practice of paper and pulp industry in Bangladesh is investigated. Thirdly, problems of current practice of paper and pulp production are analyzed and finally, some conclusions as well as recommendations are made. Review of literature is predominantly based on secondary data and the global good-standard practice has been used while making suggestions. Secondary data from different local and international organizations are used. The principle method of the research is qualitative analysis and used multi disciplinary approach including methods from environment, technology and management.

This paper is organized as follows. Section 2 gives an overview of Bangladeshi paper and pulp industry and the concept of industrial MFM, its coverage. Problems of paper and pulp industry in relating material flow and its management in Bangladesh is outlined in Section 3. Both general and industry specific problems of implementing industrial MFM are discussed in Section 3. Different tools of industrial MFM are discussed in Section 4 before making suggestions on how to improve the existing system detailed in Section 5. Concluding remarks are offered in Section 6.

BACKGROUND AND BASIC CONCEPTS

2.1 Overview of Paper and Pulp Industry in Bangladesh

In Bangladesh, both state owned and private pulp and paper mills have been operating since long. State-controlled four pulp mills are Karnafuli Paper Mills (KPM), Sylhet Pulp and Paper Mills (SPPM), North Bengal Paper Mills (NBPM), Khulna Newsprint Mills (KNM). Among these KPM, NBPM and KNM are integrated pulp and paper mills and SPPM produces only market pulp and are run by Bangladesh Chemical Industries Corporation (BCIC) (The Independent, 6 March 2002). The KPM is an integrated pulp and paper mill, where the Kraft pulping process is used. Bamboo and hardwood are the fibrous raw materials. Bamboo, however, is now a scarce raw material. So the mill uses heterogeneous mixture of different hardwoods (BCIC, 2009). There are more than 20 producers of different sizes running under private ownership allover the country but concentrated mostly near the capital city. These private sector mills use waste paper, market and imported pulp as the fibrous raw material. Waste papers are mostly imported, and only a small quantity is collected locally (Banglapedia, n.d.).

Paper and pulp manufacturing can be classified either by its production type, like – printing and writing paper, facial tissue and sanitary tissue, containerboard or boxboard etc. or by the pulping process used by the manufacturers, namely – mechanical pulping and chemical pulping. In any case, pulping process has the most impact on environment. Mechanical pulping from chips is not used for papermaking in Bangladesh; only ground wood process is used in the country, mainly in newsprint mill at Khulna (KNM) (Banglapedia, n.d.). The preferred wood species are light colored and long fibred softwoods. No softwood is available

in Bangladesh. Gewa wood (Excoecaria agallocha) with a mild chemical treatment before grinding is used. In chemical pulping, sufficient lignin is dissolved mainly from the middle lamella to allow the fibers to separate with little, if any, mechanical action; however, a portion of lignin is retained in the fiber wall (Gutierrez and Jose del Rio). Complete removal of lignin during pulping would result in excessive degradation of the pulp. In Bangladesh different hardwoods, for instance, gamar (Gmelina arborea), shimul (Bombax ceiba), kadam (Anthocephalus chinensis), pitraj (Amora species), Koroi (Albizia species), etc, are generally used for chemical pulping. Table 1 (see annexure) shows some selected production parameters of pulp and paper industry:

2.2 Basics of Industrial Material Flow Management

Material Flow Management (MFM) often misunderstood with resource management and/or environmental management. Resource Management comprises the analysis, planning and allocation, exploitation, and upgrading of resources (Brunner and Rechberger, 2004). From organization point of view, resource management refers to efficient and effective deployment of resources of any kind, like- financial, inventory, human, production, IT etc, whenever these are used or required. Similarly, environmental management refers to managing the environment while manufacturing product and/or generating services. Here the term 'managing environment' refers to reducing impact on local and/ or global environment arises from raw material acquisition, process or disposal or any other causes. The extent to which material flow management differs (more specifically, MFM's superiority) has been clarified by the Commission of Inquiry of the 12th Deutsche Bundestag[1] as"…the objective-oriented, responsible, integrated and efficient controlling of material systems, with objectives arising from both the economic and ecological sector and with the inclusion of social aspects" (Deutschen Bundestages, 1994).

The term corporate material flow management and industrial material flow management are used synonymously. From the definition, it is clear that MFM is neither simply resource management nor environmental management, rather its focus comprises both the terms. MFM ensures three corners - economical, environmental and social issues – of sustainable development. From national perspective, MFM deals with efficient and effective use of resources and energy to serve consumption of the population, so that wastes remain at the lowest possible limit; environmental impacts hang about minimum; society enjoys better standard of living and increased feeling of well-being. From corporate point of view, MFM focus on corporate benefits by means of the best (not better!) utilization of resource and energy at lowest cost possible to produce optimum quality of products and services to serve consumers. Material flow management offers the opportunity to combine economic profit with regional added value and environment protection (Heck and Bemmann, 2002).

2.2.1 MFM and Its Coverage

MFM is a multi-disciplinary approach with specific options for individual situation. MFM tries to close the loop of ordinary linear model of input-process-output. Changing the current material flow to future material flow with high resource efficiency and added value is the

goal of MFM strategies. MFM is linked with other disciplines of business, environment and engineering (Heck and Bemmann, 2002) as shown in Figure 1 (see annexure):

2.2.2 Obstacles of Material Flow Management

Even MFM has been getting focus by industries as well as both local and national government, the process of development is still dawdling. There are several obstacles blocking the widespread dissemination of the material flow management in corporate practice (Wagner and Enzler, 2006). The major issues that are hindering the development of MFM are mentioned below:

- The existing value-added chains are of great priority to the stakeholders and they think changes in the structure may reduce the interest they have now.
- Lack of cooperation among the companies when the design for MFM is drawn on a dependent chain of actions.
- Some MFM approaches are yet to be tested and require field implementation to make these feasible actions.
- Lack of understanding the concept of MFM as a unique company task and thereby lack of motivation to implement such concept.

3. Problems Relating Material Flow and its Management in Paper and Pulp Industry

The resources being used, the level of emissions from the production and waste volume are not observed almost in all industries in Bangladesh. Traditional out-of-date technology does not have the system of data storage and the owners are not in position or even willing to change the technology as long as the oldest set of machinery and equipment can produce desired output. Both the practice and man behind the practice are equally responsible for not observing the resource issues relating core and ancillary production process. The following part of the paper tries to focus on problems regarding material flow management in the paper and pulp industry of Bangladesh.

3.1 Industry Specific Problems

In terms of organized and capital intensive forest industries in Bangladesh, the pulp and paper industry ranks first. Government owned major pulp and paper mills rely highly on forest for their fiber resources whereas private sector paper and board mills rely on imported pulps (Saha el al., 1997). Paper manufacturing is an energy intensive complex process. Pulping is the process which reduces wood to a fibrous mat by separating the cellulose from the lignin (USEPA, n.d.). The yield of this pulping process is high ranging from 95%-99%. In chemical pulping the wood is cooked under high pressure in heavy acid or alkaline solution yielding about 50%-60% (Lieshout, 2006).

Pulping and bleaching process of pulp and paper manufacturing process have the most significant environmental impacts. In some processes, sulfur compounds and nitrogen

oxides are emitted to air and chlorinated and organic compounds, nutrients and metal are discharged to the wastewaters; the mills are the source of significant amounts of pollutants that are released to the environment (World Bank, 1998). Both separated and integrated pulp and paper mills have the same level of emissions.

3.1.1 Emission Problem

Both pulping process and power generation unit, if any, of paper and pulp mills generate emissions. Pulping and bleaching stages as wee as energy generation emit the most. Emissions from paper industry occur to air, water and land surface.

Emission can be categorized as fugitive emissions, i.e. dust from stockpiles, material handling or from equipment leaking etc. and point source emissions that are exhausted into vent or stack and emitted through a single point source (NPI, 2013). Common air emissions from paper and pulp process are listed in the Table 2 (see annexure):

The basic water emissions from pulp and paper manufacturing process are listed in the Table 3 (see annexure):

Surface impoundments of liquids and slurries as well as unintentional leaks and spills are the substances emitted to land. This includes solids wastes, sediments, storage and distribution liquids etc. The pulp production produces vast solid waste everyday and finally dewatered and burned or landfilled, all of which have ultimate environmental impact.

3.1.2 Energy Problem

The forest product sector has several unique energy consumption attributes that distinguishes it from other manufacturing sectors (ICF, 2007). Rate of paper consumption and production will be influenced both by higher literacy rate and increased population in Bangladesh. The annual production at about 80 to 90% of the installed capacity is 126,000 air dry ton (ADt) in entire Bangladesh (FAO, 2000). To meet this huge demand, production will go up and proportionately energy consumption will increase too.

3.1.3 Waste Problem

Paper and pulp manufacturing process produces huge volume of waste and the majority is green liquor dregs, ash, lime sludge, coating sludge and de-inking sludge. Even, in general, only small quantities of hazardous wastes are produced by the paper and pulp manufacturing, due to higher volume, more space is required for landfilling or disposing the wastes. In the developed manufacturing process, volume of landfill waste from paper and pulp industry is reduced.

3.2 General Problems

The general problems regarding industrial MFM practice in Bangladesh are attributed to the following points:

- Lack of knowledge of stakeholders

- Lack of awareness and commitment of the stakeholders
- Lack of institutionalization of resource consumption
- Lack of technology
- Lack of motivation
- Lack of government initiatives

4. Opportunities for Implementation of Industrial MFM in the Industry

The scale of modern industrial activity, even today, when four fifth of the world is relatively non-industrialized, is great enough to have changed significantly the natural global cycles of carbon and nitrogen (Matthews et al., 2000). Under such condition, enormous opportunities are there for pulp and paper industry to get rid of excess waste, to gain efficiency by reducing use of virgin resources and by using less fossil fuel. The opportunities are totally chlorine free (TCF) pulp production; changing raw material to Jute plant etc. (Mohiuddin, 2004). In addition, corporate MFM will help to optimize the process by reducing input costs for a given output quantity or by increasing output for a given quantity of inputs with efficient implementation of the concepts of reduce-reuse-recycle for energy and resource recovery as shown in Figure 2 (see annexure):

Material flow management combines many technical and planning tools in the field of resource and energy efficiency and thereby, applies them coordinated and tailor made to a company or a region. The basic tools that are widely used and are proven to be successful are discussed below:

4.1 Eco-efficiency Application Tool

Eco-efficiency enables more production with better process while reducing resource consumption, waste, pollution and emissions. WBCSD (2005) focuses eco-efficiency benefits as, "delivery of competitively priced goods and services…that bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle". In modern complex globalized business, to ensure competitive advantage and to enhance image as *sustainable entity*, firms have no alternatives other than reducing cost of production as well as emission and pollution levels, which is easy to achieve by eco-efficiency tools (WBCSD, 2005). Seven elements for eco-efficiency improvement (Verfaillie and Bidwell, 2000) are:

- Reduced Material Intensity
- Reduced Energy Intensity
- Reduced Dispersion of Toxic Substances
- Enhanced Recyclability
- Maximized use of Renewable
- Extended Product Life
- Increased Service Intensity

4.2 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) is a tool for analyzing the environmental impact of production process of a particular product or service starting from raw material preparation to after use disposal. UNEP (2004) suggests that life cycle assessment studies can recognize opportunities and threats of product and/or technology from cradle to grave; UNEP (2004) also remarked that, life cycle approach promotes awareness and informed selection. One has to consider that LCA does not provide results like, "right or wrong" or "best or worst", rather it helps decision maker to trade off between costs and benefits. Depending on the coverage, intensive LCA process can be time and resource consuming. In broader scale, to manage the total life cycle of a product or service, Life Cycle Management (LCM) can be applied (Jensen and Remmen, 2004).

LCA is a systematic process that starts with defining and describing the product, process or activity. In second phase, inventory analysis is done by identifying energy, water and material consumption and environmental releases. Quantifying is also conducted in second phase. During the third phase impact assessment is conducted based on inventory analysis. It assesses both human and ecological effects. Finally the results are evaluated for selection of preferred product, process or service (EPA, 2006).

4.3 Material Flow Accounting (MFA)

As an integral part of MFA, Material Flow Accounting, as defined by European Environment Agency (EEA, n.d.), is *"...a monitoring system for national economies based on methodically organized accounts and denoting the total amounts of material used in the economy. Material flow accounting enables monitoring of total consumption of natural resources and the associated indirect flows, as well as calculation of indicators"*. Material Flow Assessment or Accounting (MFA) is the tool for physical accounting of material (including primary and secondary raw material), production and manufacturing process, emission, waste and energy in regional level. Based on primary interest, basic accounting types are *problem-specific material focused*, where specific material is studied if it is relevant for creation of environmental impact. For example, CO can be studied as it is affecting global warming; and v*olume-specific region focused,* where sustainability of a particular region is studied with the volume and structure of materials. Figure 3 (see annexure) shows the analysis process flow of MFA.

4.4 Input-Output Analysis (IOA)

With primary application in economics, Input-Output analysis (IOA) refers to tool for tracing inputs (resources) and outputs (products) within an economy. Broadly, IOA is an accounting framework used for developing a holistic view of regional economy showing flows of materials and resources to and from industry and society (institutions). In company level, IOA can show how efficiently the inputs are transformed to become output. In addition to IOA, energy balance and emission level calculation will provide a picture of environmental impact for a given quantity of production. Accounting framework involving both goods and waste by extending the IO table to lodge the flow of waste is

fundamental to analyzing relationships between the level of economic activity and the emission of waste (Nakamura and Kondo, 2002). Some manufacturers of electrical appliances have recently started providing waste disposal sectors with detailed information on procedures for efficiently disassembling waste appliances to raise the productivity of disposal sectors (Nakamura, 1999)

4.5 Production Integrated Environmental Protection (PIUS) / Cleaner Production

Production Integrated Environmental Protection (German Acronym is PIUS[2]) is an initiative of five companies, namely - Sonderabfall-Management-Gesellschaft Rheinland-Pfalz (SAM), Landesamt für Natur und Umwelt (LANU), Hessische Industriemüll Technologie GmbH (HIMTECH), ABAG-itm Gesellschaft für innovative Technologie- und Managementberatung mbH, Niedersächsische Gesellschaft zur Endablagerung von Sonderabfall mbH (NGS) for cleaner production system. PIUS increases the competitive advantage by reducing costs as well as by efficient usage of resource and energy in every step of operation and thereby increasing profit margin (PIUS, 2001). Examples of PIUS initiatives lead to the following benefits:

- Substitutions of environmentally un-friendly auxiliary and industrial materials
- Application of efficient and innovative processes
- Usage of energy saving potential i.e. heating Internal circulation management of materials used
- Valuable utilization of unavoidable residues
- Awareness of pre and post stages of production processes
- Ecological product creation (Longevity, ease of repair, lower energy consumption, ease of recycling etc.),
- Usage of, as opposed to, sales of products (ecology leasing).

The tools proposed in this research are already in practice in different countries. The tools are not mutually exclusive. For example, German innovation PIUS may work with other tool like IOA or MFA. In most of the cases, output of various tools may be required as input of other tools or to compare the system efficiency what may also be possible while implementing other tools. For example, in MFA the volume of waste and unavoidable resource measurement is possible. This is also possible with LCA, IOA and PIUS investigation. Implementation of multiple tools may help identify gap in analysis to secure efficient production system.

Suggestions for Implementation of MFM Practice in Paper and Pulp Industry

A typical corporate MFM strategy implementation steps may take the following shape:

Team Formation: The very step is to develop a team consisting people both from inside and outside the organization with expertise in material flow management and

understanding of issues relevant to MFM. The team's responsibilities may include assessment of inputs and outputs, energy and heat as well as fresh and processed water; selection of the process steps etc,

Process Analysis: The activities in this step may include analysis of the process through a flow chart or material balance; calculation of waste streams etc.

Suggestion for Improvement: In this step, suggestions are to be made for the causes identified in the second step. With detailed examination of the process step, and with expert opinion, some suggestions are to be made for upgrading the existing system.

Analysis of Proposed Solution: The proposed solution is to be analyzed from sustainability point of view, where lies the concept of MFM. The suggested solution need to have three fold benefits – economic, environmental and social – in addition to technical feasibility of the solution. While deciding a solution from these four perspective (technical, economical, environmental and social), a balance can be made with some more benefits of one by offsetting some benefits of others; but at the end, it must have positive impact.

Implementation and Monitoring: The last step is implementation of the desired solution to enjoy the whole benefits of industrial MFM strategies. Corporate MFM is not a final solution for resource management and/or sustainability. It needs continuous monitoring. With changes in technological development, industrial MFM reshapes its thinking and policies. So continuous monitoring is must even with better-than-before outcome from the system. With repeated assessment process can be optimized as and when required.

Opportunities for pulp and paper industry to get rid of excess waste, to gain efficiency by reducing use of virgin resources and less fossil fuel are huge. The opportunity for the industry is totally chlorine free (TCF) pulp production that will enable less toxic emission to air and water. With this one goal of sustainable production process, the following benefits will be enjoyed –

- Chlorine-free production will protect water quality, human and environmental health, and good working condition.
- Closing the loop for resources and energy will benefit with less odor, less air pollution and higher workplace safety.
- Green energy generation for own use.
- Image creation as a *green producer.*

CONCLUSION

Corporate material flow management is nothing but a managerial aspect focusing both resource efficiency and environment friendly production process of goods and services. Successful implementation of MFM strategies will lead to enormous benefits irrespective

of the type and size of companies. The major benefits will include improved efficiency in production; higher profit margin by way of cost reduction; resource and energy conservation in the reign of constantly increasing trend of resource prices; easy access to corporate loans, good working environment and hygienic conditions for employees; enhanced image of the company by gaining international standards, like- ISO, EMAS etc. Implementation of industrial MFM requires active and spontaneous involvement of all the units of the company, so the willingness to adopt industrial MFM strategies must be accepted by corporate values. The top management initiates such ideas and the middle and lower management brings it to action. Every layers of the management needs to know the goals of the strategy as well as the outcome of the new techniques. It has been experienced by companies that major change efforts have helped organizations to strengthen their competitiveness and few took significant market share; but in many cases change efforts were proved disappointing with wasted resources and frustrated employees (Kotter, 1996). An effective tool for making a sustainable business is required to be competitive in global and local market. As such industrial material flow management gives the industry an opportunity to become global player in the long run.

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ANNEXURE

Table 1: Production of Selected Items of Paper and Pulp in Bangladesh

Item	Years(Quantityinthousandton)				
	2008	2009	2010	2011	2012
Bleached Sulfate Pulp	11	11	11	11	11
Chemical Wood Pulp	11	11	11	11	11
Mechanical Wood Pulp	36	36	36	36	36
Other Fiber Pulp	18	18	18	18	18
Other Paperand Paperboard	8	8	8	8	8
Printingand Writing Papers	30	30	30	30	30
Source : FAOSTAT, Food and Agricultural Organization of the UN, 2013					

Table 2: Air Emission Sources and Characteristics of Paper and Pulp Manufacturing

Source	Effluent Characteristics
Kraft recovery furnace	Particulate matter (PM_{10})[1]
Fly ash from wood waste and coal fired boilers	Particulate matter (PM_{10})
Sulphite mills operations	Sulfur oxides
Kraft pulping and recovery process	Reduced sulfur gases
Chip digester and liquor evaporation	Volatile organic compounds (VOC)
All combustion processes	Oxides of nitrogen ,SO_x, CO, PM_{10}
Source:USEPA 1995, Pulp and Paper Industry Sector Note book Project.	

Table 3: Water Emissions Sources and Characteristics of Paper and Pulp Manufacturing

Source	Effluent Characteristics
Water usedin wood handling, debarking and chip washing	Solids, biological oxygen demand(BOD), color
Chip digester and liquor evaporator condensate	Concentrated BOD, reduced sulfur compounds
'White waters' from pulp screening,thickening and cleaning	Large volume of water with suspended solids (possibly with significant BOD)BOD, color, chlorinated organic compounds
Bleach Plant Washer filtrates	Solid, often precipitated for reuse
Paper machine Awater flows	Solid, BOD, color
Fiber and liquor spills	
Source:USEPA 1995, Pulp and Paper Industry Sector Note book Project.	

Figure 1: Material Flow Management Approach and Outcome

[1] Also known as 'fine particles'; very small solid or liquid particle suspended in gas

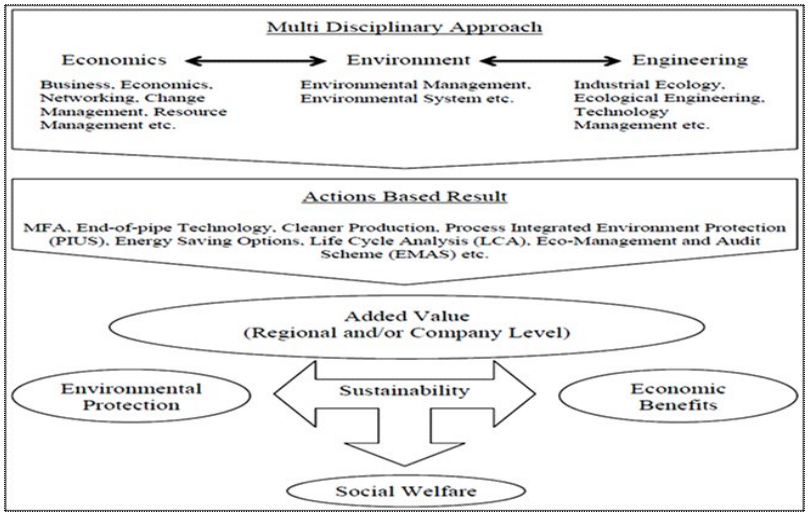


Figure 2: Corporate Material Flow Management Framework for Optimum Benefit

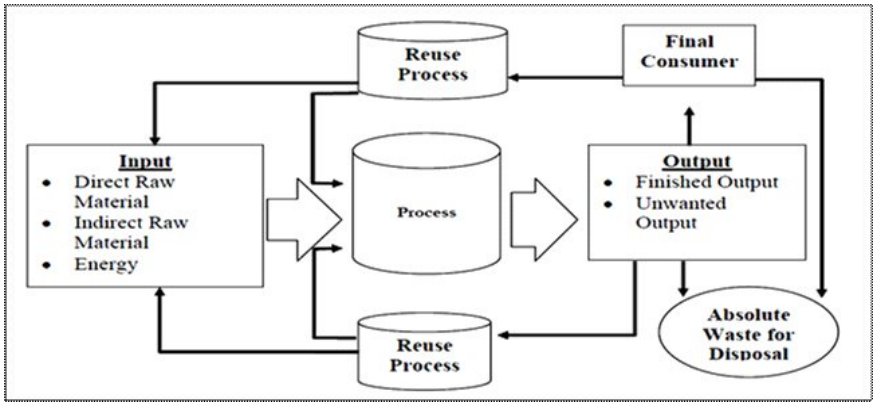
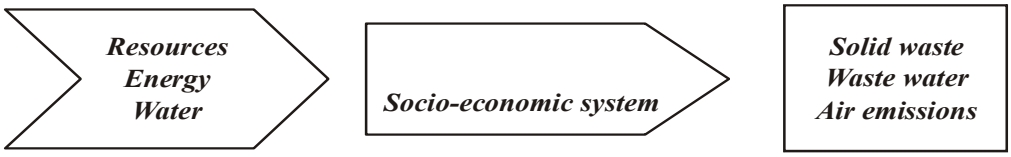


Figure 3: Material Flow Analysis



Source: Adapted from Hinterberger et al. (2003)