A

PROJECT REPORT

ON

Environmental Impact Of Construction Materials And Practices

UNDERTAKEN AT

"<u>MIT School of Distance Education</u>"

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EXECUTIVE PGDM IN CONSTRUCTION AND PROJECT MANAGMENT

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YEAR 2023-2025

PROJECT EXECUTED CERTIFICATE

To
The Director
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This is to request you to kindly exempt me from submitting the certificate forProject Work due to the reason mentioned below:

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Thanking you in anticipation of your approval to

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Regards

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Student Name: - ABHIJIT KAR

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DECLARATION

I hereby declare that this project report entitled **“Environmental Impact Of Construction Materials And Practices”** bonafide record of the project work carried out by me during the academic year **2023-2025**, in fulfillment of the requirements for the award of **“EXECUTIVE CONSTRUCTION AND PROJECT MANAGMENT”** of MIT School of Distance Education.

This work has not been undertaken or submitted elsewhere in connectionwith any other academic course.

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ACKNOWLEDGEMENT

I would like to take this opportunity to express my sincere thanks and gratitude to **"DR. JAYANTA PANIGRAHI"**, Faculty of MIT School of Distance Education, for allowing me to do my project work in your esteemed organization. It has been a great learning and enjoyable experience.

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CHAPTER 1

INTRODUCTION

Buildings, building materials and components consume nearly 40 percent of global energy annually in their life cycle stages, such as production and procurement of building materials, construction, use and demolition. The total life cycle energy of a building constitutes the embodied as well as the operational energy. Embodied energy is the total amount of energy consumed during the production, use (renovation and replacement) and demolition phase, whereas operational energy is the energy required to operate the building in processes, such as space conditioning, lighting and operating other building appliances. Compared to embodied energy, operational energy constitutes a relatively larger proportion of a buildings total life cycle energy. However, recent research has emphasized the significance of embodied energy and has acknowledged its relative proportion of total energy, which is growing with the emergence of more energy efficient buildings.

Furthermore, the relative proportions of embodied and operational energy depend on factors, such as location, climate and fuel sources used. Black et al. have pointed out a relationship between energy use in buildings and greenhouse gas emissions, thus underscoring the environmental significance of embodied energy. Current embodied energy (EE) data and databases exhibit inaccuracy and variability because of inconsistent methodologies that are used to determine the embodied energy of building materials. This leaves the industry with published embodied energy values that are not comparable. Parameters, such as system boundaries, primary or delivered energy and feedstock energy, define the input variables that are included in embodied energy calculations. Other parameters, such as age and source of data, data representativeness (temporal, spatial and technological), and methods of measurement, affect data quality. These parameters differ in current databases and influence the process of decision-making in the construction industry. Global comparability and reliability are vital data qualities for embodied energy research, in part because of the increasing significance of embodied energy in the total life cycle of a building. While a preference for low energy intensive building material could result in large savings in energy consumption in

Building, a high embodied energy material may also reduce a buildings operational energy consumption. For an accurate comparison and informed decision, the embodied energy data of two materials or components should be measured on the basis of similar parameters. Furthermore, for successful implementation of environmental practices, such as eco-labeling, which informs the customers about the environmental characteristics of a product, it is vital that embodied energy data are accurate and consistent. Although several methods exist to compute the energy embedded in a building or building material these methods produce differing results. Most current databases of embodied energy include data that are derived using guidelines set forth by the International Standardization Organization (ISO) for Life Cycle Assessment (LCA). Most research studies performed either energy analysis or LCA to calculate embodied and operational energy in the whole life cycle of a building. Studies that performed LCA mention either using ISO LCA standards or none. However, studies that are skeptical about using LCA for assessing buildings in environmental impact terms exist. Literature suggests that development of a set of standards or protocol could minimize problems of variation in energy data and could introduce accuracy and completeness to the embodied energy figures. ISO LCA standards do not provide complete guidance to the process of LCA. Moreover, some issues, such as system boundary definition and data quality, remain unresolved . This paper performs a review of literature in the realm of embodied energy and Life Cycle Assessment (LCA) and provides a survey of existing international LCA standards. We identify parameters causing variations in embodied energy data, and determine unresolved issues in existing international LCA standards. Furthermore, we also recommend an approach to establish an embodied energy measurement protocol. Both the LCA and embodied energy analysis literature are utilized, as nearly all of the LCA studies cited in this paper actually involve embodied energy analysis.

1.1 Overview

The increase of unstable activities by human is resulting in some serious damages like tsunami, wildfires, flooding and drought due to global warming, rising of sea level, depletion of ozone layer causing increasing threats of cancer and land loss due to contamination of soil. Construction industries have a larger part in contributing these environmental problems. The extensive resource depletion is occurred due to the usage of large volumes of construction materials. All round the world construction materials generate million tons of waste annually. These construction materials require high embodied energy resulting with large CO_2 (Carbon Dioxide) emissions. The embodied energy of steel is about 32 MJ/Kg and for cement is about 7.8 MJ/Kg Scientific and Industrial Research Organization). The highest CO_2 producing material is cement and a large amount of CO_2 is produced in the processing of construction materials and in the transport of these materials. If the consumption of the construction materials remains the same all around the world then by the year 2050 the production of the cement in the world could reach 3.5 billion metric tons. But annually the production and consumption of the construction materials are increasing simultaneously, if this is the case then the production of cement itself annually could reach over 5 billion metric tons with approximately about 4 billion tons of CO_2 (carbon dioxide) emissions. Due to the abundant usage of the construction materials the impact of these materials is dominated than from the impact of the other sources. Due to the frequent changes in the lifestyle and demands of human the average life of the buildings is decreasing, the demolition or renovation of the buildings are resulted with more land-fills or recycling annually. Because of the huge consumption of the construction materials and embodied energy a high level of resource depletion is taking place all around the world.

1.2 Problem discussion:

This thesis work gives an insight of the environmental hazards faced due to the consumption of uncontrolled construction materials. Although the achievement is to reduce these impact but with the increase in consumption of construction materials these achievement looks unpromising. To appease these unfavorable environmental impacts is the more realistic ultimate goal. Based on this the thesis problem statement is developed as to estimate the unfavorable environmental impacts caused due to consumption of construction materials and defining the important methods to alleviate these impacts. By reducing the consumption of construction materials or by reducing the impacts caused by each construction material the unfavorable environmental impacts can be alleviated to some extent. This can be done in two methods to diminish the environmental hazards.

1. Abate the consumption of construction materials: The natural resources are gradually reducing with growing population and peoples demand. By recycling and reusing the construction materials will avoid the need for new resources and thus saving the natural resources or reducing the consumption of construction materials.

2. Selection of construction materials: Designer plays an important role in selection of the material. This can be done by the environmental performance of the material. To evaluate the judgment a tool should be available to the designer for selecting material to accomplish the goal of minimizing the environmental impacts.

1.2.1 Purpose of this study:

The purpose of this thesis work is to give an overview and to understand deeply the concept of ―Environmental Impact of Construction Materials and Practices‖ which is defined and interpreted in theory. In order to get an overview theoretical study is conducted which is carrying out by research work on relevant literature through textbooks, scientific articles, internet etc.

1.2.2. Theoretical objectives:

- Brief presentation and an overview of the concept of ―Environmental Impact of Construction Materials and Practices‖.
- Emphasize the various impacts on environment and the methodology in the selection of materials based on their performance on environment.
- Reducing the consumption of materials by recycling and reuse by implementing latest technology and policy.

1.3. METHODOLOGY

1.3.1 Research Strategy

Mainly there are two types of approaches in writing thesis they are theoretical and empirical. In the theoretical approach, it requires an exclusive textual investigation and in the empirical approach, it requires a broad communication and interactions with people. This thesis mainly focuses on the theoretical approach and it is essential to have a good theoretical background. A theoretical foundation is defined by reviewing the literature which is present in the references of the theoretical frame. Based on these facts, we will focus on the analysis part using the references of the theoretical frame.

1.3.2 Scientific Perspective

1.3.2.1. Positivistic Paradigm

Basically the positivistic approach is theory based and it depends on explanations and description. Based on the deductions and discussions, the theories give a very strong framework. On the basis of logical, reasonable and rational approach this research is performed which is very systematic. In this approach the persuasions such as emotions, beliefs and feelings are not accepted because they are not tangible or objective and due to the reality that they are not constant across time. The aim of the approach is at the critical evaluation of all descriptions from the facts which can be guaranteed or validated with certain probabilities. The true knowledge and objectives are led by falsifying and verifying theories and hypothesis.

1.3.2.2. Deductive Approach

For every deductive method, the base point is the theory behind it. The goal then will be to find some data based on the theory which supports the predetermined predictions made. The theory then concludes, what information should be collected? How it should be interpreted? And how the results can be related to the existing theory?

1.4 Problem Assessment:

Natural resources are limited on earth but looking at the uncontrolled able consumption of construction material it is apparently unsustainable. Consumption of construction materials has compatibly increased along with production in the past century (Fig 1.1). Although there are few drops in the graph during 1940‘s and 1990‘s but no sustainability was employed for the economy of construction materials. With this trend of consumption of uncontrolled able construction materials will result in environmental degradation on a global scale and that will indicate extinction for humanity. In this chapter we will study the trend of consumption of structural construction materials of cement and steel, there environmental impacts and embodied energies.

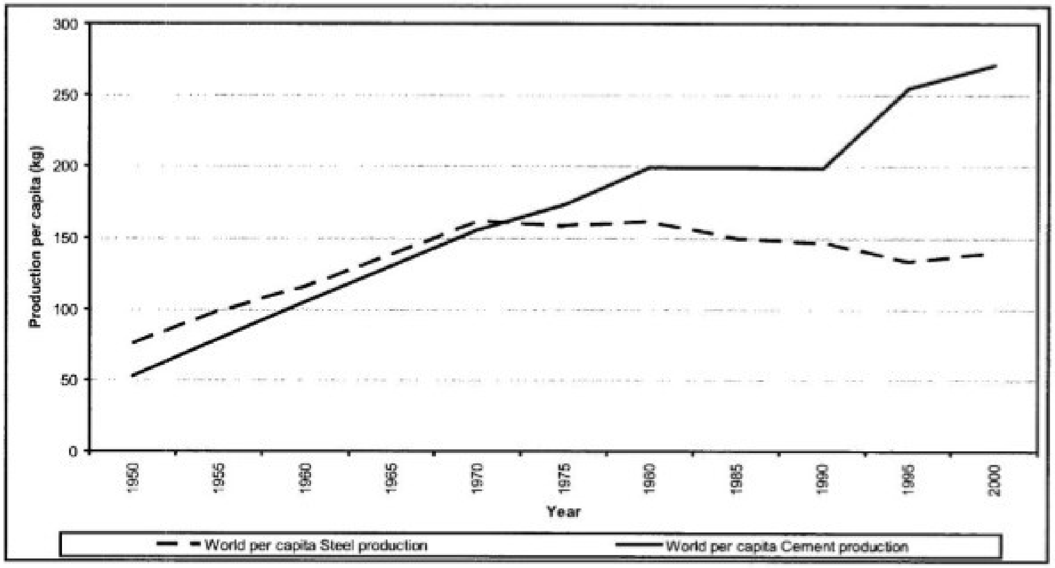

Figure 1.1: Trends of World and US. Steel and Cement consumption

1.4.1 Trends in consumption

Based on the analysis from Figure 1.2. the consumption of cement has been mounting relatively high when compare to the consumption of steel throughout the world. Cement production is a major source of emissions of the carbon dioxide (CO_2) Figure 1.4. About 40% of the construction industry's carbon dioxide emissions originate from cement production when to compare to the embodied energy of steel. Only one part of steel is consumed in construction industry when compared to all steel consumed. Cement is the major structural construction material used in the construction industry causing adverse environmental impacts.

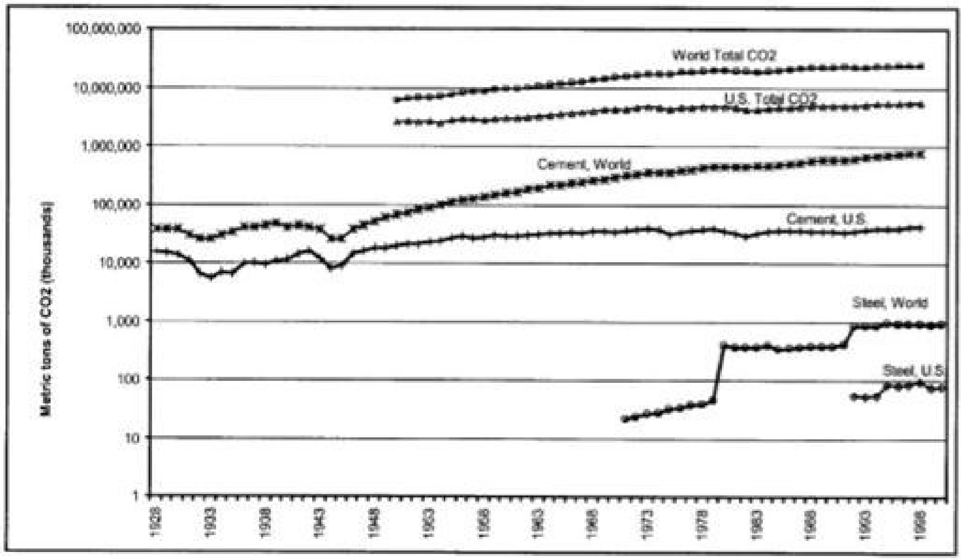

Figure 1.2 World and U.S. CO_2 emissions due to steel and cement consumption

Cement and steel production increased at an incredible rate in the past century. Though the production of steel reduced after 1960's whereas the production of cement continues to be relatively high as shown in Figure 1.2

The amount of steel and cement which was produced throughout the world in 2000 was around 800 million metric tons of steel and around 1.6 billion metric tons of cement was produced. The per capita production of steel and cement is shown in the Figure 1.3 at an interval of five years. As per the analysis 139 kg's of steel and 271 kg's of cement is required per person annually throughout the world. The demand for cement is relatively higher than compared to steel as per the figure.

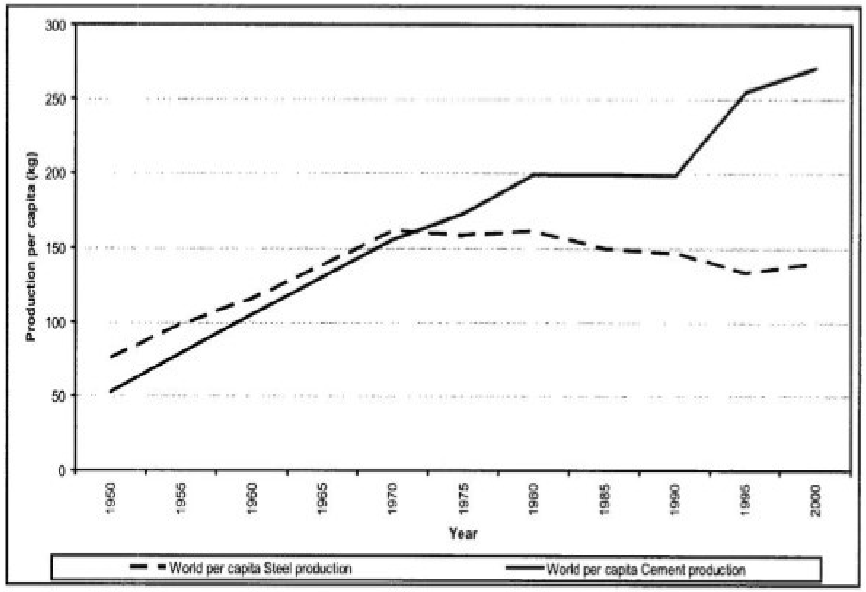

Figure 1.3 World per capita production of steel and cement

CHAPTER 2

LITERATURE REVIEW

[1] Suzzane Goldberg in Yokohama, Japan

The head of the United Nations climate panel said he hoped its report on the rising threat of climate change would ―jolt people into action‖.

The report, released on Monday, is a 2,600-page catalogue of the risks to life and livelihood from climate change – now and in the future.
Rajendra Pachauri, who has headed the IPCC for 12 years, said he hoped it would push government leaders to deal with climate change before it is too late.

The volume of scientific literature on the effects of climate change has doubled since the last report in 2007, and the findings make an increasingly detailed picture of how climate change – in tandem with existing fault lines such as poverty and inequality – poses a much more direct threat to life and livelihoods.
This was reflected in the language. The summary mentioned the word ―risk‖ more than 230 times, compared to just over 40 mentions seven years ago, according to a count by the Red Cross.

[2] Manish Kumar Dixit

Building materials have the promising potential of significantly reducing energy use in the construction industry as EE is gaining importance among researchers, professionals, builders and material manufacturers. Current research efforts in the form of embodied energy inventories and methodologies suffer from inaccuracy and unreliability of energy data and thus are incomplete and inaccurate. This problem is due to parameters that vary and is related to various stages of embodied energy analysis. There is a stated and identified need to address the problem of variation and inconsistency by identifying and eliminating impacts of differing embodied energy parameters.

His paper identifies and presents a set of parameters that differ and which cause variation and inconsistency in embodied energy figures. This paper discusses the existing state of unclear interpretation about embodied energy and provides an idea about the inherent variation. The literature indicates that the geographic location is stated by most of the studies while feedstock energy consideration is the one least stated. These parameters, if addressed, could result in a consistent, translatable and comparable database of embodied energy of building materials. This paper points out the need to evolve a standardized approach to data collection (embodied energy) that includes necessary guidelines and requirements to address difference of parameters, which could be followed by research and practice worldwide. Once the industry has a standard template for collecting and analyzing information, an energy economy that accounts for most of the energy embodied in a building will be useful to compare products and buildings regarding effective use of energy.

[3] Grahm John Treloar

Embodied energy is the energy required directly and indirectly to manufacture products. Its analysis requires data on energy use and upstream requirements for other products. However, previous industry-based methods of embodied energy analysis are incomplete in framework. Previous national statistical methods, while comprehensive, are a ‗black box', subject to errors. A new method is derived involving the decomposition of a national statistical model to allow more reliable industry data to be integrated. The method is demonstrated for an individual residential building, showing that—for many products—more types of industry data may need to be derived than previously thought.

CHAPTER 3.1

INTRODUCTION

The increase of unstable activities by human is resulting in some serious damages like tsunami, wildfires, flooding and drought due to global warming, rising of sea level, depletion of ozone layer causing increasing threats of cancer and land loss due to contamination of soil. Construction industries have a larger part in contributing these environmental problems. The extensive resource depletion is occurred due to the usage of large volumes of construction materials. All round the world construction materials generate million tons of waste annually. These construction materials require high embodied energy resulting with large CO_2 (Carbon Dioxide) emissions. The embodied energy of steel is about 32 MJ/Kg and for cement is about 7.8 MJ/Kg (Scientific and Industrial Research Organization). The highest CO_2 producing material is cement and a large amount of CO_2 is produced in the processing of construction materials and in the transport of these materials. If the consumption of the construction materials remains the same all around the world then by the year 2050 the production of the cement in the world could reach 3.5 billion metric tons. But annually the production and consumption of the construction materials are increasing simultaneously, if this is the case then the production of cement itself annually could reach over 5 billion metric tons with approximately about 4 billion tons of CO_2 (carbon dioxide) emissions. Due to the abundant usage of the construction materials the impact of these materials is dominated than from the impact of the other sources. Due to the frequent changes in the lifestyle and demands of human the average life of the buildings is decreasing, the demolition or renovation of the buildings are resulted with more land-fills or recycling annually. Because of the huge consumption of the construction materials and embodied energy a high level of resource depletion is taking place all around the world.

CHAPTER 3.2

ENVIRONMENT

2.1 Natural Environment

In biology and ecology the environment is all of the natural materials and living things, including sunlight. This is also called the *natural environment*. The important things in the environment that we value are called natural resources. For example fish, sunlight, and forests. These are *renewable* natural resources because more grow naturally when we use them. *Non-renewable* natural resources are important things in the environment that do not come back naturally, for example coal and natural gas.

The natural environment encompasses all living and non-living things occurring naturally on Earth or some region thereof. It is an environment that encompasses the interaction of all living species. The concept of the *natural environment* can be distinguished by components**:**

- Complete ecological units that function as natural systems without massive human intervention, including all vegetation, microorganisms, soil, rocks, atmosphere, and phenomena that occur within their boundaries.
- Universal natural resources and physical phenomena that lack clear-cut boundaries, such as air, water, and climate, as well as energy, radiation, electric charge, and magnetism, not originating from human activity.

The natural environment is contrasted with the built environment, which comprises the areas and components that are strongly influenced by humans. A geographical area is regarded as a natural environment.

It is difficult to find *absolutely natural* environments, and it is common that the naturalness varies in a continuum, from ideally 100% natural in one extreme to 0% natural in the other. More precisely, we can consider the different aspects or components of an environment, and see that their degree of naturalness is not uniform.[2] If, for instance, we take an agricultural field, and consider the mineralogical and the structure of its soil, we will find that whereas the first is quite similar to that of an undisturbed forest soil, the structure is quite different.

2.2 Composition of Natural Environment

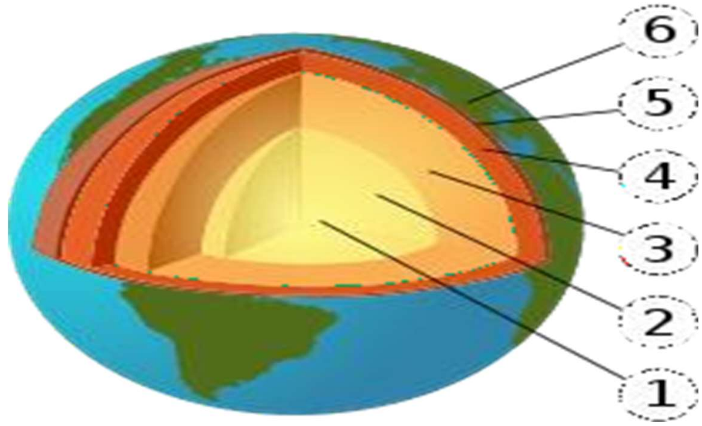

Fig 3.2.1: Earths layered structure

Earths layered structure.

(1) Inner core;

(2) Outer core;

(3) Lower mantle;

(4) Upper mantle;

(5) Lithosphere;

(6) Crust.

Earth science generally recognizes 4 spheres, the lithosphere, the hydrosphere, the atmosphere, and the biosphere as correspondent to rocks, water, air, and life. Some scientists include, as part of the spheres of the Earth, the cryosphere (corresponding to ice) as a distinct portion of the hydrosphere, as well as the pedosphere (corresponding to soil) as an active and intermixed sphere.

2.3 Atmosphere, climate and weather

The atmosphere of the Earth serves as a key factor in sustaining the planetary ecosystem. The thin layer of gases that envelops the Earth is held in place by the planet's gravity. Dry air consists of 78% nitrogen, 21% oxygen, 1% argon and other inert gases, such as carbon dioxide. The remaining gases are often referred to as trace gases,[16] among which are the greenhouse gases such as water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Filtered air includes trace amounts of many other chemical compounds. Air also contains a variable amount of water vapor and suspensions of water droplets and ice crystals seen as clouds. Many natural substances may be present in tiny amounts in an unfiltered air sample, including dust, pollen and spores, sea spray, volcanic ash, and meteoroids. Various industrial pollutants also may be present, such as chlorine (elementary or in compounds), fluorine compounds, elemental mercury, and sulphur compounds such as sulphur dioxide [SO_2].

The ozone layer of the Earth's atmosphere plays an important role in depleting the amount of ultraviolet (UV) radiation that reaches the surface. As DNA is readily damaged by UV light, this serves to protect life at the surface. The atmosphere also retains heat during the night, thereby reducing the daily temperature extremes.

2.3.1 Atmospheric layers

1. Principal layers

Earth's atmosphere can be divided into five main layers. These layers are mainly determined by whether temperature increases or decrease with altitude. From highest to lowest, these layers are:

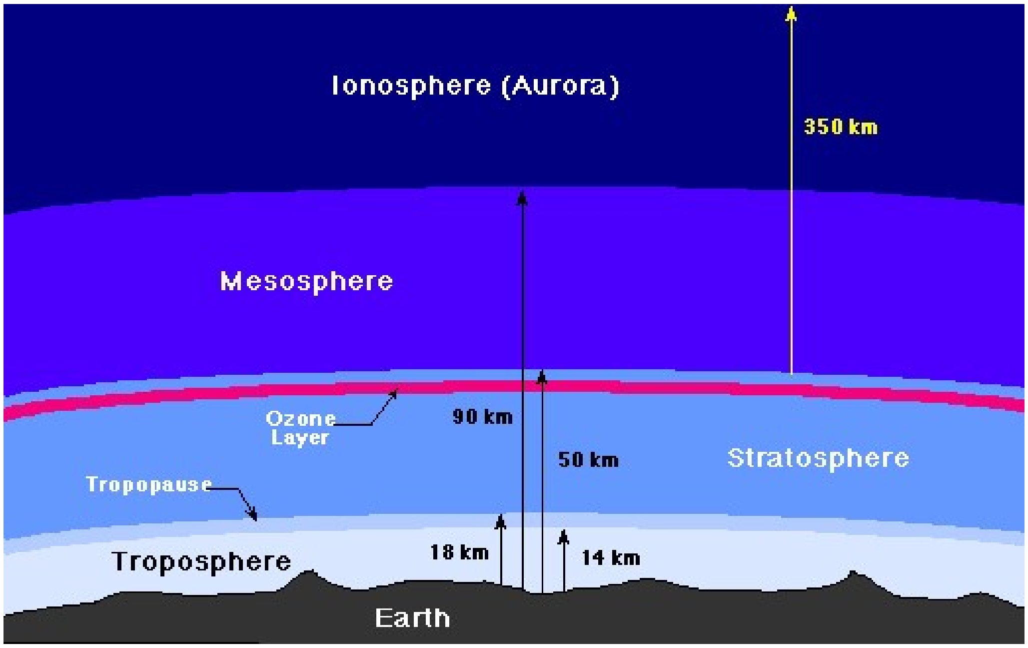

Fig.3.2.2 Principle Layers

- ***Exosphere***: The outermost layer of Earth's atmosphere extends from the exobase upward, mainly composed of hydrogen and helium.

- ***Thermosphere***: The top of the thermosphere is the bottom of the exosphere, called the exobase. Its height varies with solar activity and ranges from about 350–800 km (220–500 mi; 1,150,000–2,620,000 ft). The International Space Station orbits in this layer, between 320 and 380 km (200 and 240 mi).

- ***Mesosphere***: The mesosphere extends from the stratopause to 80–85 km (50–53 mi; 262,000–279,000 ft). It is the layer where most meteors burn up upon entering the atmosphere.

- ***Stratosphere:*** The stratosphere extends from the tropopause to about 51 km (32 mi; 167,000 ft). The stratopause, which is the boundary between the stratosphere and mesosphere, typically is at 50 to 55 km (31 to 34 mi; 164,000 to 180,000 ft).

- ***Troposphere***: The troposphere begins at the surface and extends to between 7 km (23,000 ft) at the poles and 17 km (56,000 ft) at the equator, with some variation due to weather. The troposphere is mostly heated by transfer of energy from the surface, so on average the lowest part of the troposphere is warmest and temperature decreases with altitude. The tropopause is the boundary between the troposphere and stratosphere.

2. Other layers

Within the five principal layers determined by temperature are several layers determined by other properties.

- The ozone layer is contained within the stratosphere. It is mainly located in the lower portion of the stratosphere from about 15–35 km (9.3–21.7 mi; 49,000–115,000 ft), though the thickness varies seasonally and geographically. About 90% of the ozone in our atmosphere is contained in the stratosphere.
- The ionosphere, the part of the atmosphere that is ionized by solar radiation, stretches from 50 to 1,000 km (31 to 621 mi; 160,000 to 3,280,000 ft) and typically overlaps both the exosphere and the thermosphere. It forms the inner edge of the magnetosphere.
- The hemisphere and heterosphere: The hemisphere includes the troposphere, stratosphere, and mesosphere. The upper part of the heterosphere is composed almost completely of hydrogen, the lightest element.
- The planetary boundary layer is the part of the troposphere that is nearest the Earth's surface and is directly affected by it, mainly through turbulent diffusion.

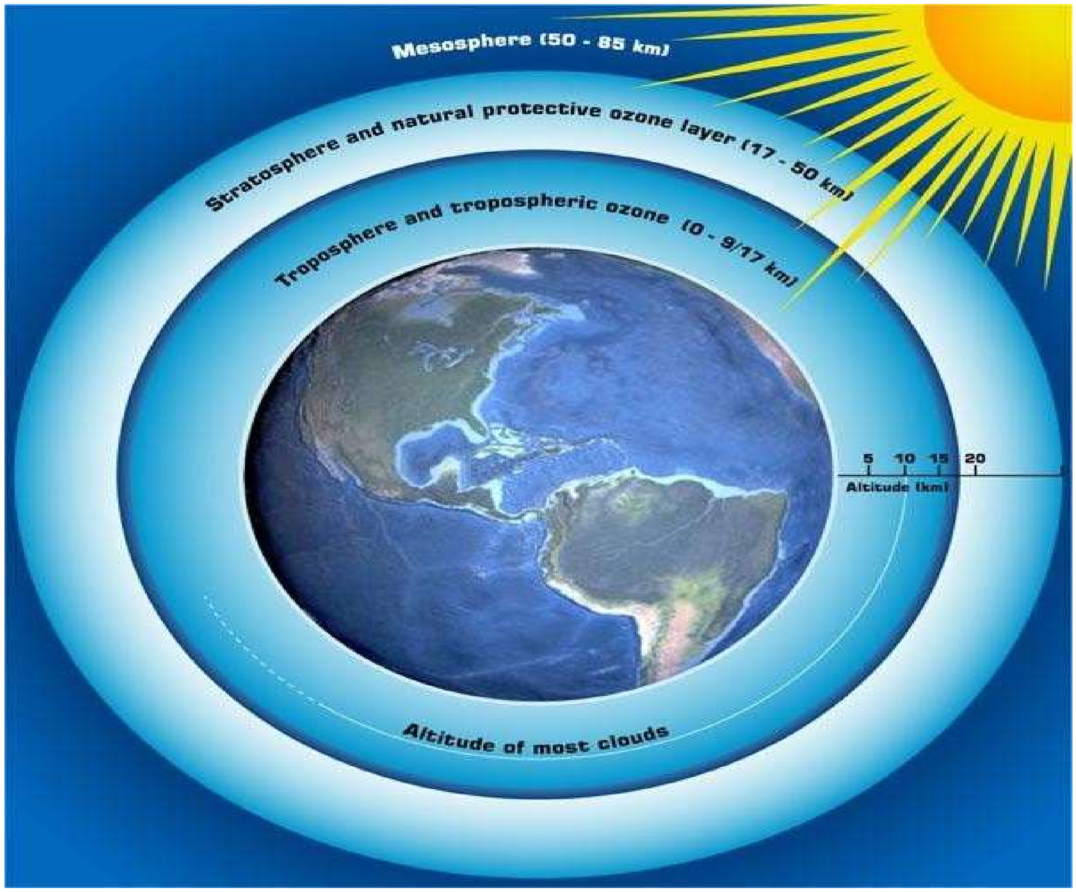

Fig 3.2.3 Other layers

2.4 Effects of global warming

The potential dangers of global warming are being increasingly studied by a wide global consortium of scientists. These scientists are increasingly concerned about the potential long-term effects of global warming on our natural environment and on the planet. Of particular concern is how climate change and global warming caused by anthropogenic, or human-made releases of greenhouse gases, most notably carbon dioxide, can act interactively, and have adverse effects upon the planet, its natural environment and humans' existence.

It is clear the planet is warming, and warming rapidly. The most recent report from the Intergovernmental Panel on Climate Change (the group of the leading climate scientists in the world) concluded that the earth will warm anywhere from 2.7 to almost 11 degrees Fahrenheit between 1990 and 2100. Efforts have been increasingly focused on the mitigation of greenhouse gases that are causing climatic changes, on developing adaptive strategies to global warming, to assist humans, animal and plant species, ecosystems, regions and nations in adjusting to the effects of global warming. Some examples of recent collaboration to address climate change and global warming include:

- The United Nations Framework Convention Treaty and convention on Climate Change, to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system
- The Kyoto Protocol, which is the protocol to the international Framework Convention on Climate Change treaty, again with the objective of reducing greenhouse gases in an effort to prevent anthropogenic climate change.
- The Western Climate Initiative, to identify, evaluate, and implement collective and cooperative ways to reduce greenhouse gases in the region, focusing on a market-based cap-and-trade system.

2.5 Climate

Climate encompasses the statistics of temperature, humidity, atmospheric pressure, wind, rainfall, atmospheric particle count and numerous other meteorological elements in a given region over long periods of time. Climate can be contrasted to weather, which is the present condition of these same elements over periods up to two weeks.

Climates can be classified according to the average and typical ranges of different variables, most commonly temperature and precipitation.

2.6 Weather

Weather is a set of all the phenomena occurring in a given atmospheric area at a given time. Most weather phenomena occur in the troposphere, just below the stratosphere. Weather refers, generally, to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over longer periods of time. When used without qualification, "weather" is understood to be the weather of Earth. Weather occurs due to density (temperature and moisture) differences between one place and another. Surface temperature differences in turn cause pressure differences. Higher altitudes are cooler than lower altitudes due to differences in compression heating. Weather forecasting is the application of science and technology to predict the state of the atmosphere for a future time and a given location. The atmosphere is a chaotic system, and small changes to one part of the system can grow to have large effects on the system as a whole.

Human attempts to control the weather have occurred throughout human history, and there is evidence that human activity such as agriculture and industry has inadvertently modified weather patterns.

CHAPTER 3.3
ENVIRONMENTAL SUSTAINABILITY

3.1 Environmental sustainability and what it means for us all

Sustainability is broadly defined as ―meeting the needs of the present generation without compromising the ability of future generations to meet their own needs‖. The term ―sustainability,‖ when applied institutionally within a university, is the development of a process or management system that helps to create a vibrant campus economy and high quality of life while respecting the need to sustain natural resources and protect the environment.

Environmental sustainability involves making decisions and taking action that are in the interests of protecting the natural world, with particular emphasis on preserving the capability of the environment to support human life. Environmental sustainability is the ability to maintain the qualities that are valued in the physical environment.

For example, most people want to sustain (maintain):

- Human life
- The capabilities that the natural environment has to maintain the living conditions for people and other species (e.g. clean water and air, a suitable climate)

Threats to these aspects of the environment mean that there is a risk that these things will not be maintained. For example, the large-scale extraction of non-renewable resources (such as minerals, coal and oil) or damage done to the natural environment can create threats of serious decline in quality or destruction or extinction. Traditionally, when environmental problems arise environmental managers work out how to reduce the damage or wastage. But it is not always easy to work out exactly when and where threats will have their effects and often the impacts are hard to reverse. So increasingly environmental managers adopt strategies aimed to prevent damage being done in the first place. A full sustainability program needs to include actions to prevent threats and impacts from arising, actions to protect the environment from threats and damage, and restoration to reverse damage already done. Sustainability issues arise wherever there is a risk of difficult or irreversible loss of the things or qualities of the environment that people value. And whenever there are such risks there is a degree of urgency to take action These sustainability programs need to operate on an adequate scale and need to continue operating reliably for as long as the threats continue.

Some of the issues that pose major environmental sustainability problems include:

• Destruction of the living environments (habitats) of native species.

• Discharge of polluting chemicals and other materials into the environment.

• Emission of greenhouses gases into the atmosphere than can cause climate change.

• Depletion of low cost oil and other fossil fuels.

Some environmental issues are largely of local significance while others have regional or even global relevance. Understanding and use of the word ―environmental‖ quite often tends to be associated with some kind of human impact on natural systems. This context distinguishes it from the word ―ecological, ‖ which can be characterized as a concept of interdependence of elements within a system. As discussed above in the essay, ―Ecological Sustainability as a Conservation Concept, ‖ the authors suggest that an ecological definition of sustainability be advanced that is in better accord with biological conservation. At the personal or household level, there are a host of actions that people can take to contribute to environmental sustainability at home, when travelling or accessing services or goods, at work, or when acting as a community member or citizen or as an investor of personal funds. Some useful examples are include living close to work where possible and walking, using a bike or using public transport. These are good options to save energy and reduce greenhouse gases. If these options are not possible then using an ultra-efficient hybrid petrol/electric vehicle can cut greenhouse gases and petrol consumption by about 50% and cut other toxic pollutants by about 90%. Buying products made of recycled materials will generally save materials and energy, cut greenhouse gases and toxic pollution, and reduce impacts on living things in the wild. Installing a water tank and low flow shower can save water. Involvement in or donations to community environmental groups can help with practical projects like re vegetation or by building support for effective government policies. And investing savings in ethical investments can help accelerate the creation of an environmentally-sustainable economy.

In short ―environmental sustainability‖ as an expansion of our common perception of the nature of human activity so as to more clearly connect it with the ecological concept of interdependence and to serve as a goal for environmental managers.

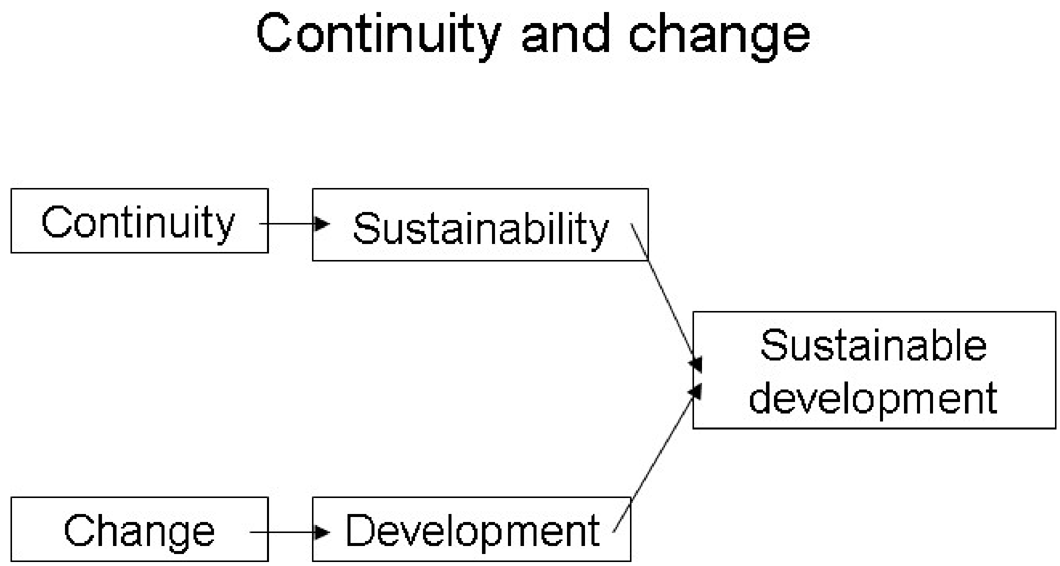

Fig 3.3.1. Continuity and change

Sustainability is about *continuity* and development is about *change*. There are many things about life that we want to sustain (maintain) and many that we want to change. So it makes sense to create the notion of '*sustainable development*' that combines desired change and desired continuity - for example we might change exploitation, unhappiness, poverty, destructiveness, etc. and sustain the rest of nature, trust, tolerance, honesty, happiness, health, etc. Treated in this way *sustainable development* doesn't have to be an oxymoron (a combination of conflicting terms). While theory says that sustainable development does not have to be an oxymoron, it can sometimes take quite a bit of negotiation before a whole society can be comfortable with a shared definition of what should be maintained and what should be changed.

3.2 Human Behavior and Environmental Sustainability:

Environmental sustainability is a key issue for human societies throughout the 21st century ‘s world. All countries need to secure sufficient quality—in the short and the long term of natural resources, ecosystems, and the diversity of plant and animal species, including the human living environment. Since 1987, the term ―sustainable development‖ has been used to denote economic, social, and environmental dimensions of our future survival (WCED, 1987; see Robinson, 2004, for a conceptual review). In this issue, we focus on environmental sustainability and its relation to human quality of life. Our focus is on positive and negative qualities of human living environments including nature for people, on what they ―do‖ to people, what people ―do‖ to them, and how this could be changed for the common good.

Highlights of Environmental Developments 2004–2005 (from WWI, 2004, 2005), as Documented by Scientific Research:

- **Pollution:** Oil tanker *Prestige* carrying 77,000 tons of oil splits apart, contaminating Spain ‘s Galicia coastline and unleashing public anger worldwide.

- **Energy:** More than 150 countries attend *Renewable 2004,* the largest-ever meeting of government and private-sector leaders focused on achievable renewable energy goals.

- **Population:** By 2050 world population will be 8.9 billion, down from earlier forecast of 9.3billion.

- **Biodiversity:** if global temperature rises 2–6 degrees as now predicted, 18–35 percent of the world ‘s species could be gone by 2050.

- **Climate:** Concentration of carbon dioxide, the main global warming gas in Earth ‘s atmosphere, posts largest two-year increase ever recorded.

- **Fisheries:** Industrial fishing has killed off 90% of the world 's biggest and most economically important fish species.

- **Food:** AIDS is fueling famine in southern Africa, where 7 million farmers have died from the epidemic.

- **Transportation:** Traffic delays cost U.S. motorists about $8 billion a year in wasted fuel and 3.5 billion hours in lost time.

- **Climate:** Atmospheric concentrations of methane, the second most potent greenhouse gas, have leveled off after two centuries of growth.

- **Wildlife:** a surge in demand for skins of tigers, leopards, and other endangered wildlife as the fashion industry once again embraces fur.

- **Marine systems:** the number of oceans and bays with _dead zones 'of water, so devoid of oxygen that little life survives, has doubled to 146 since 1990.

- **Energy:** World energy demand will grow 54 percent by 2025, with oil use rising from 81 Million to 121 million barrels a day.

- **Water:** World Bank is boosting its funding of large dam projects to the detriment of the Environment and local peoples.

- **Toxics:** The Stockholm Convention on Persistent Organic Pollutants enters into force to rid the world of 12 hazardous chemicals, including PCBs, dioxins and DDT.

- **Urbanization:** The world will soon become predominantly urban, with 60 percent of people living in cities by 2030.

Defining Sustainability in the Context of a Profession:

While the concept of sustainability is increasingly discredited as a useful concept by itself, it appears to be serving some purpose when preceded by a delineating modifier like ―ecological" or ―agricultural‖ or ―economic. ‖ Efforts have been made by members of various professions to give meaning to the term within the context of those respective professions. Callicott and Mumford, for example, develop the meaning of the term ―ecological sustainability‖ as a useful concept for conservation biologists; In ―Ecological Sustainability as a Conservation Concept, ‖ these authors advance an ecological definition of sustainability that connects human needs and ecosystem services: ―meeting human needs without compromising the health of ecosystems. ‖ They propose this concept as a guiding principle for areas where human activities take place. In ―Economic Sustainability and the Preservation of Environmental Assets, ‖ Foy explains that from an economic standpoint, sustainability requires that current economic activity not disproportionately burden future generations. Economists will allocate environmental assets as only part of the value of natural and manmade capital, and their preservation becomes a function of an overall financial analysis. In contrast, the ecologist will seek to preserve minimum levels of environmental assets in physical terms. He suggests that since an ecological approach will better characterize the present situation, it should serve to limit conventional economic reasoning to ensure sustainability. Economic sustainability should involve analysis to minimize the social costs of meeting standards for protecting environmental assets but not for determining what those standards should be.

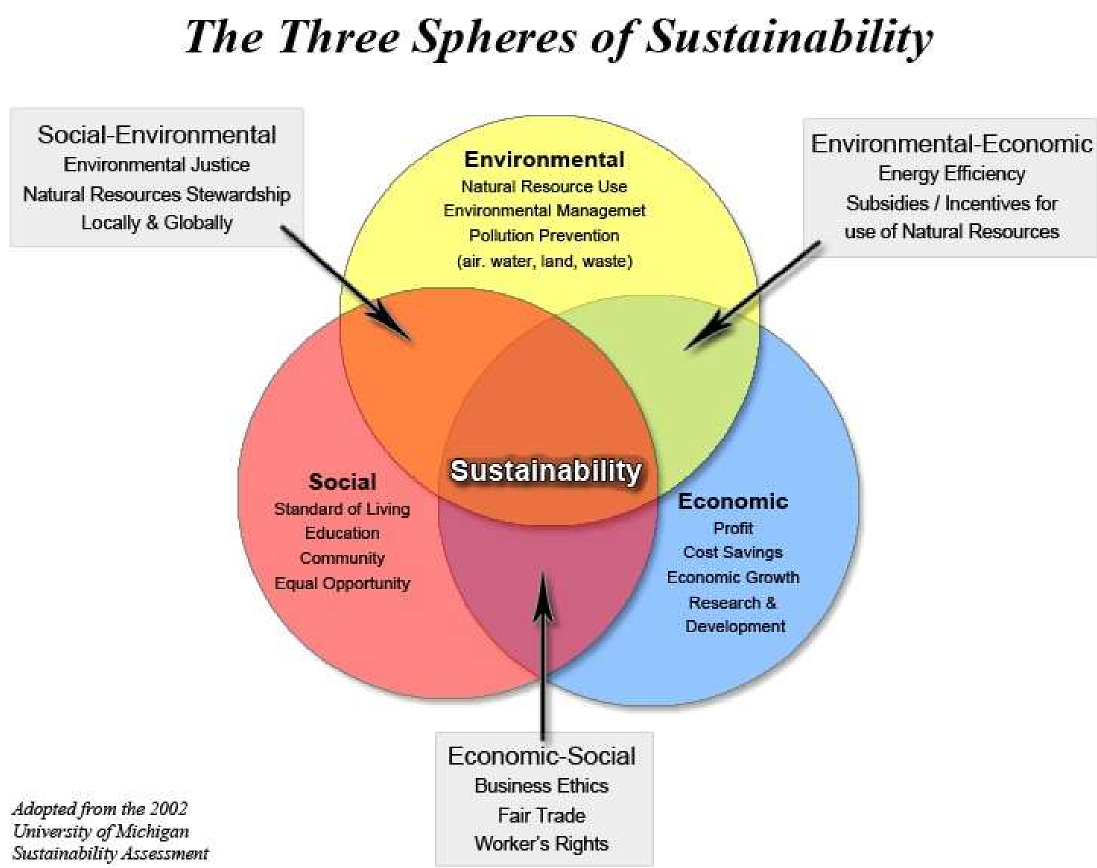

Fig 3.3.2. Three spheres of sustainability

3.3 What makes a sustainability issue?

A sustainability issue arises whenever a valued system, object, process or attribute is under threat. The *existence* of the valued system, object, process or attribute could be threatened or its *quality* could be threatened with serious decline. In other words there is a sustainability issue whenever there is something that is valued that faces the risk of not being maintained. Whenever there is a strong sense of urgency, there is always a sustainability issue involved. This urgency could relate to something that *already exists* or to an understood *potential*. For example, biodiversity might be threatened with extinction or the chance to realize the potential of a human being might be threatened, for example, if they remain in poverty or their lives are threatened by violence or disease. (The latter would usually be thought of as being *social* sustainability issues.)

Currently, India ranks 101 out of 146 countries on the 2005 Environmental Sustainability Index (ESI), which ranks countries based on such measures as health, governance, technology, and international cooperation and evaluates ―the likelihood that a country will be able to preserve valuable environmental resources effectively over the period of several decades. Sustainable development is the watchword of the day, which means that care must be taken to preserve existing environmental resources for the benefit of future generations. At the risk of failure, India may also provide a shining model of how to simultaneously advance democracy, economic growth, quality of life, and environmental health

3.4 Factors directly or indirectly responsible for depletion of sustained elements:

3.4.1 Population:

How is this relevant to sustainability? Obviously, population is a key driving factor in environ-mental degradation, as more people consume more resources, occupy more land, release more wastes, etc. Nevertheless, population is only one factor; analysts and environmentalists from Thomas Malthus in the 18th century to Paul Ehrlich in 1967 have exaggerated its singular impact. Economic growth is also a significant factor, yet so is resource use and environmental pol-icy. Dennis Anderson, for instance, argues that ―technical progress, together with the policies which induce it, is by far the most important factor in enabling countries to reconcile economic growth with environmental improvement‖ (255).

3.4.2 Land Use & Agriculture:

Energy-intensive agriculture also runs into limits, ―since growth in output is increasingly dependent on limited fossil fuel reserve. Two possible solutions to the problems of current energy sources are alternative energy or more labor-dependent agriculture. Groundwater depletion is another problem, intensified by a move, typical in developing countries, toward water intensive food, such as vegetables and animal products. The classic pattern has been from grain-based diets toward increased consumption of a diversity of vegetables, as well as meat and milk.

As the World Bank ex-plains, •\land and soil nutrients have suffered from overgrazing, deforestation, and poorly planned irrigation schemes. Furthermore, agriculture inevitably leads to deforestation, yet forests provide ecosystem services that, over time, benefit farm land (such as preventing soil erosion). In India, which remains deficient in modern energy infrastructure, fuel wood collection has also harmed forests. Illegal tree harvesting for a variety of uses is common. Of India's 329 hectares of land, •\around 21% is classified as forestland. (Gundimeda et al, 636)[2]. Yet land volume is only one aspect of the problem; forest quality is another. Although shrinkage of forest land appears to have stopped, density of forest cover seems to be diminishing. Forest ecosystem services, such as replenishment of land, sequestering of carbon, protection from weather events, and recreational uses, remain threatened.

3.4.3 Air and Water:

Agricultural policy cannot be extricated from water use; indeed, about 80% of Indians fresh water is used for agriculture (Bhaskar et al 315)[3]. A growing population is placing increasing stress on India_s water supply, a situation likely to be ex- acerbated by climate change. According to the World Watch Institute, ―in India, the demand for water in urban areas is expected to double and industrial demand to triple by 2025.Water shortages, exasperated by intermittent droughts, are a recurring problem in India. Water is often distributed by wells, with distribution determined locally according to land ownership: ―Property rights under the law entitle anyone to pump any amount of water from a well dug on his own land, even if this reduces the water table below the reach of neighboring wells

3.4.4 Energy:

Energy use is integrally connected to the environment, most obviously to air pollution. In India, coal is the primary energy source, supplying over half of total energy needs (U.S. Energy). Coal is widely considered one of the dirtiest fuels; furthermore, the coal on which India relies, currently some 250 million tons per year, is of low quality, thus contributing heavily to India_s poor air quality.

What exactly are we trying to maintain in the physical environment?

There is no automatic, fixed agenda built into the term *environmental sustainability*. We have to look to the context to see what might be sustained. And many people and Organizations already have well developed ideas about what aspects of the total 'Environment' should be sustained when *environmental sustainability* is pursued.

What motivates us to want to sustain something in the physical environment?

We might want to sustain something in the physical environment because it is useful to us: e.g. the quality of local urban environments. Or we might want to do it because we care about the wellbeing of other people or other species - for their sake, not ours. That is we can be motivated by utilitarian concerns and/or altruism.

Sometimes we maintain something in the environmental domain in order to make it possible to achieve another goal in another domain. For example, we might sustain marine habitats in order to support the livelihood of coastal townships. Or we might sustain renewable resources so that we can support economic development or genuine progress.

How long should we try to sustain something?

This question can only be answered after deciding specifically what needs to be sustained and why. For example, ecosystems services for clean air would need to be sustained as long as there are living things (including people) that need to breathe clean air. For all practical purposes that means 'forever '.Living species seem to last on average a few million years before becoming extinct though some may evolve into new species. So if we maintained a natural extinction rate for species it is so low that for practical purposes we would need to manage in the here and now *as if* we wanted all species to survive, effectively 'forever'. Sustaining the recycling of certain materials may only need to continue for as long as those material types are needed technologically, and depending on the pace of technical change this could be for centuries or for decades. It is risky to assume that resources are only needed for a short time however as society might find new uses for materials as technology, lifestyles and environmental awareness develop.

CHAPTER 3.4

THE IMPACT OF CONSTRUCTION INDUSTRIES

Most human activities that impact on the environment have backwards or forward linkages to the construction industry and their impact can be mitigated through changes in the practices of the construction industry. The industry ‘s environmental impact is the most measurable, but its socio-economic impact should not be negated. Sustainable construction in the developing countries tends to focus on the relationship between construction and human development, often marginalizing the environmental aspects.

The environmental impact of the construction industry as an industry sector is probably larger in developing countries than it is in developed countries. This is due to the fact that the developing countries are virtually still under construction and that they have a relatively low degree of industrialization, making the construction industry one of the biggest factors impacting on the biophysical environment.

The physical environment and the construction sector are linked principally by the demands made by the latter on global natural resources, and this assumes huge environmental significance with the rapid growth in global population and the attendant implications for natural resources. This is especially the case with housing and infrastructure, which are very resource-intensive. The call and desire for sustainable construction is in realization of the construction industry ‘s capacity to make a significant contribution to environmental sustainability because of the enormous demands it exerts on global resources.

The simplest point at which to begin evaluating the impact of the construction industry is to look at its consumption of energy and greenhouse gas emissions. The biggest culprits in terms of climate change are the materials that form the basis of modern construction – concrete and steel. Twice as much concrete is used in formal construction around the world than the total of all other building materials – including wood, steel, plastic and aluminum. Cement production is, after the burning of fossil fuels, the biggest anthropogenic contributor to greenhouse gas emissions. Cement kilns have been identified as a stationary source of nitrogen oxides, releasing more than 25 tons per year. Although cement makes up only 12-14% of the final concrete mix, further embodied energy comes from the transportation and extraction of aggregates and, in the case of reinforced concrete, the manufacturing of steel.

Steel is one of the most energy-intensive materials. Together, the production of iron and steel is responsible for 4.1% of global energy use. The manufacturing and final use of both these materials can also be very water-intensive. Construction activities, whether through the manufacturing of construction materials, or through the operational activities of actual construction, also lead to a number of other environmental problems. These include noise pollution, dust, and hazardous contamination through toxic waste.

Apart from the energy embedded in building materials and products, and the associated greenhouse gas emissions, massive environmental pollution also occurs during processing of the raw materials and manufacturing of the product. Toxic gases and effluents are discharged into the environmental media with devastating effects on aquatic and marine life, as well as contributing to atmospheric pollution. The production of iron, steel and non-ferrous metals, as well as the production of other construction materials such as cement, glass, lime and bricks, is responsible for 20% of annual dioxin and furan emissions.

This exclude emissions due to the production and use of PVC and other chlorinated substances used in the construction industry as paints, sealants, plastics and wood preservatives, for which specific figures are not yet available. Road transport infrastructure, especially road paving with asphalt, contributes a further one percent of annual dioxin emissions. The bulk of dioxin emissions (69%) come from the incineration of municipal waste. The incineration of treated waste wood, floor coverings and electrical wiring from demolition sites makes a significant contribution to this Table.

Material	KWh/Kg	KWh/m3	Coal (Kg)
Sawn timber	0.7	350	0.8
Cement	1.4	1 750	260
Concrete	0.3	700	25
Bricks	0.8	1 360	140
Steel	5.9	46000	1 000
PVC Plastic	18.0	24700	1 800
Aluminum	52.0	141500	4 200

Table 1: Energy consumption in the production of construction materials in Brazil

Construction and demolition waste is another important issue, as waste is often dumped illegally in dams, river courses and any available hollow. If left unchecked, dumping sites become breeding grounds for mosquitoes and vermin. High material consumption rates are due to high material wastage, both as waste and as material unnecessarily incorporated in the building. (Material wastage can be defined as the amount of material consumed in addition to the planned amount.) The highest rates of wastage are recorded for Portland cement and concrete and ceramic blocks, all materials which significantly contribute to climate change through their manufacture.

The building materials manufacturing industry is also responsible for the pollution of watercourses and filling up of landfill sites. The raw materials for building materials are often extracted from the rural hinterlands, where they cause degradation of land and ecosystems. The processing and production of these usually take place close to the city, where they produce air and dust pollution and consume a great deal of energy.

Any discussion on the environmental impact of construction would not be complete without the inclusion of the mining and mineral-related industrial sector. Pollution, land degradation and widespread disruption of natural terrain are direct impacts that are exacerbated by the lack of programmers and regulations regarding the rehabilitation of mining sites.

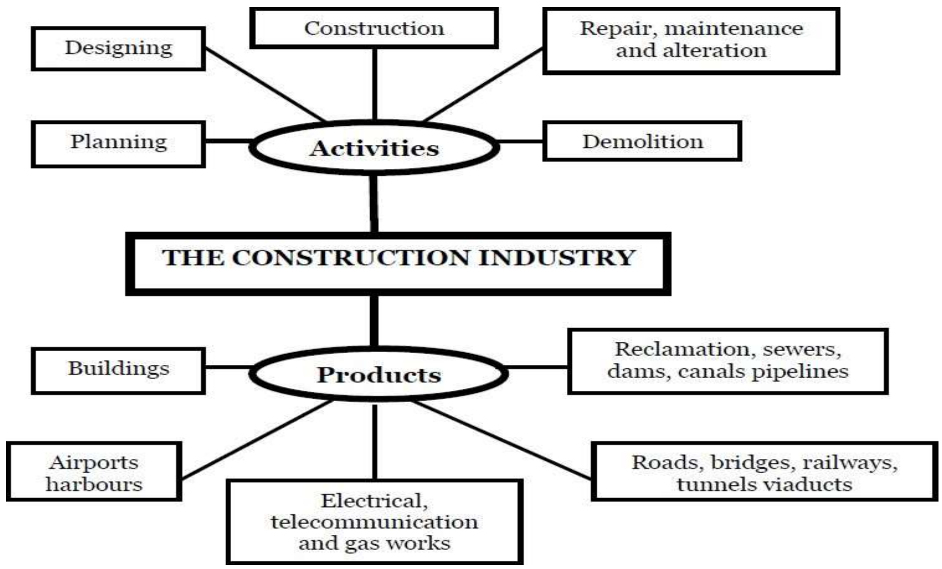

Fig 3.4.1: Activities and products of construction industry

The following sections focus primarily on environmental impacts relevant to construction activities.

4.1 Environmental impact of construction activities

Globally, the construction sector is arguably one of the most resource intensive industries. Concern is growing about the impact of building activities on human and environmental health. It is clear that actions are needed to make the built environment and construction activities more sustainable (Hill and Bowen, 1997; Barrett *et al.* 1999; Cole, 1999; Holmes and Hudson, 2000; Morel *et al.,* 2001; Scheuer *et al.* 2003; Abidin, 2010) [4]. The construction industry and the environment are intrinsically linked and it has found itself at the center of concerns about environmental impact. According to Abidin (2010), buildings are very large contributors to environmental deterioration. Kein *et al.* (1999) and Ding (2008) describe the building industry as uncaring and profit motivated, and the members as destroyers of the environment rather than its protectors. Indeed, the construction industry has a significant irreversible impact on the environment across a broad spectrum of its activities during the off-site, on-site and operational activities, which alter ecological integrity (Uher, 1999; Ding, 2008). Construction activities affect the environment throughout the life cycle of a construction project. This life-cycle concept refers to all activities from extraction of resources through product manufacture and use and final disposal or recycle, i.e. from ―cradle to grave. ‖

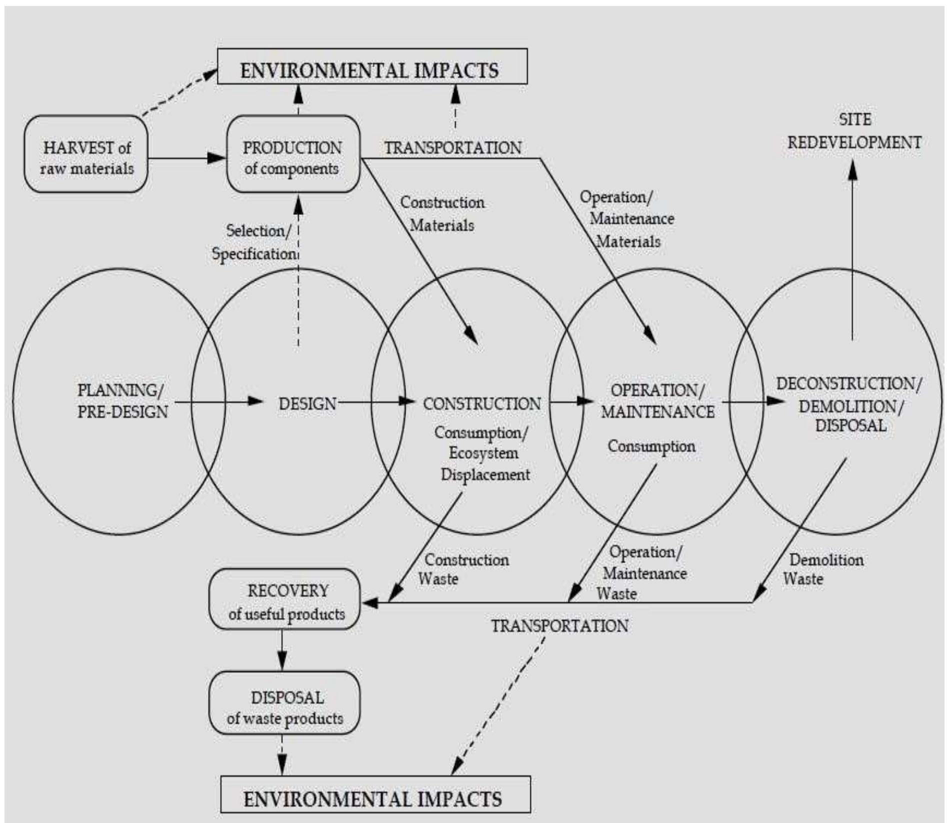

Figure 3.4.2 Life Cycle Environmental Impact of Building Construction

Source: Franklin Associates (1990)

Even though the construction period is comparatively short in relation to the other stages of a building's life, it has various significant effects on the environment.

Therefore the analysis of the impact of the construction industry on the environment may need to look at a _cradle to grave‘viewpoint.

4.1.1 Raw material consumption and its associated impacts

The construction industry is one of the largest exploiters of renewable and nonrenewable natural resources. According to World-watch Institute (2003), building and construction activities worldwide consume 3 billion tons of raw materials each year, or 40% of total global use. According to Levin (1997), in the USA construction uses 30 percent of raw materials, 40 percent of energy and 25 percent of water. In Europe, the Austrian construction industry has about 50 percent of material turnover induced by the society as a whole per year and 44 percent in Sweden (Sterner, 2002). The UK construction industry consumes around 420 million tons of materials annually, the highest of any sector (DTI, 2006; Plank, 2008). It relies heavily on the natural environment for the supply of raw materials such as timber, sand and aggregates for the building process. This extraction of natural resources causes irreversible changes to the natural environment of the countryside and coastal areas, both from an ecological and a scenic point. The subsequent transfer of these areas into geographically dispersed sites not only leads to further consumption of energy, but also increases the amount of particulate matter in the atmosphere.

4.1.2 Pollution generation and its associated impacts

Raw materials extraction and construction activities also contribute to the accumulation of pollutants in the atmosphere, mostly in the processing of materials for construction. And again, not surprisingly, the construction industry has the biggest effect of all sectors because of the quantity of materials used in construction. According to Holton *et al.,* (2008), the UK construction is responsible for 40 percent of atmospheric emissions, 20 percent of water effluents and 13 percent of other releases. Dust and other emissions include some toxic substances such as nitrogen and sulphur oxides. They are released during the production and transportation of materials as well as from site activities and have caused serious threat to the natural environment. The DTI (2006) reports that the global greenhouse gas emissions increased more than four-fold in the last half of the twentieth century. Other harmful materials, such as chloro-floro-carbons (CFCs), are used in insulation, air conditioning, refrigeration plants and fire-fighting systems and have seriously depleted the ozone layer (Clough, 1994; Langford *et al.* 1999). Pollutants have also been released into the biosphere causing serious land and water contamination, frequently due to on-site negligence resulting in toxic spillages which are then washed into underground aquatic systems and reservoirs. According to Langford et al, about one third of the world's land is being degraded and pollutants are depleting environmental quality, interfering with the environment's capacity to provide a naturally balanced ecosystem. The BRE defined pollution from construction as ―particles, noise, vibration and vaporous discharges‖. Risk should be identified and steps taken to minimize potential pollution. The construction industry must consider enhancing or at least protecting biodiversity as it ―considers all things and their habitats‖ and there is an obligation to consider biodiversity in developments in terms of good design and material selection. If the construction industry continues to overuse these natural resources, a limit on economic growth will eventually emerge. In other words, the destruction of the environment will inevitably affect the construction industry.

4.1.3 Waste generation and its associated impacts

The construction industry produces an enormous amount of waste. A large volume results from the production, transportation and use of materials. Construction activity contributes approximately 29 percent of waste in the USA and more than 28 percent in Malaysia reports that 14 million tons of wastes are put into landfill in Australia each year, and 44% of this waste is attributed to the construction industry. In the European Union, the construction industry contributes about 40–50 percent of wastes per year . Furthermore, waste from construction and demolition constitutes one of the largest waste streams in Europe. Report of a study carried out for the European

Commission in 1999 showed that in the EU-15 arising of core‘construction and demolition waste amount to around 180 million tons each year and that only about 28% across the EU-15 as a whole is re-used or recycled with the remaining 72% going to landfill. Five Member States accounted for around 80% of the total, broadly consistent with the share of the overall construction market accounted for by these countries.

Member state	**“Core” construction and demolition waste**	**% re-used or recycled**	**% incinerated or Land filled**
Germany	59	17	83
UK	30	45	55
France	24	15	85
Italy	20	9	91
Spain	13	<5	>95
Netherland	11	90	10
Belgium	7	87	13
Austria	5	41	59
Portugal	3	<5	>95
Denmark	3	81	19
Greece	2	<5	>95
Sweden	2	21	79
Finland	1	45	55
Ireland	1	<5	>95
Luxembourg	0	N/A	N/A

Table 2: Construction and Demolition Waste Arising and Recycling

Source: Burgan and Sansom (2006)

In the UK 90 million tons of inert construction waste (suitable for reprocessing into aggregate) is produced every year. Of this, some 50 per cent is reused and recycled and just over 30 per cent goes to landfill. Other non-inert waste accounts for around 20 million tones annually. This includes site construction and refurbishment waste and a further 1.7 million tons of hazardous waste. The UK government projected that landfill capacity will be reached by 2017. To lessen the the cost associated with waste disposal and to increase levels of recycling and recovery, the government have introduced landfill tax and aggregate levy which has helped to drive waste management practices among construction organization. As a result, most major construction organizations now have waste management policies and practices in place.

Most construction waste is unnecessary according to Sterner who says that many construction and demolition materials have a high potential for recovery and reuse. However, due to the economic nature of the building industry, every stage of the construction period is minimized. In addition, time and quality are crucial and virgin materials are considered superior to second hand products for these reasons alone. Screening, checking and handling construction waste for recycling are time consuming activities and the lack of environmental awareness amongst building professionals may create significant barriers to the usefulness of recycling. The depletion of natural resources by the building industry is a topic of serious discussion as most of the recyclable material from building sites ends up in landfill sites. Sterner states that implementing a waste management plan during the planning and design stages can reduce waste on-site by 15 percent, with 43 percent less waste going to the landfill through recycling, and it delivers cost savings of up to 50 percent on waste handling.

4.1.4 Energy consumption and its associated impacts

Apart from waste generation, the building industry rapidly growing world energy use and the use of finite fossil fuel resources has already raised concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts. Building material production consumes energy, the construction phase consumes energy, and operating a completed building consumes energy for heating, lighting, power and ventilation. The existing building stock in European countries accounts for over 40% of final energy consumption in the European Union (EU) member states, of which residential use represents 63% of total energy consumption in the buildings sector. The built environment is responsible for 50% of the total UK energy consumption; 45% to heat, light and ventilate buildings and 5% to construct them, while arguably more than 50% of all UK carbon emissions can be attributed to energy use in buildings (including residential and business emissions) . The government set a target to achieve 60% energy reduction by 2050. However, the Royal Institution of Chartered Surveyors (RICS) believed that the government is failing in its energy policy to make enough difference. In response to the UK energy Review, RICS believed the ―Energy review is a failed opportunity to challenge the wider and more fundamental issues about sustainability and how we live and work‖. The current low levels of energy efficiency in the built environment offer vast scope for improvement in energy performance, which may be achieved through the deployment of an array of techniques ranging from simple plant and insulation upgrades to the deployment of advanced energy monitoring and control.

4.1.5 Deforestation and its associated impacts:

Furthermore, massive deforestation in developing countries can be attributed to the building materials industry – not just locally, but also for export. Timber for construction and related industries is often harvested from indigenous forests and only minimally replaced, causing soil erosion, siltation of watercourses, and reduced precipitation and its concomitant problems. These indirect impacts generate growing regional inequalities, impoverishment, and underemployment. Site design and the impact of the actual construction process on the natural environment remain common problems. Without a proper investigation of the site, the natural environment ceases to be an integral part of design and construction implementation and is thereby compromised. As argued by Schaefer, architects, developers, builders and owners often overlook the site as one of the significant elements of sustainable development and construction. He further argues that development proceeds in a heroic mode – that nature is to be conquered, the rugged individual mastering and subduing the land for economic gain.

In many urban areas of the developing world, the construction of buildings, especially residential buildings, has been carried out to occupy the entire site. In the process, the natural green system has been destroyed and compaction has taken place to a level that prevents air movement in the soil, even after construction has been completed. The existing natural environment has in many cases been destroyed beyond repair. In South Africa, for example, new housing, especially in the state low-cost projects, has changed places of good natural vegetation into desert, with construction activity causing the removal of all the trees on site, rather than integrating them into the built environment.

The construction industry also has a huge impact on agricultural land. Soil erosion and other forms of land degradation now rob the world of 70-140000 km^2/year of farming land. Urbanization alone is responsible for the loss of 20-40000 km^2/year. Again, the impact is most dire in developing countries with poor-quality soils, such as most African countries. Land is a costly commodity and the basis of many an economic activity on which survival rests. The development of land, especially where there is lack of stringent application of environmental standards and regulations, tends to disregard the quality of the built and natural environment in pursuit of maximum economic gain.

4.1.6 Climate change and its associated impacts:

Climate change has become synonymous with global warming and it is caused by the build-up of greenhouse gases, which trap energy on the Earth's surface. Significant climate change over the next century is expected. The continuing of global warming has intensified many atmospheric extremes leading to significant increase in the frequency and severity of heat waves and associated effect on human health as shown in table 2. The greenhouse gas effect is not a new problem. As early as 1896, a Swedish chemist already proposed that the changing atmospheric carbon dioxide concentration was the major cause of global temperature fluctuations, the carbon dioxide concentration in 1765 was about 280 parts per million by volume but it has increased to approximately 364 ppm in 2009.

The concentration of carbon dioxide was due to the burning of fossil fuels leading to global warming. In 1985, researchers claimed that global warming was caused by human activities and the first Intergovernmental Panel on Climate Change (IPCC) confirmed this claim in 1988. The subsequent report, published in 1990, confirmed that there is a greenhouse effect and the increased atmospheric concentration of carbon dioxide was caused by human activities. A second IPCC followed in 1995 and a third in 2001 both expressed increasing confidence that greenhouse gases will cause dangerous future climate change. Figure 4.1.6 provides a projection of future greenhouse gas emissions of developed and developing countries. Total emissions from the developing world are expected to exceed those from the developed world by 2015.

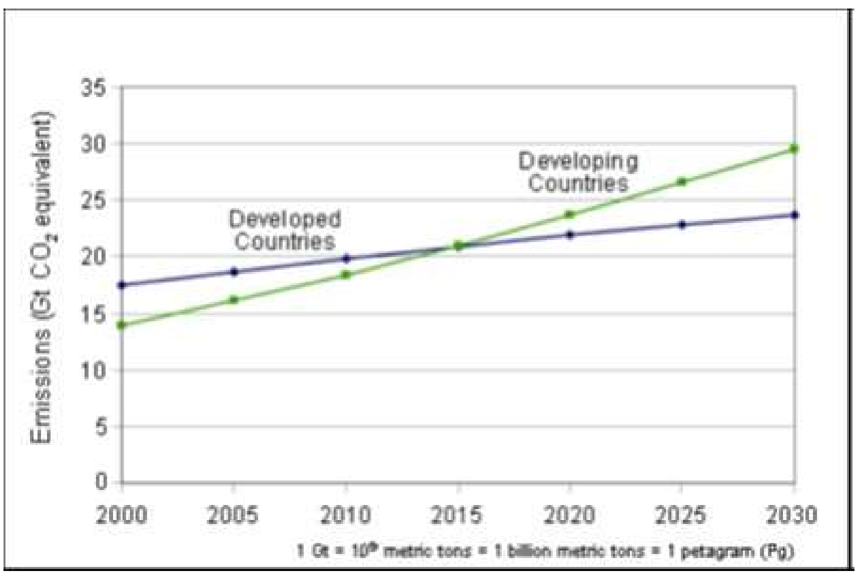

Figure 3.4.3: World Greenhouse Gas Emissions by region
Source: United States Environmental Protection Agency (EPA).

Apart from the increased atmospheric concentration of carbon dioxide, atmospheric concentrations of other greenhouse gases such as methane, nitrous oxide and chlorofluorocarbons are also increasing as a result of human activities. According to the third IPCC in 2001, the Earth's surface temperature has increased between 0.3°C and 0.6°C during the last 150 years, and if no environmental pressure or controls are introduced, an increase in global mean temperature of about 2.5°C can be expected by the year 2100.The warming of the Earth's surface has a significant effect on the living creatures On Earth and as well as the structure of the atmosphere. Human health will be affected by the increased heat stress and widespread vector-borne diseases such as malaria. Increasing global temperature warms and expands the oceans, melts polar ice caps and, in turn, raises sea levels. It is estimated that there will be an average increase in sea level of about 6cm per decade for a temperature rise of between 1.5 to 5.5°C. The sea levels are expected to rise by about 0.5m by 2100. The potential impacts of climate change on anthropogenic (manmade activities) systems, of anthropogenic systems on natural systems, and their subsequent influences on natural and human-induced disasters are illustrated in figure 3.4.3. As sea levels rise, soil erosion, flooding and storm damage to some coastal regions will follow.

Ecosystems at river mouths and the quality of fresh water are also affected. Reduced snow and ice will reflect less light back into space and produce even greater warming. High concentration of carbon dioxide in the atmosphere will also affect coastal ecosystem productivity. The high concentration of carbon dioxide in the atmosphere also increases the rate of plant loss, that is, loss of biodiversity, another environmental problem that threatens human existence.

4.1.7 Land degradation & Its Associated Impacts

Fragile eco-zones in many countries are being destabilized because of construction activities. Occurrence of floods, land and mud slides caused by construction on delicate hill slopes and wet lands testify to the vulnerability of the environment to interventions of the construction sector. Physical destruction of land is also caused by extraction of sand and gravel for concrete and extraction of clay for the production of bricks. The rate of deforestation is extensive due to lumbering, land clearing for farming and building construction, which has even penetrated restricted areas like forest reserves on hill sided and highlands. This resulted in increased instability of the natural landscape and increased in erosion. Rational decision-making and implementation of transparent and effective strategies are needed to solve the conflicts between land use and the construction sector is urgently required and should be given high priority by decision makers.

4.1.8 Sand Mining & its Associated Impact

For thousands of years, sand and gravel have been used in the construction of roads ings today, demand for sand and gravel continues to increase. Mining operators, in on with cognizant resource agencies, must work to ensure that sand mining is in a responsible manner.

Excessive in stream sand-and-gravel mining causes the degradation of rivers. In stream mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system.

Excessive instream sand mining is a threat to bridges, river banks and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.

Instream and mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. These physical impacts cause degradation of riparian and aquatic biota and may lead to the undermining of bridges and other structures. Continued extraction may also cause the entire streambed to degrade to the depth of excavation.

Sand mining generates extra vehicle traffic, which negatively impairs the environment. Where access roads cross riparian areas, the local environment may be impacted.

4.1.8.1 Sand Budget

Determining the sand budget for a particular stream reach requires site-specific topographic, hydrologic, and hydraulic information. This information is used to determine the amount of sand that can be removed from the area without causing undue erosion or degradation, either at the site or at a nearby location, upstream or downstream.

In-channel or near-channel sand-and-gravel mining changes the sediment budget, and may result in substantial changes in the channel hydraulics. These interventions can have variable effects on aquatic habitat, depending on the magnitude and frequency of the disturbance, mining methods, particle-size characteristics of the sediment, the characteristics of riparian vegetation, and the magnitude and frequency of hydrologic events following the disturbance.

Temporal and spatial responses of alluvial river systems are a function of geomorphic thresholds, feedbacks, lags, upstream or downstream transmission of disturbances, and geologic/physiographic controls. Minimization of the negative effects of sand-and-gravel mining requires a detailed understanding of the response of the channel to mining disturbances.

Decisions on where to mine, how much and how often require the definition of a reference state, i.e., a minimally acceptable or agreed-upon physical and biological condition of the channel. Present understanding of alluvial systems is generally not sufficient to enable the prediction of channel responses quantitatively and with confidence; therefore, reference states are difficult to determine. Still, a general knowledge of fluvial processes can provide guidelines to minimize the detrimental effects of mining. Well-documented cases and related field data are required to properly assess physical, biological, and economic tradeoffs.

4.1.8.2 Stability of Structures

Sand-and-gravel mining in stream channels can damage public and private property. Channel incision caused by gravel mining can undermine bridge piers and expose buried pipelines and other infrastructure.

Several studies have documented the bed degradation caused by the two general forms of instream mining:

(1) pit excavation

(2) bar skimming.

Bed degradation, also known as channel incision, occurs through two primary processes:

(1) Head cutting

(2) Hungry water.

In head cutting, excavation of a mining pit in the active channel lowers the stream bed, creating a nick point that locally steepens channel slope and increases flow energy. During high flows, a nick point becomes a location of bed erosion that gradually moves upstream.

4.1.9 Depletion of non-renewable Resources

The construction industry is a major consumer of natural non-renewable resources such as metals, fossil fuel and non-renewable energy resources. Construction sector activities and the Manufacturing processes of basic building materials such as cement, steel, aluminum, glass, bricks and lime are highly energy dependent where fossil fuel is a major non-renewable resource requires generating huge amount of energy. The world-wide recognition of the limited supply of fuels and the high degree of dependency on energy by the construction industry has led to regional efforts in search of alternative energy sources and renewable sources. Malaysia, Thailand, Vietnam are known to have invested in the search of alternative energy resources for construction (UNESCAP). Consequently, as fossil fuel become more and more precious fuel wastage are prevented, and the overall energy efficiency become the overriding criterion in the design and operation of buildings. Energy efficiency is seen as the most attractive factor why stakeholders invested in sustainable building and construction.

4.1.10 Use of Brown Sites for Construction

In some countries in Southeast Asia, in order to relieve the pressure on undeveloped land, theUse of previously built-on and contaminated sites is always encouraged and has become common practice for developments. The contamination left a significant toxic legacy in the soil, eco-system and food chains thus becoming potential threats to human health. The need for decontamination of these sites in line with statutory regulations is vital to ensure that any health risks are either removed or reduced to within acceptable limits.

4.1.11 Building Materials Shortage

The local production of building materials in countries is not sufficient to meet the demand for the construction sectors. In many countries that produce cement, there are severe bottlenecks in the supply of this materials cause by demand fluctuations and lack of capital for the build-up of supplies, or inputs. In cement producing countries, cement is often regarded as a local product even when 60 % of the production cost is due to imported energy.

In fact, the biggest factor influencing climate change is concrete and steel. Cement production is the biggest contributor to greenhouse gas emissions. Although cement makes up only 12-14 % of the final concrete mix, further embodied energy comes from the transportation and production of aggregates and in the case of reinforced concrete the manufacturing of steel Shortage of other locally produced building materials, such as aggregates, bricks and tiles are also experienced.

4.1.12 Health and well being

Burgan and Sansom (2006) observe that on average we spend some 90% of our lives in buildings, therefore the internal environment of the buildings we live, work and play in has proved to be a major contributor to our quality of life. For example, the fact that poor quality living space is responsible for health problems has been recognized by the World Health Organization (W.H.O.) for some 15 years in what Burgan and Sansom observe that on average we spend some 90% of our lives in buildings, therefore the internal environment of the buildings we live, work and play in has proved to be a major contributor to our quality of life. For example, he fact that poor quality living space is responsible for health problems has been recognized by the World Health Organization (W.H.O.) for some 15 years in what it terms ―sick building syndrome‖ and the W.H.O. estimates that worldwide, 30% of offices, hotels, institutions and industrial premises have the syndrome. Observe a similar trend in that inadequate heating or cooling, waste disposal, and ventilation systems result in adverse health effects, including respiratory illnesses, asthma, infectious diseases, injuries, and mental health disorders. Carbon dioxide emissions from buildings are primarily caused by the use of electricity to provide heating, cooling, lighting, water, information management, and entertainment systems. Because of their long life expectancies, buildings affect the environment and public health for many years. In England, for example, the construction industry accounted for 31% of all fatal injuries to workers in 2002/3, significantly higher than other industrial sectors, and workers with the least time with their current employer (or least time self-employed) had the highest rate of reportable injury. The figures for Europe are shown in Fig. 3.4.4.

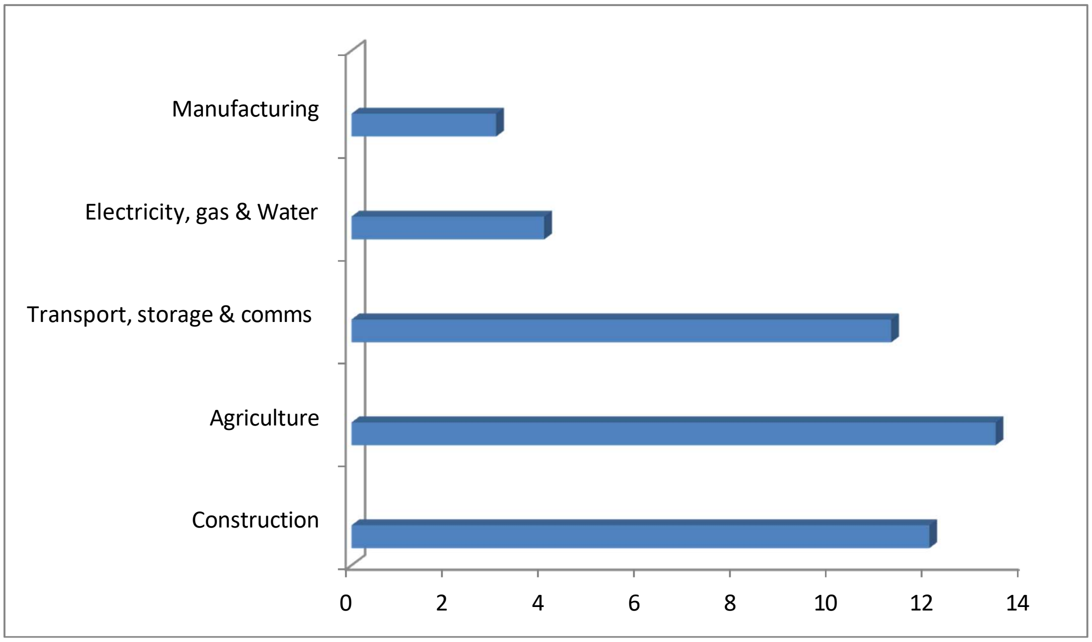

Figure 3.4.4. Rates of Fatal Accidents per 100,000 Workers (EU Average, Eurostat).

Source: Burgan and Sansom

Construction industry must inevitably change its historic methods of operating with little regard for environmental impacts to a new mode that makes environmental concerns a centerpiece of its efforts. According to Abidin, the concern on environment is previously a relatively small part of most of construction development. However, with the growing awareness on environmental protection, this issue have gain wider attention by the construction practitioners worldwide. Implementing sustainable construction practices has been advocated as a way forward in fostering economic advancement in the construction industry while minimizing impact on the environment. A shift in paradigm is now necessary from developing with environmental concern as a small part of the process into integration of all building projects within the wider context of environmental agenda . Thus, the activities of construction industry must work and comply with the needs to protect and sustain the environment.

4.2 Social impact

Given that the products of the industry are used to underpin and facilitate all facets of socio-economic relations, it is possible to enhance social sustainability through the construction process. This is particularly the case with the labour-intensive nature of construction activities and the opportunities it presents for poverty alleviation. Construction also has social impacts in terms of its labour relations and business practices.

The construction industry (in its narrow definition) is the largest industrial employer in the world with 111 million employees worldwide. Of these, 74% are in the low-income countries. Since low-income countries produce only 23% of the global construction output, it is clear that the "employment intensity" of construction activities is much higher in low-income countries than in the high-income ones. The construction industry and its employment conditions can therefore play a major role in human development and improving the quality of life for the poor.

However, the construction sector has a reputation for greed, corruption, unfair labor practices and environmental destruction. In a recent international Gallup poll, the sector was perceived as even more corrupt than the arms and energy sectors. Corruption in the construction sector, leading to sub-standard construction products, was also partially held to account for the high death tolls in recent earthquakes in Turkey and India. A study by the International Labor Organization (ILO) found that construction workers almost everywhere in the world do not view their employment in a favorable light and in many countries – both rich and poor – people work in construction out of necessity and rarely out of choice. Few would want their children to enter the industry

.

The same study also found that among blue-collar worker's high rates of gender discrimination and sexual harassment continue to limit the equal participation of women in the industry, despite government programmers to promote gender equality in the sector. While the situation is better for women in the built-environment professions, they too still deal with high, if more subtle, levels of gender discrimination and harassment.

According to the ILO study, the construction industry also has a very bad safety record, although reliable data on this is scarce, especially in developing countries where the rarity of workman 's insurance means that accidents often go unreported. This high accident rate is ascribed to lack of formal training and subcontracting to the unregulated informal sector.

The fluctuating nature of the industry, coupled with low profit margins and a high turnover of informal workers, is also contributing to the collapse of the apprenticeship system, and subsequently to a reduced national skills base.

4.3 Economic impact

The construction industry also has the potential to enhance economic sustainability through its structure, conduct and performance. In almost every country in the world, the built environment normally constitutes more than half of total national capital investment, and construction represents as much as 10% of GNP The industry is also playing a substantial role in the creation of small, medium and micro enterprises (SMMEs). Ninety per cent of construction workers are employed in micro firms with fewer than ten people. The contribution of small and informal contractors to the economy should also not be underestimated. Most cement and paint is sold to smaller consumers. Small companies are also responsible for a large proportion of building material manufactured. In Brazil alone there are about 11000 small companies manufacturing ceramic bricks and tiles. These companies promote local economic development in a way that the large national and multinational companies cannot do.

There is also a direct relationship between the economic sustainability of the sector and its environmental impact. An economically efficient construction industry enhances environmental sustainability by ensuring least-cost methods of construction that encourage optimal allocation of resources and discourage waste. Furthermore, economic sustainability within construction requires that social and environmental costs are internalized and reflected in the final product prices.

4.4 How will project operation affect the geology, soils, and groundwater?

4.4.1 Direct Effects

Long-term geology, soils, and groundwater-related effects could occur during normal operations of SR 167. The project will be designed based on the available subsurface information, design procedures and criteria approved and the existing site conditions. If subsurface conditions at the site are different from those disclosed during the field explorations, or site conditions change during the life of the project, future effects to the site could occur.

4.4.1.1 Seismic Considerations

Slopes an earthquake could trigger landslides on steep slopes, settlement, or liquefaction in alluvial deposits, that could slide or slough during an earthquake include new fill embankments and cut slopes. Alluvial deposits that are potentially susceptible to liquefaction during a seismic event underlie the project area. If liquefaction occurs beneath or alongside foundation structures, loss of bearing capacity, settlement, and lateral displacement may occur. If liquefaction occurs beneath proposed embankments, slope instability and settlement could damage the existing roadway and adjacent facilities.

4.4.1.2 Settlement

Down drag occurs when the skin friction force is in the same direction as the axial load. When the settlement of the surrounding soils exceeds the downward movement of a pile or shaft negative skin friction occurs. This typically happens when a pile or shaft passes through an Under consolidated layer of fill that is consolidating under its own weight, but can also be a result of lowering the water table or additional surcharge loads being applied. Cuts into Existing Slopes Construction activities will require that cuts into existing slopes be made for storm water detention ponds. These cuts may experience erosion and surface sloughing over the lifetime of the project. The degree of erosion experienced will depend on near-surface soil types, weather conditions, potential seismic events, vegetation, surface drainage, and other causes.

4.4.1.3 New Fill

Widening to accommodate the new HOT lane will require placement of structural fill. As discussed previously, even though most fill will occur on top of the fill placed in the 1970's, some fill will be placed toward the existing toe of slope where the existing fill is the shallowest. The new fill may have steeper side slopes than the existing fill. Fill, peat, and alluvium deposits could settle as a result of the new fill loads. Granular deposits (fill and alluvium) may settle as the load is applied. Soft or cohesive soil (alluvium and peat) may settle during the first few years after construction, which could cause pavement distress, drainage problems, and other utility problems. In areas where soil deposits containing numerous organics are present (peat and organic alluvium), secondary compression could result in long-term, ongoing settlement. Settlement could damage utilities near or beneath the proposed fills.

4.4.1.4 Permanent Drainage

Permanent drainage facilities may result in increased water flow to existing culverts or drainage ditches. Sediment from slope erosion may accumulate in ditches, culverts, swales, and other drainage features. Water that overflows or is incorrectly directed onto slopes or properties couldcause erosion, landslides, and other effects. Permanent drainage could decrease groundwater recharge and lower the water table.

CHAPTER 3.5

KYOTO GASES AND IMPACT ON GLOBAL ENVIRONMENT

5.1 What's the difference between cement and concrete?

- The terms cement and concrete are often used interchangeably. Cement is an ingredient of concrete. It's the fine, gray powder that, when mixed with water, sand and gravel, forms the rock-like mass known as concrete. Cement acts as the binding agent or glue. Cement is produced by cement manufacturers around the world in cement plants.
- The product from the burning process during manufacture of cement, called clinker, is then underground with other ingredients to produce the final cement product.
- Concrete is the rock-like product that is used to build our homes, buildings, roads, bridges, airports and subways, among other critical structures. Concrete is used in almost every form of construction. It's made by concrete producers who combine materials, including cement, water, sand and gravel, along with other chemicals and minerals to create concrete.

5.2 Does cement manufacturing generate CO_2?

- As with all industrial processes requiring energy, manufacturing cement does result in the generation of CO_2.
- Cement is manufactured from a combination of naturally occurring minerals - calcium (60% by weight) mainly from limestone or calcium carbonate, silicon (20%), aluminum (10%), iron (10%) and small amounts of other ingredients and heated in a large kiln to over 1500° C (2700^0F) to convert the raw materials into clinker.
- For the most part, CO_2 is generated from two different sources during the cement manufacturing process:

  - Use of fossil fuels in the burning process;

  - Calcination

The most commonly used cement is called Portland cement. It contains about 92% to 95% clinker by weight. Some companies produce blended cements that incorporate other industrial byproducts that have cementitious properties, thus reducing the amount of clinker in the cement.

- Other parts of the manufacturing process such as operating mining equipment for extracting the raw materials and transportation of the raw materials to the cement plant emit relatively small amounts of CO_2.
- According to the Department of Energy, cement production accounts for 0.33% of energy consumption in the U.S. The current level is low compared with other industries, such as petroleum refining at 6.5%, steel production at 1.8% and wood production at 0.5%.
- According to EPA, between 900 and 1100 kg (1984 and 2425 lbs.) of CO_2 is emitted for every 1000 kg (2205 lbs.) of Portland cement produced in the

  U.S. This depends on the fuel type, raw ingredients used and the energy efficiency of the cement plant.
- Between 50% and 60% of the CO_2 emitted is a result of calcination of calcium carbonate raw materials, a necessary part of the manufacturing process. The remaining CO_2 emitted is a result of burning fossil fuels such as coal and natural gas to heat the raw materials in the kiln.
- The U.S. cement industry accounts for approximately 1.5% of U.S. CO_2 emissions, well below other sources such as heating and cooling our homes (21%), heating and cooling our buildings (19%), driving our cars and trucks (33%) and industrial operations (27%).

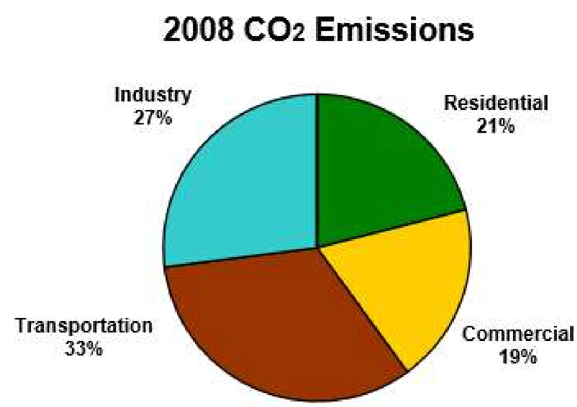

Figure 3.5.1. 2008 U.S. CO_2 emissions by category.

- Global CO_2 emissions from cement production (377 million metric tons of carbon in 2007) represent 4.5% of global CO_2 releases from fossil-fuel burning and cement production.
- In 2010, the U.S. cement industry manufactured about 62 million metric tons (Mt) (68 million tons) of cement and imported about 5.5 Mt (6.1 million tons).
- In 2010, the U.S. was the third largest cement manufacturing country behind China, 1,814 Mt (2,000 million metric tonnes) and India, 191 Mt (210 million tons.) Total global cement production in 2010 was 3084 Mt (3,400 million tons). U.S. cement manufacturing capacity is 4.3% of global capacity.

5.3 Does concrete manufacturing produce CO_2?

Water, sand, stone or gravel, and other ingredients make up about 90% of the concrete mixture by weight. The process of mining sand and gravel, crushing stone, combining the materials in a concrete plant and transporting concrete to the construction site requires very little energy and therefore only emits a relatively small amount of CO_2 into the atmosphere. The amounts of CO_2 embodied in concrete are primarily a function of the cement content in the mix designs. It is important to note that structures are built with concrete and not cement.

Figure 3.5.2. Typical composition of hydraulic cement concrete.

5.4 How much CO_2 is embodied in concrete?

Concrete uses about 7% and 15% cement by weight depending on the performance requirements for the concrete. The average quantity of cement is around 250 kg/m3 (420 lb/yd^3). One cubic meter (m^3) of concrete weighs approximately 2400 kg (1 cubic yard weighs approximately 3800 lb). As a result, approximately 100 to 300 kg of CO_2 is embodied for every cubic meter of concrete (170 to 500 lb per yd^3) produced or approximately 5% to 13% of the weight of concrete produced, depending on the mix design. A significant portion of the CO_2 produced during manufacturing of cement is reabsorbed into concrete during the product life cycle through a process called carbonation. One research study estimates that between 33% and 57% of the CO_2 emitted from calcination will be reabsorbed through carbonation of concrete surfaces over a 100-year life cycle.

5.5 How does concrete compare to other building materials?

Concrete compares favorably to other building materials such as steel, wood and asphalt when analyzing energy consumption and CO_2 emissions. Concrete building systems such as insulating concrete forms and tilt-up concrete incorporate insulation, high thermal mass and low air infiltration to create energy efficient wall systems that save energy over the life of a building. The result is significantly lower CO_2 emissions related to building occupancy when compared to wood and steel frame construction.

In one research study comparing energy performance of various concrete wall systems to wood frame and steel frame structures, concrete wall systems reduced energy requirements for a typical home by more than 17%. By comparison, a stick-frame house would have to be built with 2x12 number and R-38 insulation to achieve the same energy performance as the insulated concrete wall comprised of 150 mm (6 in) of concrete and two layers of 60 mm (2 in) thick rigid insulation.

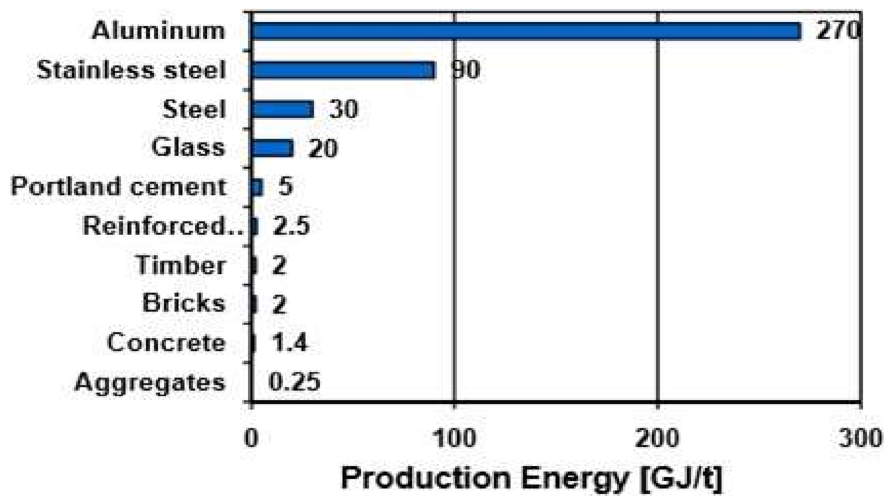

Figure 3.5.3. Energy of production of common building materials

5.6 What is the cement industry doing to reduce greenhouse gases?

The cement industry was among the first to tackle the issue of climate change. Since 1975, the cement industry has reduced emissions by 33%. PCA members adopted a voluntary Code of Conduct, (principles, performance measures, and a reporting protocol) to support the Cement Manufacturing Sustainability Program. By the year 2020, the industry plans to voluntarily reduce CO_2 emissions by 10%, energy use by 20% and cement kiln dust by 60% below a 1990 baseline.

The primary options for reducing the quantity of CO_2 generated during cement manufacturing process are to use alternatives to fossil fuels, change the raw ingredients used in manufacture and inter-grind additional materials with the clinker.

The most recent progress involves newly introduced guidelines that will allow for greater use of limestone as inter-ground material in finished cement. This will have no impact on product performance but will ultimately reduce CO_2 by more than 2.5 Mt (2.8 million tons) per year in the U.S. Using inter-ground limestone in cement is already common practice in Europe and Canada.

5.7 What is the concrete industry doing to reduce greenhouse gases?

The U.S. concrete industry is committed to continuous environmental improvement through process innovation and product standards that lead to reduced environmental impact.

The U.S. concrete industry has implemented the P2P Initiative (Prescriptive to Performance Specifications for Concrete) which provides concrete producers more flexibility to optimize concrete mixtures for intended performance that will also reduce environmental impact, including CO_2 emissions. Traditionally, construction specifications for concrete have required unnecessarily high quantities of Portland cement along with other limits on the use of supplementary cementitious materials. These limits are incorporated in the industry‘s standards and specifications. The P2P Initiative proposes to eliminate many of these limits and evolve to performance-based standards. This will reduce the environmental impact of concrete as a building material.

The U.S. concrete industry uses a significant amount of industrial byproducts such as fly ash, blast furnace slag and silica fume to supplement a portion of the cement used in concrete. These industrial products, which would otherwise end up in landfills, are called supplementary cementitious materials or SCMs for short. The use of SCMs in concrete work in combination with Portland cement to improve strength and durability in addition to reducing the CO_2 embodied in concrete by as much as 70%, with typical values ranging between 15 and 40%.

Fly ash is the waste byproduct of burning coal in electrical power plants. Generally, 15% to 20% of burned coal takes the form of fly ash. At one time, most fly ash was landfilled, but today a significant portion is used in concrete. Based on NRMCA research, the amount of fly ash used in concrete was about 80 kg (135 lb/yd3) in 2002, extending cement supply and enhancing concrete performance.

Blast furnace slag is the waste byproduct of iron manufacture. After quenching and grinding, the blast furnace slag takes on much higher value as a supplementary cementitious material for concrete. Blast furnace slag is used as a partial replacement for cement to impart added strength and durability to concrete. In 2002, when blast furnace slag was used in concrete, the average quantity was about 150 kg/m^3 (250 lb/yd^3), extending cement supply and enhancing performance.

Silica fume is a waste byproduct of processing quartz into silicon or ferro-silocon metals in an electric arc furnace. Silica fume consists of superfine, spherical particles that when combined with cement significantly increases strength and durability of concrete. It is used for some high-rise buildings to produce concretes which exceed 140 MPa (20,000 psi) compressive strength and in bridge and parking garage construction to help keep chlorides from deicing salts from corroding steel reinforcement.

In 2010, the U.S. electric power industry generated a total of about 118.1 Mt (130.2 million tons) of coal combustion ash of which about 38% was used in construction and industrial processes. The cement and concrete industry use accounted for more than 12.0 Mt (13.2 million tons) in 2010.The use of slag has increased significantly resulting in large reductions in CO_2 emissions. Besides use as a cementitious material, iron slags are used as raw feed in cement manufacture and aggregates in concrete mixtures. The USGS reports a total of 17.1 Mt (18.8 million tons) of iron blast furnace slag (air-cooled and granulated) produced in 2008 of which 2.7 Mt (3.0 million tons) is granulated and 94% of this is used as a cementitious material. The concrete industry also incorporates a variety of environmental best management practices in the production of its product. These include the reuse and recycling of waste from concrete manufacture such as water and unused returned concrete. It also incorporates waste byproducts from other industries such as recycled industrial waste water, foundry sands, glass and other materials that would typically end up in landfills.

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CHAPTER 3.6

RECYCLING AND REUSE

The consumption of construction materials can be reduced through recycling and reuse. However, the consumption of materials always increases with the increase of the population. Even so, the only way to reduce the consumption of construction materials is to economize the use of materials, recycling and reuse. There are many trends and policies which are been used in the process of recycling and reuse of construction materials.

6.1 Recycling and Reuse

6.1.1 Recycling:

Recycling the land-filled waste construction materials reduces the use sage of the virgin materials as these materials already exist and to produce a virgin material huge energy is consumed with high percentage of emissions. One of the most recycling materials is steel which gets downgraded after recycling and to a large extent it can be recycled because structural steel is the lowest grades of steel. The other construction material which can be recycled is concrete and it gets downgraded after recycling.

6.1.2 Reuse:

The other way to reduce the consumption of construction material is to reuse the virgin materials. Annually million tons of waste material is generated due to construction, demolition or renovations of buildings. These constructions or renovations of buildings take place because of the shorter lifetime of the buildings and due to some changes in the usage of the buildings. With these kinds of changes in the construction of the buildings it is always possible to regain most of the useful materials from the wastage of the buildings efficiently and effectively, reuse them before the end of the materials lifespan. With this kind of method, the consumption of the energy, cost and emissions are reduced.

6.2 Recycling and Reuse of Steel

6.2.1 Recycling of steel

There are two issues which we need to be considered when we discuss about recycling in construction industries.

1. How much amount of the used steel in the construction industries is been recycled?

2. How much amount of the recycled steel is used in the production of steel which is used in construction?

6.2.1.1 The amount of steel recycled in the construction industries.

Steel is also called ―The Environmental‖ as it is the most recycled metal on earth. Steel can be recycled over and over again without any losses of properties. Moreover, recycling has grown in parallel with the increase in the consumption of steel. Steel is one of the highly recycled materials with 85% of the recovery rate from consumed construction industries. It is very difficult to separate steel from other construction materials and to estimate the end life of the steel. Recycling trends are different in each industry. In construction industries it is always manageable to identity the sources of steel production but at the same time it is very difficult to calculate what happened to the steel at end of life. In construction, steel is mixed with other construction materials like for example concrete which is very difficult to separate but it is managed with different performances. Even after some performances some steel is simply land-filled like a worthless material. These land filled material is a mixture of steel and concrete and it is very difficult to calculate how much steel got recycled and how much was land-filled. From Steel Recycling Institute it is estimated that 95% of the construction steel is been recycled (Steel Recycling Institute, 2006).

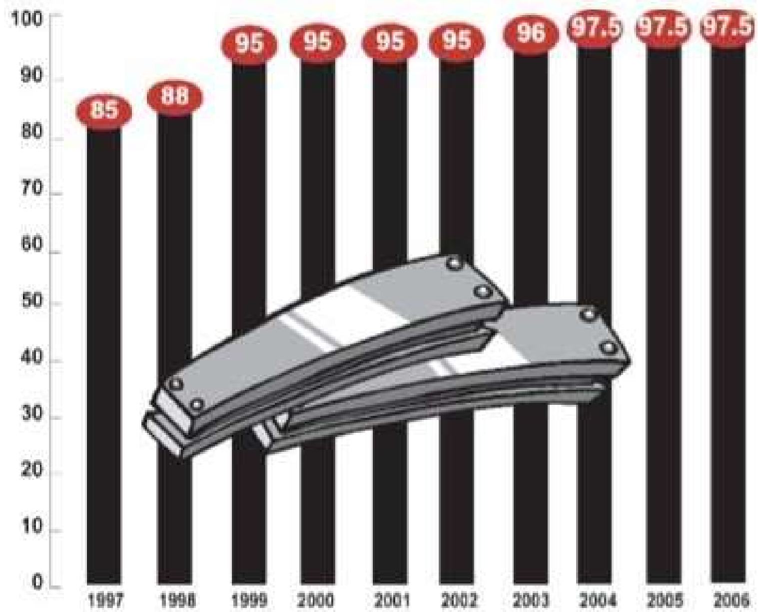


Figure 3.6.1 (a) Construction structural, Recycling rates(in percent*)*

(Courtesy: http://www.recycle-steel.org/)

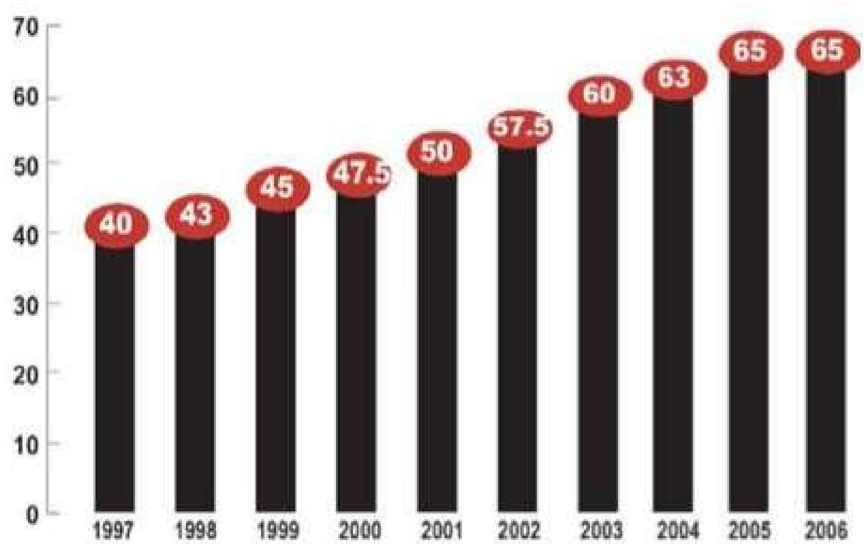


Figure 3.6.1 (b) Construction reinforcement, Recycling rates (in percent)

(Courtesy: http://www.recycle-steel.org/)

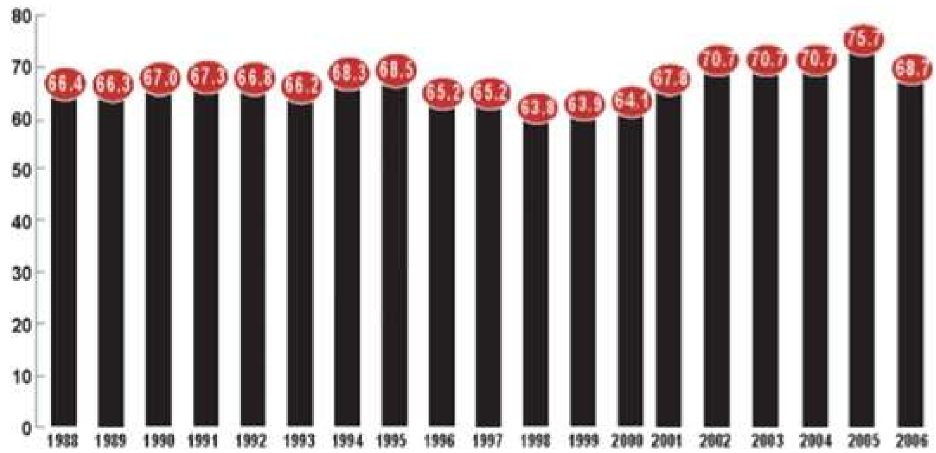


Figure 3.6.1 (c) Overall steel recycling rates(in percent)

(Courtesy: http://www.recycle-steel.org/)

A targeted policy needs to be developed in recycling products to ensure which product is being recycled and which is not recycled. Form Steel Recycling Institute, 2006 it is estimated that (95%) of the bulky products like steel beams are highly recycled and only (50%) of the products like reinforcing bars are recycled with very low recycling rate this is because of the difficulties in separation of concrete from steel while recycling. From the figures 3.6.1 (a) and 3.6.1 (b), 4% of the reinforce bars and 10% of the sections are produced out of the total crude steel produced in the world. But it is always important that reinforce bars and sections should be properly recycled. Reinforce bars are decreasing all around the world according to the latest trends. Where in the world, reinforce bars doesn't form as larger percentage of the total construction steel. In brief, construction steel is highly recycled. Products like beams are awfully recycled whereas products like reinforce bars are not highly recycled and new policies should be introduced and designs to advance recycling of reinforce bars.

6.2.1.2 Composition of steel used in construction industry

To operate steel mills huge amount of fossil fuels are burnt resulting large amount of embodied energy. Steel has very high embodied energy and it is clear that due to high embodied energy steel is one of the most environmentally harmful construction materials when measured by weight. Concrete has low embodied energy because of low fossil fuel consumption with low emission when compared with steel. In steel production construction steel is one of the lower grades steel and is 100% recyclable. Steel can have recycled infinitely without any loss of quality. To create construction steel, it is always possible to collect recycled steel from all other industries reducing the usage of energy and other raw materials.

6.2.1.2.1 Basic Oxygen Furnace (BOF):

To produce new steel, basic oxygen furnace (BOF) uses 25% to 35% old steel. Where this furnace produces products like encases of refrigerators, automotive cover etc whose major characteristic is draw ability. In 2006 by Steel Recycling Institute, to produce 46,802,100 tons of raw steel the basic oxygen furnace (BOF) consumed a total of 13,509,000 tons of ferrous scrap where 1,000,000 tons of these ferrous scrap tons had been produced as non-salable steel products. In steel industry, these tons of scraps are classified as ―home scrap‖ which is a mixture of pre-consumer scrap and runaround scrap. By the Steel Recycling Institute, it is estimated that 80% of the home scrap as pre-consumer scrap which is equating to 800,000 tons. For these kinds of operations during certain time frame 122,400 tons of superseded scrap is consumed. This kind of volume is known as post-consumer scrap. Therefore, from the above results the outside purchases of scrap is equal to 12,386,600 tons [13,509,000 - (1,000,000 + 122,400)].

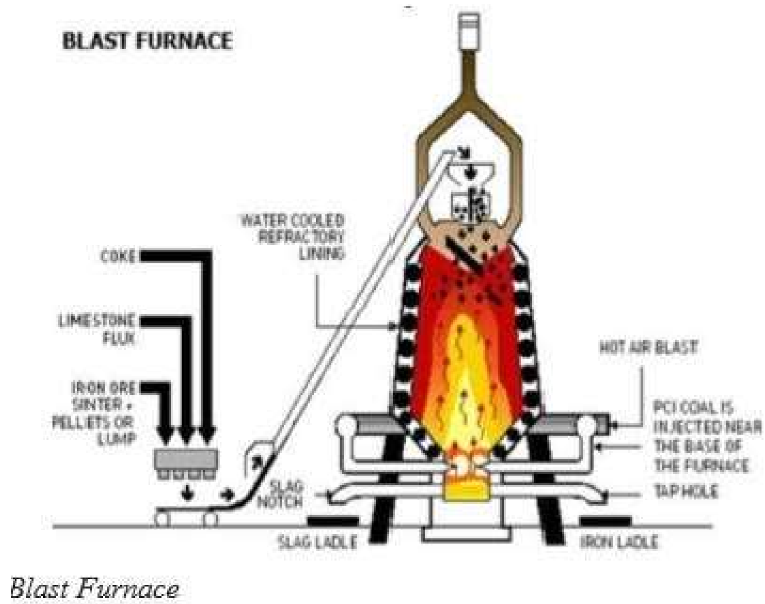


Figure 3.6.2: Blast furnace

(Courtesy:http://www.maccoal.com.au/Operations/Products/MetallurgicalProducts/tabid/96/Default.aspx /)

According to the study of Fordham University the purchased ferrous scrap ‘s post-consumer fraction would be 83.4% and the per-consumer of this purchase is 16.6% which equates to 2,056,200 tons (12,386,600 x 16.6%) of pre-consumer scrap. The production process that generates the scrap for the products made with steel are the ―prompt scrap‖ Therefore, the total recycled content to produce the 46,802,100 tons of raw steel in the BOF is:

13,509,000 / 46,802,100 = 28.9%

(Total Tons Ferrous Scrap / Total Tons Raw Steel)

The post-consumer recycled content is:

(12,386,600 - 2,056,200) + 122,400 = 10,452,800

And 10,452,800 /46,802,100 = 22.3%

(Post-Consumer Scrap / Total Tons Raw Steel)

The pre-consumer recycled content is:

(800,000 + 2,056,200) / 46,802,100 = 2,856,200/ 46,802,100 = 6.1%

(Pre-Consumer Scrap / Total Tons Raw Steel)

Plant	Total Primary Energy Consumption, MJ/ton steel			Total CO_2 Emission, ton CO_2/ton steel		
	Avg	Max	Min	Avg	Max	Min
Global Average Coil and Plate (35 Sites)	25500	31700	21450	1.97	2.60	1.61

Table 3: Total primary energy consumption and CO_2 emission (global average, Blast furnace)

6.2.1.2.2 Electric Arc Furnace (EAF):

In 2006 by Steel Recycling Institute, to produce 59,126,400 tons of raw steel the electric arc furnace (EAF) consumed a total of 48,966,900 tons of ferrous scrap where 16,320,000 tons of these ferrous scrap tons had been produced as non-salable steel products. In steel industry, these tons of scraps are classified as ―home scrap‖ which is a mixture of pre-consumer scrap and runaround scrap. By the Steel Recycling Institute, it is estimated that 80% of the home scrap as pre-consumer scrap which is equating to 13,056,000 tons (16,320,000 x 80%). For these kinds of operations during certain time frame 358,300 tons of superseded scrap is consumed. This kind of volume is known as post-consumer scrap. Therefore, from the above results the outside purchases of scrap is equal to 32,288,600 tons [48,966,900 - (16,320,000 + 358,300)].

According to the study of Fordham University the purchased ferrous scrap ‘s post-consumer fraction would be 83.4% and the per-consumer of this purchase is 16.6% which equates to 5,359,900 tons (32,288,600 x 16.6%) of pre-consumer scrap. The production process that generate the scrap for the products made with steel are the ―prompt scrap‖

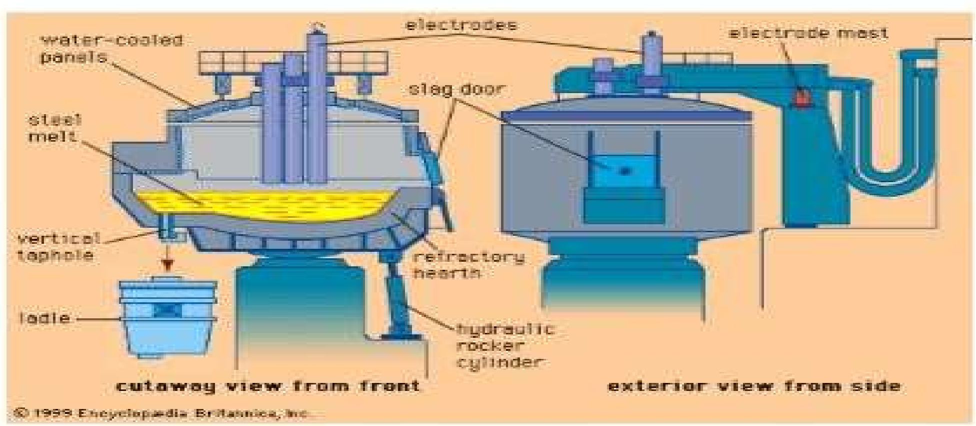


Figure 3.6.3 (a): Electric Arc Furnace

(Courtesy:http://www.britannica.com/EBchecked/topic-art/32400/1531/An-electric-arc-furnace)

Therefore, the total recycled content to produce the 59,126,400 tons of raw steel in the

EAF is:

48,966,900 / 59,126,400= 82.8%

(Total Tons Ferrous Scrap / Total Tons Raw Steel)

(Post-Consumer Scrap / Total Tons Raw Steel)

The pre-consumer recycled content is:

(13,056,000 +5,359,900) / 59,126,400 =

18,415,900 / 59,126,400 = 31.1%

(Pre-Consumer Scrap / Total Tons Raw Steel)

(Courtesy: Steel Recycling Institute)

Plant	Total Primary Energy Consumption, MJ/ton steel			Total CO_2 Emission, ton CO_2/ton steel		
	Avg	Max	Min	Avg	Max	Min
Global Average						
- Section (4 Sites)	11200	15300	8600	0.54	0.77	0.31
- Rebar (10 Sites)	11800	16400	5000	0.59	1.08	0.15

Table 4: Total primary energy consumption and CO_2 emission (global average, Electric arc furnace)

Figure 3.6.3 (b): Steel recycling

Electric arc furnace (EAF) produces large amount of construction steel with a very high recycled rate. In previous chapter we have discussed and compared energy and emissions of virgin steel and virgin concrete.

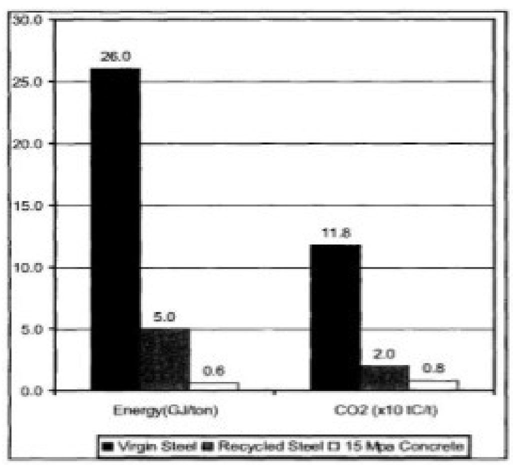


Figure 3.6.3 (c): Comparison of energy and CO_2 emissions per ton of virgin steel, recycled steel and concrete

6.3 Reuse of Steel

One of the main characteristic of steel buildings is that the buildings can be designed to simplify deconstruction or disassemble before the end of the useful lives. Reuse of steel has many environmental advantages; the steel components which are recovered from deconstruction or dissemble can be reused in future buildings eliminating the requirement of steel recycling. With this kind of reuse process, the energy required for recycling or for producing virgin steel, CO_2 and other environmental troubles which are generated in the process of manufacturing construction steel is reduced. An additional advantage of designing buildings with the concept of reuse of the construction materials can reduce the pollution and disruption to the neighborhood. The possibility of waste going in to the landfill is also reduced.

6.4 Recycling and Reuse of Concrete

In structural construction material concrete is the other major building material. In this chapter we going to discuss about recycling and reuse of structural concrete. There are no standards for reuse of concrete unlike steel.

6.4.1 Recycling of Concrete

When concrete is recycled it gets scattered and gets downgraded. Crushed concrete aggregates engineering properties do not match with the virgin aggregate. Hence for structural purposes the crushed concrete aggregate is not used. It is used as a base material for pavements, roads, bridges, parking lot. With such _synthetic ‘aggregates, ordinary Portland cement concrete does not bind well. Cement mix really well by absorbing with reactive magnesia and bind well with synthetic aggregates. Recycling of concrete aggregate would be encouraged by using this cement mix. Between 1994 and 1996, according to AGC (Association of General Contractors) the use of crushed concrete aggregate with new concrete has increased by 170 percent, this means from every one mile of concrete pavement the amount of concrete that can be reclaimed is approximately 5,996 tons. According to AGC, large blocks of recycled concrete can be used as a material for shoreline protection and erosion control. The recycled crushed concrete can used as a base material for roads, drainage material placed around underground pipes, as a base material for footings and foundations, landscaping material, as an aggregate in new concrete. In the past, when buildings were damaged or demolished the material was sent to the landfill all together but was not separated. The trucking and tipping fees was paid by the demolition company. With the help of separating machine, all the waste was sorted at the landfill. Then the recycled material was selling by the landfill to the construction companies and steel mills. The construction companies used the crushed concrete as aggregate and the steel as scrap material.

But now a business opportunity has been identified by the construction companies. A demolition waste separating machine is hired or bought by the company doing the construction. Using the crushing machine, the separated material is recycled on site for concrete and steel is sold as a scrap material to the steel mills. All other material that is left is used selectively for land filling. The cost of buying the aggregate is saved and also the cost of trucking and tipping is also saved. The cost saving figures reported is different on several websites. According to Waste-Handling website the cost saving ranges from $8-$9 per ton of material and according to AGC website the cost saving ranges from $100 per ton of material. As per the current reports, the construction waste that is recycled on site or at the landfill is approximately 85-95%. For recycling the concrete, companies which do the _reprocessing 'charges a fee but when compared to the landfills, there charges are half of that of landfill. After recycling they sell the recycled steel as scrap to mills and the recycled concrete is crushed and washed, and sell it as aggregates. As per the information from Madison Environment Group 2001, the _reprocessing'firms which charge a fee for recycling from the construction companies are, for recycling steel it is $3.77/ton and for recycling concrete it is $6.72/ton. Recycling has been encouraged because of the economics of buying new materials.

6.4.2 Reuse of Concrete

Due to concrete ‘s density and deficiency in modifying, the reuse of concrete is attended by difficulty. In the event of cast in place concrete, it is specifically true. In the massive construction like the footings, foundations, shear walls, concrete columns, concrete slab, etc. it is used as filling materials and reuse is prevented. In demolished buildings, concrete is reused on the same site as the structural skeleton in the new building. This kind of situation can be considered as renovation instead of considering it as a demolition followed by reuse

CHAPTER 3.7

EMBODIED ENERGY

Embodied energy is the total energy required for the extraction, processing, manufacture and delivery of building materials to the building site. Energy consumption produces CO_2, which contributes to greenhouse gas emissions, so embodied energy is considered an indicator of the overall environmental impact of building materials and systems. Unlike the life cycle assessment, which evaluates all of the impacts over the whole life of a material or element, embodied energy only considers the front-end aspect of the impact of a building Material. It does not include the operation or disposal of materials.

The construction industry, along with its support industries, is one of the largest exploiters of natural resources, both renewable and non-renewable, that is adversely altering the environment of the earth. It depletes two-fifths of global raw stone, gravel, and sand and one-fourth of virgin wood, and consumes 40 percent of total energy and 16 percent of water annually.

The construction sector, in particular, is one of the largest consumers of commercial energy in the form of electricity or heat by directly burning fossil fuels. Urge-Vorsatz and Novikova assert that, during 2004, buildings alone depleted nearly 37percent of the world ‘s energy and this figure is anticipated to reach 42 percent by 2030. Construction activities not only consume energy, but also cause environmental pollution and emission of greenhouse gases, which lead to climate change. Therefore, it is urgent to review, as well as modify, current construction practices such as design and engineering methods, construction techniques and manufacturing technology to tame energy consumption.

The total life cycle energy of a building includes both embodied energy and operating energy

> ***(1) Embodied energy*** *(EE)*: sequestered in building materials during all processes of production, on-site construction, and final demolition and disposal

> ***(2) Operating energy*** (OE): expended in maintaining the inside environment through processes such as heating and cooling, lighting and operating appliances.

Until recently, only operating energy was considered, owing to its larger share in the total life cycle energy. However, due to the advent of energy efficient equipment and appliances, along with more advanced and effective insulation materials, the potential for curbing operating energy has increased and as a result, the current emphasis has shifted to include embodied energy in building materials. Ding suggests that the production of building components off-site accounts for 75 percent of the total energy embedded in buildings and this share of energy is gradually increasing as a result of the increased use of high energy intensive materials. Thus, there is a genuine demand to calibrate the performance of buildings in terms of both embodied and operating energy in order to reduce energy consumption.

At a macro-level, proper accountability of embodied and operating energies will contribute to data and information needed to create an energy economy that accounts for indirect and direct contributions. Langston and Langston suggest that, while measuring operating energy is easy and less complicated, determining embodied energy is more complex and time consuming. Furthermore, there is currently no generally accepted method available to compute embodied energy accurately and consistently and as a result, wide variations in measurement figures are inevitable, owing to various factors

7.1. Interpretation of embodied energy

Buildings are constructed with a variety of building materials and each material consumes energy throughout its stages of manufacture, use and deconstruction. These stages consist of raw material extraction, transport, manufacture, assembly, installation as well as its disassembly, deconstruction and decomposition. The energy consumed in production (in conversion and flow as proposed by koskela is called the ―embodied energy‖ of the material and is the concern of energy consumption and carbon emissions. Gonzalez and Navarro assert that building materials possessing high-embodied energy could possibly result in more carbon dioxide emissions than would materials with low embodied energy.

According to Miller, the term ―embodied energy‖ is subject to various interpretations rendered by different authors and its published measurements are found to be quite unclear. Crowther defines embedded energy as ―the total energy required in the creation of a building, including the direct energy used in the construction and assembly process, and the indirect energy, that is required to manufacture the materials and components of the buildings.‖ Treloar et al. state, ―Embodied energy (EE) is the energy required to provide a product (both directly and indirectly) through all processes upstream (i.e. traceable backwards from the finished product to consideration of raw materials).‖ Another characterization given by Bousted and Hancock (as cited by Langstonand Langston) is, ―Embodied energy is defined as the energy demanded by the construction plus all the necessary upstream processes for materials such as mining, refining, manufacturing ,transportation, erection and the like. . .‖ Likewise, a more comprehensive definition, provided by Baird, 1994; Edwards and Stewart, 1994; Howard and Roberts, 1995; Lawson; Cole and Kernan, 1996 (as cited in Ding), explains that ―embodied energy comprises the energy consumed during the extraction and processing of raw materials, transportation of the original raw materials, manufacturing of building materials and components and energy use for various processes during the construction and demolition of the building.‖ These definitions represent differences of opinion about the system boundaries to be included in embodied energy analyses.

7.1.1. Direct energy

Direct energy is consumed in various on-site and off-site operations like construction, prefabrication, transportation and administration.

Construction and assembly on-site: Energy inputs during the assembly of building materials and components on-site;

Prefabrication off-site: Building components that are prefabricated off-site that consume energy in the process

Transportation: Transportation involved in construction and assembly on-site and prefabrication off-site.

7.1.2. Indirect energy

Indirect energy is mostly used during the manufacturing of building materials, in the main process, upstream processes and downstream processes and during renovation, refurbishment, and demolition.

Initial embodied energy: Energy used during production of materials and components of a building, including raw material procurement, building material manufacturing and final product delivery to construction-site;

- ***Recurrent embodied energy*:** Energy used in various processes for maintenance and refurbishment of buildings (building materials and building components) during their useful life;
- ***Demolition energy*:** Energy necessary for deconstruction of building and disposing of building materials
- ***Operating energy*:** Energy required in the building for operating various electrical and mechanical services.

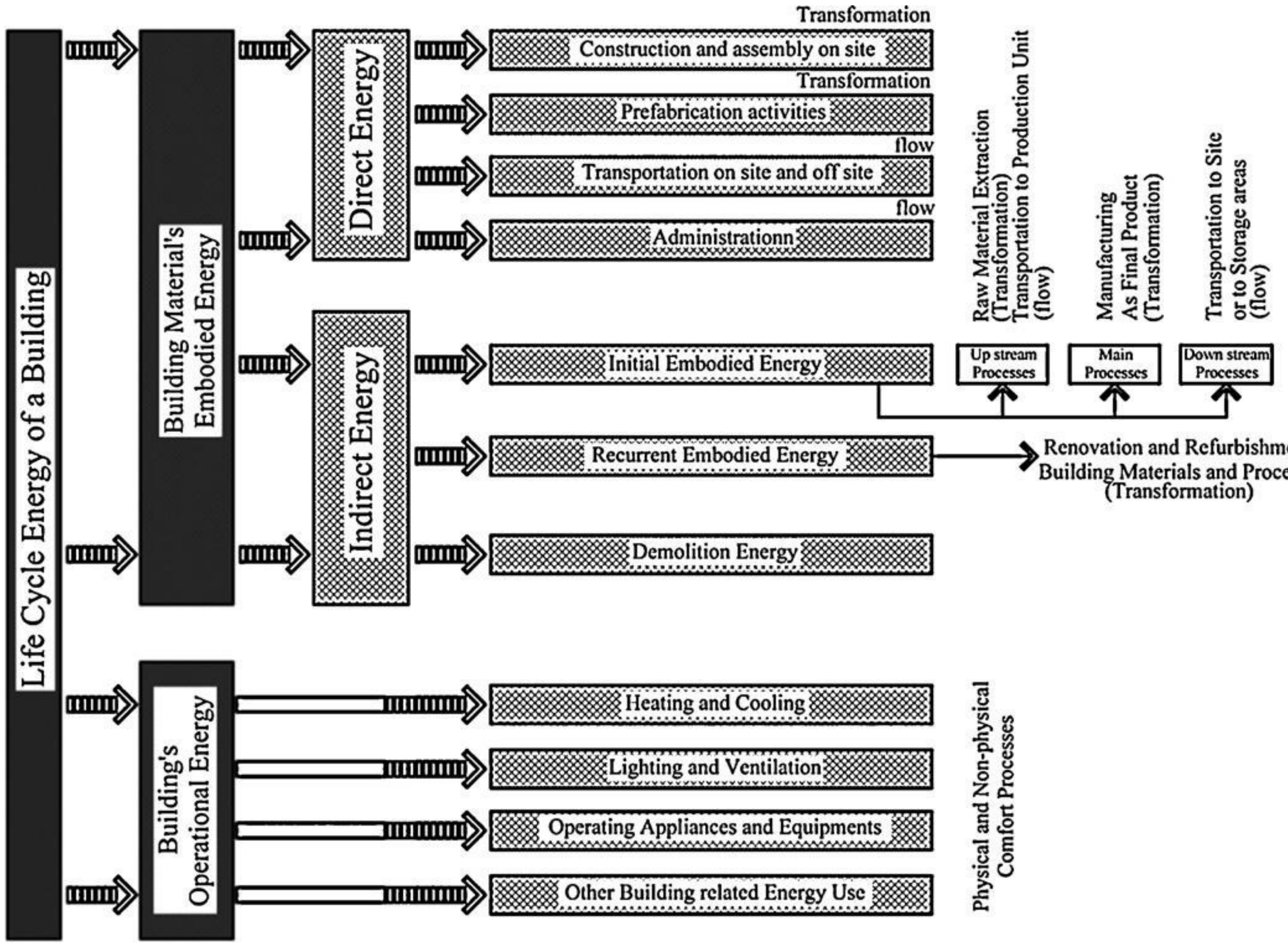


Fig. 3.7.1. Embodied energy model for the life cycle of a building

7.2 Significance of embodied energy

As mentioned earlier, until recently, major endeavors for energy conservation assumed the operating energy of a building to be much higher than the embodied energy of a building. However, current research has disproven this assumption and found that embodied energy accounts for a significant proportion of total life cycle energy. Embodied energy is expended once in the initial construction stage of a building, while operational energy accrues over the effective life of the building. Operational energy conservation could be accomplished more optimally with energy efficient appliances and advanced insulating materials, which are available more readily.

7.3 Why reduce embodied energy?

Energy consumption during manufacture can give an approximate indication of the environmental impact of the material, and for most building materials, the major environmental impacts occur during the initial processes. The total amount of embodied energy may account for 20% of the building's energy use, so reducing embodied energy can significantly reduce the overall environmental impact of the building. Embodied energy must be considered over the lifespan of a building, and in many situations, a higher embodied energy building material or system may be justified because it reduces the operating energy requirements of the building. For example, a durable material with a long lifespan such as aluminum may be the appropriate material selection despite its high embodied energy. As the energy efficiency of building increases, reducing the energy consumption, the embodied energy of the building materials will also become increasingly important.

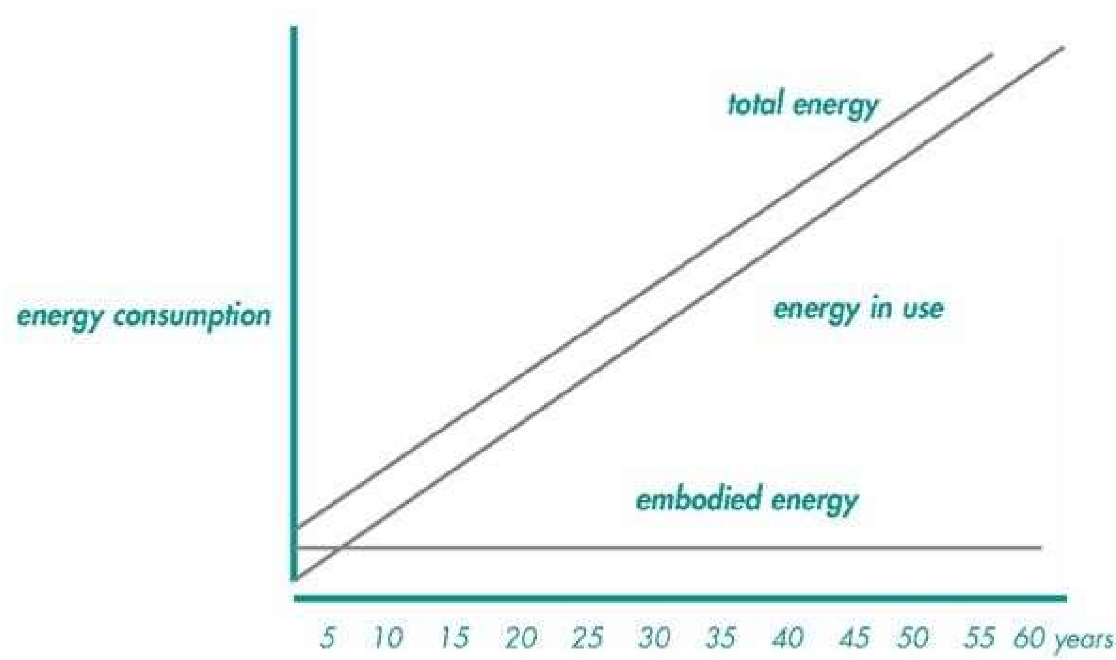


Fig.3.7.2. (a) Energy consumption for a typical three bed house

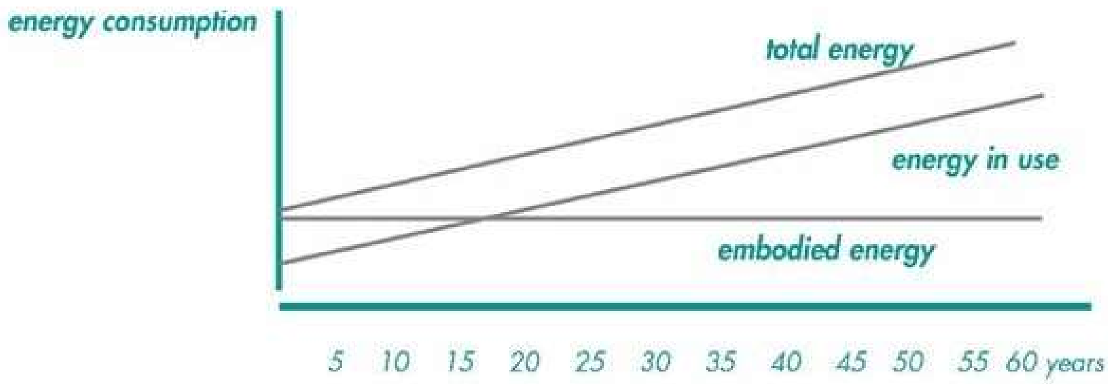


Figure 3.7.2 (b) Reducing embodied energy

Buildings should be designed and materials selected to balance embodied energy with factors such as climate, availability of materials and transport costs. Lightweight building materials often have lower embodied energy than heavyweight materials, but in some situations, lightweight construction may result in higher energy use. For example, where heating or cooling requirements are high, this may raise the overall energy use of the building. Conversely, for buildings with high heating or cooling requirements but where there is a large diurnal (day/night) temperature range, heavyweight construction (typically with high embodied energy) and the inclusion of high levels of insulation can offset the energy use required for the building.

When selecting building materials, the embodied energy should be considered with respect to:

- The durability of building materials
- How easily materials can be separated
- Use of locally sourced materials
- Use of recycled materials
- Specifying standard sizes of materials
- Avoiding waste
- Selecting materials that are manufactured using renewable energy sources.

Following points should be taken into considerations:

(a) By reducing use of energy intensive materials; optimizing thickness of walls; choice of finishes; heights of storeys, etc;

(b) By replacing energy-intensive materials with low-energy alternatives wherever available, such as:

- Lime-pozzolana mortars in place of conventional cement mortars

- Sun-dried brocks, stabilized-soil blocks or sand-lime bricks instead of kiln fired bricks Light-weight, aerated, concrete blocks instead of dense concrete blocks, effective utilization of waste materials such as gypsum-based plasters instead of cement-based plasters

(c) By selecting lower-energy structural systems such as load-bearing masonry with due diligence in place of reinforced concrete or steel frames; using pure compression-based structural systems such as arches an vaults instead of composite tensile elements

(d) By limiting construction to low-rise buildings sensitive to the location, topography, land-use, population density and ambient environment in place of high-rise buildings

(e) By selection, wherever possible, waste recycled materials, or products incorporating such materials; for example

Portland pozzolana cements using fly ash (pfa) or blast-furnace slag asphalt roofing sheets incorporating recycled paper building boards and panels for roofing and walling from agricultural waste second-hand or reclaimed building materials.

(f) By designing for longer life and adaptability to varying functional requirements

(g) Using materials with a potential for recycling; optimizing the use of reinforced concrete

On the other hand, the disposal of a variety of industrial wastes such as coal ash from thermal plants, phosphogypsum from fertilizer factories, red-mud from aluminum plants, lime-sludge from quarries and slang from steel industries was creating greater problems. These bye products of industrial processes were generally used for dumping and insensitive landfill, creating rampant pollution of land, air and water and causing substantial damage to the environment.

India offers a wide variety and choice of locally available materials and construction practices in its different regions. However, due to shortage of traditional building materials, especially to urban dwellers, the energy required for production, and the impact on environment by outdated production processes, the Government of India took initiatives so that energy-efficient and environment-friendly building materials, components and construction techniques are promoted.

Fired clay brick making, for example, has been banned since July 1997 in Delhi as none of the 300 brick kilns could control their emission levels. This encouraged the brick manufacturers to switch over to making fly ash bricks. The National Housing and Habitat Policy also made it possible for a number of waste-based materials and components to become popular, and entrepreneurial efforts are being made to establish production units in different states.

There are enough environmental reasons to reduce the energy ―embodied‖ in buildings. A high proportion of this energy is used to produce a small number of key materials such as concrete, mortar, plaster and bricks. The highest energy is used in the manufacture of aluminum, copper, stainless steel and plastics (primary energy requirements for production very from 250 Giga Joules (GJ)/ ton to 100 GJ/ton) followed by glass, cement and plaster boards (primary energy requirements for production vary from 60GJ/ton to 10GJ/ton). The energy embodied in a building is estimated to vary between 15 and 20 years of its energy consumption in use.

7.4 Need for Energy Efficient Buildings

The International Energy Report (IER) 1987 points out ―Investment in energy conservation at a margin provides a better return than investment in energy supply‖. The concept of green buildings is still a tan emerging stage in India. The concept of sustainable buildings and use of environmentally friendly construction materials like stones, timber, thatch, mud etc have been practiced since ancient times. But the perception of people about strong and durable buildings have changed with the advent and lavish use of the present modern materials like steel, cement, aluminum, glass etc. A large amount of fuel energy gets consumed in producing such materials. These materials being industrial products further need to be transported to large distances before getting consumed in the buildings thus making them energy intensive. An estimate of the energy consumed in buildings using different permutations of materials and techniques will facilitate their appropriate selection and reduce the embodied energy consumption.

Some of the salient features to optimize the energy consumption in buildings are to:

1. Minimal disturbance to landscape and site conditions
2. Use of renewable energy
3. Use of water recycling
4. Use of environmental friendly building materials
5. Effective controls for lighting and temperature for human comfort

Inappropriate design, materials and construction practices lead to the ―sick building syndrome,‖ invisibly affecting the health of millions. Production of building materials such as asbestos and crusher units in quarries also impact on health besides polluting air, water and land. Construction activities adversely affect the environment through physical disruption, depletion of key renewable resources such as fertile topsoil, forest cover and excessive consumption of energy. There is, therefore, a strong need to adopt cost effective, environmentally appropriate technologies and upgrade traditional techniques and local materials.

Building materials account for about 60 per cent of basic inputs. Of the total costs of a dwelling, cement (18 per cent), bricks (17 per cent), timber (13 per cent) and steel (10 per cent) account for a significant portion, consequently resulting in construction costs between Rs. 4,000 and Rs. 6,000 per sqm even for standard housing, Operation and maintenance (O & M) expenses over the years add up to more than actual construction cost, thus making it imperative to adopt cost-effective materials and technologies to tide over the shortage of housing in the country.

However, while large-scale and inefficient production of building materials, and added costs of transportation, result in higher end costs for the consumer, production and use of appropriate building materials have not received adequate attention and are often discouraged by outdated attitudes and unrealistic building codes and regulations.

7.5 What is Life Cycle Assessment?

Life-cycle assessment (LCA, also known as life-cycle analysis, Eco balance, and cradle-to-grave analysis) is a technique to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). The embodied energy of a typical building product is derived from the energy associated with the steps in its **lifecycle** from extraction of materials, through processing and manufacture, to transportation and construction, and in some cases its eventual disposal and reuse/recycle – this is often termed ‗cradle-to grave'. The process of analyzing and quantifying all these steps is known as Life Cycle Assessment (LCA). Embodied energy is just one of the environmental impacts associated with a building product‘s lifecycle; others include extraction of materials, water usage, pollution and toxic by-products from production etc. LCA is the basis of the assessment of sustainable materials and is at the heart of standard reference methods in this area. One such example is the BRE ―Green Guide to Construction‖ which is a database of the LCA of a variety of construction products. The Green Guide rates each production an A+ to E ranking system, where A+

represents the best environmental performance/least environmental impact, and E the worst environmental performance/most environmental impact. The Green Guide, and the related Certified Environmental Profiles, for specific materials also form the basis of material credits used in BREEAM assessment and the Code for Sustainable Homes.

LCAs can help avoid a narrow outlook on environmental concerns by:

- Compiling an inventory of relevant energy and material inputs and environmental releases;
- Evaluating the potential impacts associated with identified inputs and releases;
- Interpreting the results to help make a more informed decision.

Goals and Purpose

The goal of LCA is to compare the full range of environmental effects assignable to products and services in order to improve processes, support policy and provide a sound basis for informed decisions.

The term life cycle refers to the notion that a fair, holistic assessment requires the assessment of raw-material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence.

There are two main types of LCA. Attritional LCAs seek to establish the burdens associated with the production and use of a product, or with a specific service or process, at a point in time (typically the recent past). Consequential LCAs seek to identify the environmental consequences of a decision or a proposed change in a system under study (oriented to the future), which means that market and economic implications of a decision may have to be taken into account. Social LCA is under development as a different approach to life cycle thinking intended to assess social implications or potential impacts. Social LCA should be considered as an approach that is complementary to environmental LCA.

The procedures of life cycle assessment (LCA) are part of the ISO 14000 environmental management standards: in ISO 14040:2006 and 14044:2006. (ISO 14044 replaced earlier versions of ISO 14041 to ISO 14043.) GHG product life cycle assessments can also comply with standards such as PAS 2050 and the GHG Protocol Life Cycle Accounting and Reporting Standard.

Four main phases

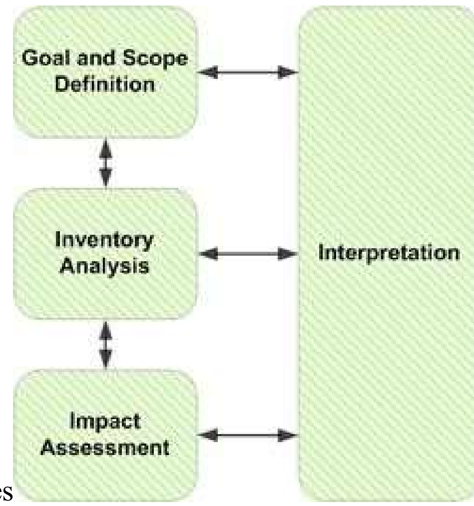


Figure 3.7.3. Four main phases

According to the ISO 14040 and 14044 standards, a Life Cycle Assessment is carried out in four distinct phases as illustrated in the figure shown to the right. The phases are often interdependent in that the results of one phase will inform how other phases are completed.

7.5.1 Goal and scope

An LCA starts with an explicit statement of the goal and scope of the study, which sets out the context of the study and explains how and to whom the results are to be communicated. This is a key step and the ISO standards require that the goal and scope of an LCA be clearly defined and consistent with the intended application. The goal and scope document therefore includes technical details that guide subsequent work:

- The functional unit, which defines what precisely is being studied and quantifies the service delivered by the product system, providing a reference to which the inputs and outputs can be related. Further, the functional unit is an important basis that enables alternative goods, or services, to be compared and analyzed.[9]

- the system boundaries;
- any assumptions and limitations;
- the allocation methods used to partition the environmental load of a process when several products or functions share the same process.

7.5.2 Life cycle inventory

Life Cycle Inventory (LCI) analysis involves creating an inventory of flows from and to nature for a product system. Inventory flows include inputs of water, energy, and raw materials, and releases to air, land, and water. To develop the inventory, a flow model of the technical system is constructed using data on inputs and outputs. The flow model is typically illustrated with a flow chart that includes the activities that are going to be assessed in the relevant supply chain and gives a clear picture of the technical system boundaries. The input and output data needed for the construction of the model are collected for all activities within the system boundary, including from the supply chain (referred to as inputs from the techno-sphere).

The data must be related to the functional unit defined in the goal and scope definition. Data can be presented in tables and some interpretations can be made already at this stage. The results of the inventory is an LCI which provides information about all inputs and outputs in the form of elementary flow to and from the environment from all the unit processes involved in the study.

Inventory flows can number in the hundreds depending on the system boundary. For product LCAs at either the generic (i.e., representative industry averages) or brand-specific level, that data is typically collected through survey questionnaires. At an industry level, care has to be taken to ensure that questionnaires are completed by a representative sample of producers, leaning toward neither the best nor the worst, and fully representing any regional differences due to energy use, material sourcing or other factors. The questionnaires cover the full range of inputs and outputs, typically aiming to account for 99% of the mass of a product, 99% of the energy used in its production and any environmentally sensitive flows, even if they fall within the 1% level of inputs.

One area where data access is likely to be difficult is flows from the techno-sphere. The techno sphere is more simply defined as the man-made world. Considered by geologists as secondary resources, these resources are in theory 100% recyclable; however, in a practical sense the primary goal is salvage.[10] For an LCI, these techno sphere products (supply chain products) are those that have been produced by man and unfortunately those completing a questionnaire about a process which uses man-made product as a means to an end will be unable to specify how much of a given input they use. Typically, they will not have access to data concerning inputs and outputs for previous production processes of the product. The entity undertaking the LCA must then turn to secondary sources if it does not already have that data from its own previous studies. National databases or data sets that come with LCA-practitioner tools, or that can be readily accessed, are the usual sources for that information. Care must then be taken to ensure that the secondary data source properly reflects regional or national conditions.

7.5.3 Life cycle impact assessment

Inventory analysis is followed by impact assessment. This phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. Classical life cycle impact assessment (LCIA) consists of the following mandatory elements:

- selection of impact categories, category indicators, and characterization models;
- the classification stage, where the inventory parameters are sorted and assigned to specific impact categories; and
- Impact measurement, where the categorized LCI flows is characterized, using one of many possible LCIA methodologies, into common equivalence units that are then summed to provide an overall impact category total.

In many LCAs, characterization concludes the LCIA analysis; this is also the last compulsory stage according to ISO 14044:2006. However, in addition to the above mandatory LCIA steps, other optional LCIA elements – normalization, grouping, and weighting – may be conducted depending on the goal and scope of the LCA study. In normalization, the results of the impact categories from the study are usually compared with the total impacts in the region of interest, the U.S. for example. Grouping consists of sorting and possibly ranking the impact categories. During weighting, the different environmental impacts are weighted relative to each other so that they can then be summed to get a single number for the total environmental impact. ISO 14044:2006 generally advises against weighting, stating that ―weighting, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public‖. This advice is often ignored, resulting in comparisons that can reflect a high degree of subjectivity as a result of weighting.

7.5.4 Interpretation

Life Cycle Interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment. The results from the inventory analysis and impact assessment are summarized during the interpretation phase. The outcome of the interpretation phase is a set of conclusions and recommendations for the study. According to ISO 14040:2006, the interpretation should include:

- Identification of significant issues based on the results of the LCI and LCIA phases of an LCA
- Evaluation of the study considering completeness, sensitivity and consistency checks; and
- Conclusions, limitations and recommendations.

A key purpose of performing life cycle interpretation is to determine the level of confidence in the final results and communicate them in a fair, complete, and accurate manner. Interpreting the results of an LCA is not as simple as "3 is better than 2, therefore Alternative A is the best choice"! Interpreting the results of an LCA starts with understanding the accuracy of the results, and ensuring they meet the goal of the study. This is accomplished by identifying the data elements that contribute significantly to each impact category, evaluating the sensitivity of these significant data elements, assessing the completeness and consistency of the study, and drawing conclusions and recommendations based on a clear understanding of how the LCA was conducted and the results were developed.

Cradle-to-grave

Cradle-to-grave is the full Life Cycle Assessment from resource extraction ('cradle') to use phase and disposal phase ('grave'). For example, trees produce paper, which can be recycled into low-energy production cellulose (fiberized paper) insulation, then used as an energy-saving device in the ceiling of a home for 40 years, saving 2,000 times the fossil-fuel energy used in its production. After 40 years the cellulose fibers are replaced and the old fibers are disposed of, possibly incinerated. All inputs and outputs are considered for all the phases of the life cycle.

Cradle-to-gate

Cradle-to-gate is an assessment of a *partial* product life cycle from resource extraction (*cradle*) to the factory gate (i.e., before it is transported to the consumer). The use phase and disposal phase of the product are omitted in this case. Cradle-to-gate assessments are sometimes the basis for environmental product declarations (EPD) termed business-to-business EDPs. One of the significant uses of the cradle-to-gate approach compiles the life cycle inventory (LCI) using cradle-to-gate. This allows the LCA to collect all of the impacts leading up to resources being purchased by the facility. They can then add the steps involved in their transport to plant and manufacture process to more easily produce their own cradle-to-gate values for their products.

Cradle-to-cradle or closed loop production

Cradle-to-cradle is a specific kind of cradle-to-grave assessment, where the end-of-life disposal step for the product is a recycling process. It is a method used to minimize the environmental impact of products by employing sustainable production, operation, and disposal practices and aims to incorporate social responsibility into product development. From the recycling process originate new, identical products (e.g., asphalt pavement from discarded asphalt pavement, glass bottles from collected glass bottles), or different products (e.g., glass wool insulation from collected glass bottles).

Allocation of burden for products in open loop production systems presents considerable challenges for LCA. Various methods, such as the avoided burden approach have been proposed to deal with the issues involved.

Gate-to-gate

Gate-to-gate is a partial LCA looking at only one value-added process in the entire production chain. Gate-to-gate modules may also later be linked in their appropriate production chain to form a complete cradle-to-gate evaluation.

Well-to-wheel

Well-to-wheel is the specific LCA used for transport fuels and vehicles. The analysis is often broken down into stages entitled "well-to-station", or "well-to-tank", and "station-to-wheel" or "tank-to-wheel", or "plug-to-wheel". The first stage, which incorporates the feedstock or fuel production and processing and fuel delivery or energy transmission, and is called the "upstream" stage, while the stage that deals with vehicle operation itself is sometimes called the "downstream" stage. The well-to-wheel analysis is commonly used to assess total energy consumption, or the energy conversion efficiency and emissions impact of marine vessels, aircraft and motor vehicles, including their carbon footprint, and the fuels used in each of these transport modes.

The well-to-wheel variant has a significant input on a model developed by the Argonne National Laboratory. The Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model was developed to evaluate the impacts of new fuels and vehicle technologies. The model evaluates the impacts of fuel use using a well-to-wheel evaluation while a traditional cradle-to-grave approach is used to determine the impacts from the vehicle itself. The model reports energy use, greenhouse gas emissions, and six additional pollutants: volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxide (NOx), particulate matter with size smaller than 10 micrometer (PM10), particulate matter with size smaller than 2.5 micrometer (PM2.5), and sulfur oxides (Sox).

7.6. Energy and Building Materials

Constructions consume a variety of building materials. Abundant raw materials are to be transported from far off distances to the industry which requires further processing thus consuming primary and commercial resources. The finished products from the industry further need to be distributed to the local areas and construction sites which increase the pressure on the commercial fuels like petrol/diesel etc. The most common building materials used in construction activity today are cement, steel, bricks, stones, glass, aluminum, timber, etc. The estimates of the energy consumed in the manufacture/extraction of a few major building materials chosen from various sources (Gartner and Smith, 1976, K.S.Jagadish,)[52] have been discussed below.

7.6.1 Cement

The principal methods forsss the manufacture of the Portland cement are Wet process, Dry process, Semi dry process. The dry process is preferred on account of very significant fuel economy. The dry process is adopted in most of the cement industries. The heat energy required per Kg of the clinker in dry process is1.57 – 2.35 MJ/Kg while in wet process it is about 2.6 – 4.2 (MJ/Kg). The highest value of 4.2 MJ/Kg has been considered for further computations.

7.6.2 Steel

The transportation of various raw materials like Iron ore lumps, sinters and pellets, coke and fluxes such as limestone, dolomite and the various processes like Melting, Refining, Casting, Rolling makes steel as an highly energy intensive material. The total energy in steel is estimated to be 36MJ/Kg, including transportation.

7.6.3 Bricks

The manual production of the bricks involves mainly four operations namely, Soil preparation, Moulding, Drying and Firing. The main process in which energy is consumed is firing of bricks. The amount of total coal required is about 18 tons to 22 tones depending upon the weather condition, quality of coal, etc. A tonne of coal gives about 12.3MJ to 13.3MJ depending upon quality of the coal generally transported from far off distances. The energy required to produce each brick inclusive of transportation comes to about 5MJper brick.

7.6.4 Glass

Raw materials used in Manufacture of glass are Glass, Sand, Soda Ash, Salt cake, Lime stone, lead oxides, pearl ash, boric acid, etc. The various processes used are Melting, Shaping or Forming, Annealing, Finishing. The embodied energy of glass is somewhat high due to melting process comes out to be 15.9 MJ/ Kg.

7.7 Computation and Comparison of Embodied Energy in Buildings

An attempt has been made in this section to evaluate the energy consumed in buildings. The estimates are based on the energy consumed in the production of the materials required and their transportation. The contribution of human labor/equipment energy for the assemblage is not considered. Four types of case studies have been considered for the computation of energy.

1. Contributions of energy from masonry walls in a three storied building.
2. Estimation of energy consumption for various roofing technologies designed for a span of 3.0 m.
3. Comparison of energy for G+1 load bearing and framed RC structure.
4. Embodied energy comparison for G+1, G+2 and G+7 framed RC structures.
   7

7.7.1. Energy in Masonry Walls of a Three Storied Building

The energy consumed in the masonry walls for a three storied building using three different building units namely bricks, stones and concrete blocks have been computed and presented in Table 5.

Sr. No	Type of Masonry adopted	Consumption of materials for Masonry	Energy Contribution of each material MJ	Total energy consumed by masonry for entire building MJ	Energy Saving in %
1	Brick Masonry	Bricks	539994	671434	---
		Cement	129766		
		Sand	1674		
2	Stone Masonry	Stones	184184	569715	15
		Cement	380926		
		Sand	4605		
3	HC Block Masonry	Cement	230230	269788	60
		Sand	1884		
		Aggregates	37674		

Table 5. Energy consumption in masonry walls for a three storied building

In case of the building constructed using bricks the energy contribution of the masonry walls is about 671.4GJ. About 80% of the overall energy is due to the energy intensive clay bricks. A 15% reduction is observed in the masonry if the bricks are replaced by stones. With the use of hollow concrete blocks the energy consumption in masonry walls drastically reduces by 60% as compared to the energy consumed by brick masonry.

7.7.2 Energy Consumption in Roofs

Table 6 gives the details of the various building materials required and the total energy consumed per square meter for each roofing alternative. The structural elements have been designed for a span of 3m x 6m and a roof slope of 25º is considered.

In case of Mangalore tiled roof the tile which needs controlled firing in kiln is the major energy consuming material. The conventional supporting structure generally consists of timber rafters which does not consume any fossil fuel. However adequate plantations are to be grown to bridge the gap between demand and supply of timber and also for the protection of the environment. The use of RC rafters shows a 27% increase in the energy for such roof which may turn out to be apparent as the solar energy necessary for growing timber is not considered.

The asbestos cement (AC sheet) sheet is lighter than Mangalore tiled roof mainly consists of 80% cement and 20% asbestos fibers. The use of steel truss or ferrocement beams as purlins instead of angle sections for the supporting structure required for fixing the sheets proves to be more energy efficient. Even though AC sheet roof seems to be less energy intensive than Mangalore tiled roof the former is already proven to be a hazardous material and also is unsuitable for tropical climates. The choice of the conventional RC roof or the Hourdi tile roof (popular in Southern India) shoots up the energy value to about 548 MJ/m^2 and 540 MJ/m^2 respectively. The composite beam-panel roof provides an energy efficiency of about 13% as compared to the RC roof.

Of the various alternatives considered the option of precast ferrocement channel units and the brick vaulted roof seem to be the best choices in context of energy efficiency. A 50% energy saving in the Ferro cement roof and 25% in case of brick vaulted roof may be achieved as relative to the RC roof.

Sr No	Type of Roof	Load in Kg/sq.m.	Quantities of Material				Energy in MJ/sq.m. of plinth area
			Tiles/Bricks No/m^2	Cement Kg/m^2	Timber cu.m/m^2	Steel Kg/m^2	
1	Mangalore Tiled Roof						
	a) Gable roof Casurina Poles	120	26	--	0.01	0.3	231
	b) Gable roof (Sawn timber)	120	26	--	0.02	0.3	256
	c) Gable roof (R.C. rafters)	148	26	5.9	--	2.17	318
2	AC Sheet roof						
	a) Angle iron purlins	83	--	13.6	--	5.0	283
	b) Steel Truss	83	--	13.6	--	0.9	135
	c) Ferrocement Beams	100	--	16.3	--	0.4	137
3	Precast Ferrocement Channel Unit roof	180	--	23.0	--	1.7	235
4	Brick Vault	220	45	18	--	0.9	393
5	Composite Beam panel roof	202	40	25.0	--	2.5	479
6	Hourdi Tile roof	286	19.5	24.0	--	3.5	540
7	Reinforced concrete roof	387	--	54.0	--	3.9	548

Table 6 : Energy estimates of various roofing alternatives (for 3.0 m span)

7.7.3 Embodied energy in different types of buildings

Table 7.7.2. contains the estimated energy values for buildings with different number of storeys. A comparison of G+1 load bearing and framed structure shows that the energy consumption in both are found to be similar. However the major energy contributing materials vary in both cases. In the load bearing structure the contribution of cement is about 50% that of the R.C building. On the other hand the bricks contribute to 60% increase in the energy consumption in case of load bearing structure as that to the R.C structure. Steel is another material which influences the increase in the energy value in case of R.C structure which is about 2.7 times as compared to load bearing structure.

A study on three R.C. buildings with different number of storeys obviously indicates a high energy value in the tallest building. The energy value for G+1, G+2 and G+7 storied buildings are 84,6493MJ, 16,91342MJ, and 1, 00, 53,683MJ respectively. The G+7 building consumes 12 times while in case of G+2 building it is 2 times that of the energy required for the G+1 building. However the increase in the energy is not proportional to the increase in the number of storeys. This may be explained to the fact that the size of the concrete columns and steel consumption in the tallest buildings depends on the various structural parameters, the proportion used in concrete and assumed sizes of columns due to which the steel requirement vary.

Brick is the major energy consuming materials in the load bearing building. The contribution of bricks is about 85% of the total energy of building On the other hand in the framed G+1 RC structure cement, bricks and steel contribute to about 43%, 25%, 24% respectively in total energy consumption of building. A comparison of the three RC buildings reveal that the percentage energy shared by cement, bricks and steel hardly change irrespective of the number of storey in the building.

However a meaningful comparison could be possible if the ratio of energy consumed to that of total area of the entire floors in each building is considered. Table 4 gives the energy consumed per m^2 of the floor area in each of the building. Thus the G+1 R.C. building consumes about 3702 MJ/ m^2. The G+2 R.C building is more efficient than the G+7 building indicating a 27% less energy consumption as that of G+1 building.

Material	Embodied Energy in MJ			
	Load bearing G+1 building	Framed G+1 building	Framed G+2 building	Framed G+7 building
Cement	166938	364506	699286	4620000
Sand	1080	1990	10815	21974
Aggregate	6218	11598	21111	149423
Bricks	544275	215540	294000	1725575
Glass	2072	2072	19646	99509
Aluminium	--	--	10991	33202
Tiles	13335	13335	55755	246225
Timber	8475	8475	7150	30325
Steel	73629	204606	504524	2844062
Paint	24371	24371	58064	283388
TOTAL	**840393**	**846493**	**1691342**	**10053683**

Table7 (a) Embodied energy comparison for G+1, G+2 and G+7 storied building

Type of building	Floor Area (m^2)	Energy per square meter of floor area (MJ / m^2)
G+1 R.C.C. structure	228.87	3702.344
G+2 R.C.C. structure	579.40	2911.233
G+7 R.C.C. structure	2783.93	3611.977

Table 7 (b): Energy consumption per unit area for various building

The figures are based on a _Cradle-to-Gate‘ analysis of publicly available information.

Material	**Energy MJ/kg**	**Carbon kg CO_2/kg**	**Density kg /m^3**
Aggregate	0.083	0.0048	2240
Concrete (1:1.5:3 in-situ floor slabs, structure)	1.11	0.159	2400
Concrete (in-situ floor slabs) with 25% PFA RC40	0.97	0.132	
Concrete (in-situ floor slabs) with 50% GGBS RC40	0.88	0.101	
Bricks (common)	3.0	0.24	1700
Concrete block (Medium density 10 N/mm2))	0.67	0.073	1450
Aerated block	3.50	0.30	750
Rammed earth (no cement content)	0.45	0.023	1460
Limestone block	0.85		2180
Marble	2.00	0.116	2500
Cement mortar (1:3)	1.33	0.208	
Steel (general - average recycled content)	20.10	1.37	7800
Steel (section - average recycled content)	21.50	1.42	7800
Steel (pipe - average recycled content)	19.80	1.37	7800
Stainless steel	56.70	6.15	7850
Timber (general - excludes sequestration)	10.00	0.72	480 – 720
Glue laminated timber	12.00	0.87	
Sawn hardwood	10.40	0.86	700 – 800

Cellular glass insulation	27.00		
Cellulose insulation (loose fill)	0.94 – 3.3		43
Cork insulation	*26.00**		160
Glass fibre insulation (glass wool)	28.00	1.35	12
Flax insulation	39.50	1.70	*30**
Rockwool (slab)	16.80	1.05	24
Expanded Polystyrene insulation	88.60	2.55	*15 – 30**
Polyurethane insulation (rigid foam)	101.50	3.48	30
Woodwool board insulation	20.00	0.98	
Wool (recycled) insulation	20.90		*25**
Straw bale	0.91		*100 – 110**
Mineral fibre roofing tile	37	2.70	*1850**
Slate (UK – imported)	0.1 – 1.0	0.006 – 0.058	1600
Clay tile	6.50	0.45	1900
Aluminium (general &incl 33% recycled)	155	8.24	2700
Bitumen (general)	51	0.38 - 0.43	
Hardboard	16.00	1.05	600 – 1000
MDF	11.00	0.72	*680 – 760**
OSB	15.00	0.96	*640**
Plywood	15.00	1.07	540 - 700
Plasterboard	6.75	0.38	800

Gypsum plaster	1.80	0.12	1120
Glass	15.00	0.85	2500
PVC (general)	77.20	28.1	1380
PVC pipe	67.50	24.40	*1400**
Linoleum	25.00	1.21	1200
Vinyl flooring	65.64	2.92	1200
Terrazzo tiles	1.40	0.12	*1750**
Ceramic tiles	12.00	0.74	2000
Carpet tiles, nylon (Polyamide), pile weight 770g/m2	279 MJ/m2	13.7 / m2	4.6 kg/m2
Wool carpet	106.00	5.53	
Wallpaper	36.40	1.93	
Wood stain / varnish	50.00	5.35	
Vitrified clay pipe (DN 500)	7.90	0.52	
Iron (general)	25	1.91	7870
Copper (average incl. 37% recycled)	42	2.60	8600
Lead (incl 61% recycled)	25.21	1.57	11340
Ceramic sanitary ware	29.00	1.51	

Windows

1200 x 1200 2x glazed, air or argon filled	**MJ per window**	**kg CO_2**

Aluminium frame	5470	279
PVC frame	2150 – 2470	110 – 126
Aluminium clad timber frame	950 – 1460	48 – 75
Timber frame	230 – 490	12 – 25
	230 – 490	12 – 25
Krypton filled add:	510	26
Xeon filled add:	4500	229

Paint

Material	**Energy MJ/m²**	**Carbon kg CO_2/m²**
Water-borne paint	59.0	2.12
Solvent-borne paint	97.0	3.13

Photovoltaic (PV) cells

Material	**Energy MJ/m²**	**Carbon kg CO_2/m²**
Mono crystalline (average)	4750	242
Polycrystalline (average)	4070	208
Thin film (average)	1305	67

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 Location:

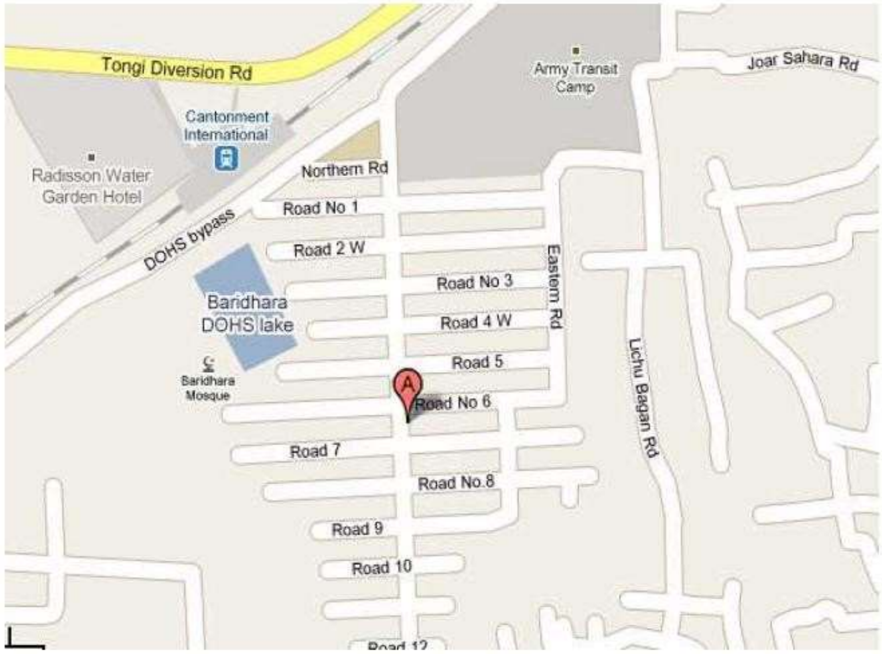


Figure: Location of DOHS Baridhara

Source: Google maps

4.2 Study Area:

The developing city like Dhaka is having an annual growth of 12% in construction sector which contributes 3.7% of GDP (Mintoo, 2006) and employs 1.6 million people. Today, real estate and construction industry is the biggest of all the locally run industries and contributing 14.50 billion BDT (US$231 million) (BBS, 2006) annually. A survey was conducted in DOHS Baridhara in the year 2009 to identify the number of houses being built and to estimate amount of CO2 based on different types of materials used. The average temperature of DOHS Baridhara is 0.5°C to 1°Chigher than its surrounding area like Gulshan and Banani as observed during the survey. The most of the heat is generated from the buildings as there are very few trees or vegetation in the area. The justification for considering this area is that the buildings are built very recently (last 20 years) and many are still in the construction phase. There is an opportunity to look at the building materials that are widely used. There are 654 houses in DOHS Baridhara with estimated population of 6,000. Of the total area, 98.2% plot areas are already occupied by houses and rest of them are still vacant plots. Almost 36% houses are still under construction. Average plot area is 3,600 sq. ft. and average covered area is2,600 sq. ft.

Sr No	Name of the item	Unit	Quantity
1	Reinforcement	Kg	50,441
2	Cement	Bag	5,204
3	Sand		32,957
4	Brick a) Picket b) First Class	 Nos Nos	 13,500 1,09,048
5	Stone	Sft	14,527
6	Door a) Wooden b) Plastic	 Sft Sft	 1,800 900
7	Window a) Grill b) Aluminium c) Tiles Work	 Sft Sft Sft	 4,010 4,010 21,252
8	Painting (Plastic)	Sft	72,075
9	Painting (Weather Coat)	sft	9,165

Table 8: Estimate of the materials required for five storied building

4.3 Results:

The analysis of building materials were based on the quantity used assuming the house is a five story building. It is estimated for an average of 2,600 sq. ft. floor area, a five story building would produce approximately 5,128,640 MJ embodied energy and 412,254 kg CO_2. This has been calculated based on the quantity of materials required for construction as shown in Table 8. The estimated materials are converted into weight and then using the embodied energy and CO_2 emission for specific materials as given in Table 9, the total amount of embodied energy and CO_2 for the five story building is calculated

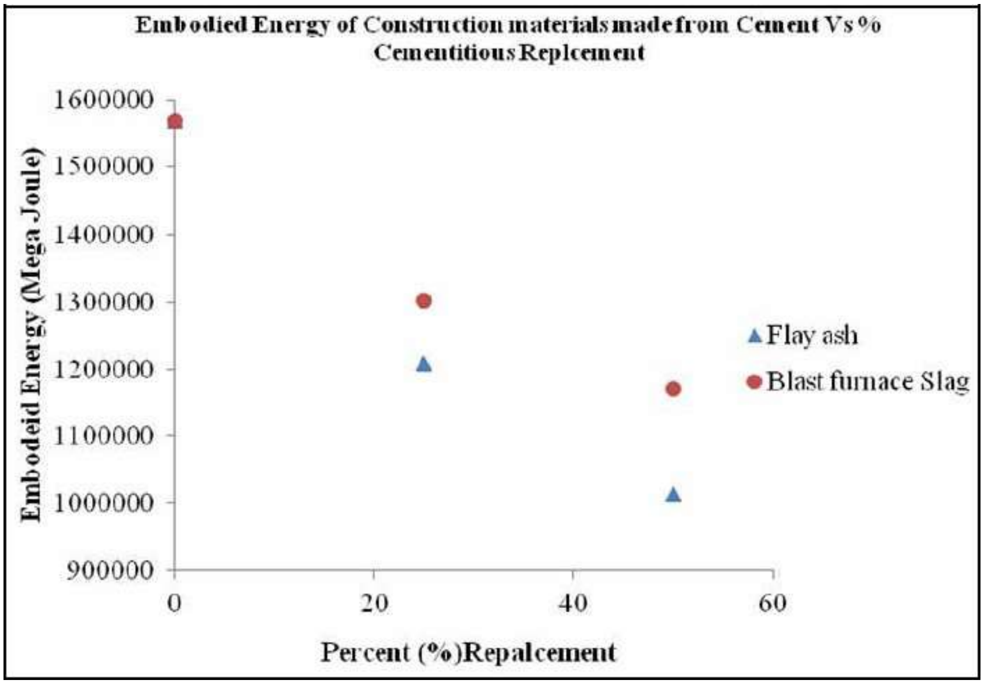
Item	Description	Embodied Energy MJ	Embodied CO_2 Kg
1	Backfill (Using General Sand)	87,653	4,383
2	Flat Soaling (Using Common Bricks)	1,17,698	8,631
3	Cement Concrete Work Using General Cement	91,683	11,431
4	Brick Works Using Common Bricks	9,14,349	67,052
5	Tiles Work Using Ceramic Tiles	2,72,184	17,843
6	Plastering Work (Mortar Using General Cement)	2,27,296	33,249
7	Painting (Double Coat)	1,68,214	8,741
8	Door (Wooden + PVC)	11,24,227	39,181
9	Windows (Aluminium Framed)	8,75,200	44,640
10	Reinforced Concrete (Using General Cement)	12,50,138	1,77,103
Total		51,28,640	4,12,254

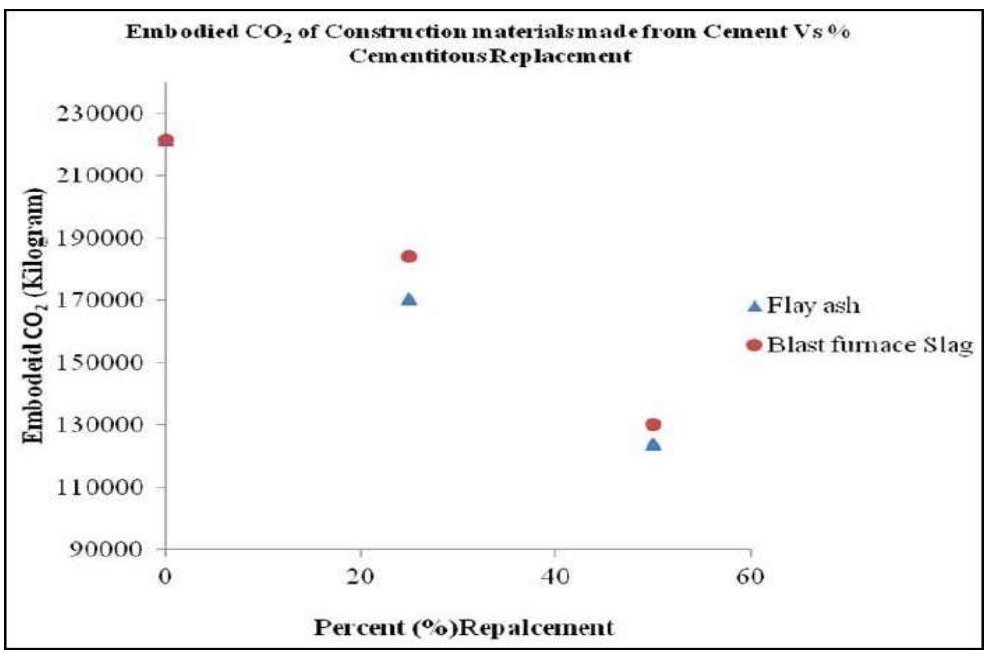
Table 9: Embodied Energy and Embodied CO_2 for a five storey building using typical combination of construction materials in the study area

Item	Description	Embodied Energy MJ	Embodied CO_2 Kg
1	Backfill (Using General Sand)	87,653	4,383
2	Flat Soaling (Using Common Bricks)	27,854	3,139
3	Cement Concrete Work Using Cement with 50% fly ash	66,679	6,906
4	Brick Works Using Common Bricks	9,14,349	67,052
5	Tiles Work Using MarbleTiles	1,17,623	6,665
6	Plastering Work (Mortar Using Cement with 50% Fly Ash)	1,13,648	16,292
7	Painting (Single Coat Coat)	84,932	4,370
8	Door (Laminated Veneer Lumber)	1,73,577	9,318
9	Windows (Timber Framed)	57,600	2,960
10	Reinforced Concrete (Using Cement 50% Fly Ash)	8,33,426	1,06,493
Total		24,77,339	2,27,579

4.4 Analysis:

Figure 3.7.4. Variation of embodied energy and embodied CO_2 of construction materials made from cement with ementitious (fly ash and blast furnace slag)





The materials for construction have a significant impact on the embodied energy and embodied CO_2 of a building. Another calculation has been made for the same five storied building using alternative combination of building materials (Table 9). In this calculation the materials are selected on the basis of their embodied energy, embodied CO_2 and availability. The analysis revealed that we can reduce approximately 52% of total embodied energy and 45% of total embodied CO_2 of a building only by using building materials with low embodied energy and low embodied CO_2. The principal materials for construction (cement concrete, mortar for plastering, reinforced concrete) in the study area are made from general cement (Type I cement as per Bangladesh Standard BDS EN197-1:2003). The study shows that there is a significant reduction in embodied energy and embodied CO_2 if the general cement is replaced with other cementitious materials like fly ash or blast furnace slag (Figure 3). These types of cement (Type-II and Type-III as per Bangladesh standard BDS EN 197-1:2003) are available in Bangladesh with similar physical and mechanical properties as type-I cement. By replacing type-I cement with type-II or type-III cement the embodied energy and embodied CO_2 can be reduced to 23% to 35% and 22% to 45% respectively. Therefore, selection of materials can significantly reduce embodied energy and CO_2 which play an important role in reducing the impact of climate change resulting from emission. The sustainable buildings should emphasis on use of recycled materials like bricks and concrete, natural ventilation using mixed mode design. Mixed mode design is a concept where mechanical and natural ventilations are provided for optimum comfort condition, which is 26 degree Celsius. The dwellers are encouraged to use water saving technologies through aerated and self-closing faucets. Currently it is not clear whether energy-efficient products and services can be competitive with existing, less-efficient versions, because of reluctance among potential buyers to pay an adequate price. This reluctance is based on the value proposition not having been fully developed and communicated. The study identified that there is a lack of information among the residents of the study area regarding energy use and the concept of sustainable buildings. There is also a lack of leadership from the real estate developers, professionals or politicians to promote sustainable construction approaches in the country.

4.5 Conclusions:

1) The use of alternative building units like hollow concrete blocks for masonry construction reduces the energy consumption by 60% as compared to brick masonry.

2) The conventional RC roof or the Hourdi tile roof are energy intensive with embodied energy values of 548 MJ/m2 and 540 MJ/m2 respectively. The composite beam-panel roof is 13% energy efficient as compared to the RC roof.

3) A 50% and 25% energy saving may be achieved in roofs made of ferrocement channel units and brick vaults as relative to RC roofs and thus are the most energy efficient choices amongst the various alternatives considered.

4) The energy consumption in single storied buildings remains unchanged irrespective of the structural system adopted. However it is better to adopt a load bearing structure as it encourages decentralized products like bricks which supports the rural economy.

5) Materials like Cement, Steel and Bricks and Glass are the major contributors to the total energy consumption in RC buildings.

6) Buildings with lesser number of storey's are more energy efficient than multi-storied buildings.

7) Attempts in minimizing or replacing the conventional high energy materials like cement, steel, bricks with cheaper and local alternatives will lead to reduction in the embodied energy in buildings.

8) The cement industry is a large contributor to global CO_2 emissions. CO_2 is emitted from the calcination process of limestone, from combustion of fuels in the kiln, and from power generation for purchased or self-generated electricity.

9) Estimated carbon emissions from cement production in 1994 were 307 MtC, 160 MtC from calcination, and 147 MtC from energy use. These emissions account for 5% of 1994 global anthropogenic CO_2 emissions.

10) Data collection for this effort is labor intensive, and we recommend that the emissions be reported in future years on a consistent basis. China accounts for by far the largest share of total emissions (33%), followed by the United States (6%), India (5%), Japan (5%), and Korea (4%). Overall, the top 10 cement-producing countries in 1994 accounted for 63% of global carbon emissions from cement production for that year. Regionally, after China, the largest emitting regions are Europe (12%), OECD-Pacific (9%), and Asian countries excluding China and India (9%), and the Middle East (8%).

11) This study was conducted to develop a model that could evaluate the CO_2 emission in the construction phase of construction projects. Towards this end, the materials and equipment inputted in the construction methods used in the construction phase of construction projects were analyzed in the process of developing the model.

12) The CO_2 emission of the materials was calculated using the I-O LCA approach, and an LCI database of construction materials was established by developing the corresponding equations.

CHAPTER 5

SUMMARY AND CONCLUSION

Conclusion:

Selection of appropriate construction materials can considerably cut down CO_2 emissions and make our buildings more sustainable and energy efficient. The analysis of a five-story building having an area of 90 sq. m. demonstrates that we can reduce approximately 52% of total embodied energy and 45% of total embodied CO_2 by altering the building materials with low embodied energy and low embodied CO_2. It has been observed from the case study that construction materials like aluminium and steel should be less encouraged due to their higher CO_2 emission rate as compared to glass and timber. The case study shows that use of bricks rather than using ceramics can cut down CO_2 emission by one third. This seems quite promising; hence, many works for high-rise building could be adapted to the cities where there is a demand for high-rise buildings with emphasis on materials which emits less CO_2 in its life cycle. A good building should incorporate as many sustainable, local materials as possible into its construction – to support local economies, to avoid the high energy and financial costs of long-distance transportation, and to fit in with local aesthetics. The fast growing cities like Dhaka need immediate attention so that buildings are designed for maximum efficiency with optimum use of resources and lesser impact on environment. It is also recommended that the real estate developers working with construction industries needs to be assessed and ranked annually based on the concept of sustainable buildings. It is recommended that sustainable construction processes should promote the increased use of energy-efficient designs and technologies and sustainable utilization of natural resources. It should provide financial incentives to promote recycling of energy-intensive materials in the construction industry. The use of construction materials and products that create pollution during their life cycle should be discouraged by imposing pollution tax.

CHAPTER 6

REFERENCES

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List of Publications:

Sr. No.	Authors	Title of Paper	Name of International journal/Paper Presentation	Place and Date of Publication
1.	Gunjan Kirpal,Trushali Puri, Ashwini Dahate,Apeksha Yenprediwar,Pankaj Dhawale	CO_2 emission and impact on global environment	SPANDAN‘14	YCCE,Nagpur 13^{th} March,2014
2	Abhilash Bhure,Shreeram Adamane,Kunal Yengandewar,Sanket Petkar	Embodied energy computations in buildings.	SPANDAN‘14	YCCE,Nagpur 13^{th} March,2014
3	Gunjan Kirpal,Trushali Puri, Ashwini Dahate,Apeksha Yenprediwar,Pankaj Dhawale	CO_2 emission and impact on global environment	PRATIKRUTI‘14	YCCE,Nagpur 22^{nd} March,2014
4	Abhilash Bhure,Shreeram Adamane,Kunal Yengandewar,Sanket Petkar	Embodied energy computations in buildings.	PRATIKRUTI‘14	YCCE,Nagpur 22^{nd} March,2014