Identification of Factors Causing Greenhouse Gas (GHG) Emission During Building Construction

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Abstract - The issue of climate change has led to an increased priority on sustainable practices in almost every aspect of our lives. The construction sector has a significant environmental impact, particularly in terms of greenhouse gas emissions and energy consumption. Most of greenhouse gases and non-greenhouse gases that have an indirect radiative effect are emitted from various construction activities and processes, during production, installation, maintenance, and end-of-life disposal of construction materials. These emissions can be controlled and reduced by optimizing the utilization of construction resources. According to the global status report 2018, buildings and construction together account for 36% of global final energy use and 39% of energy related carbon dioxide (CO_2) emissions. In this paper, a literature review was conducted to find the major sources of greenhouse gas (GHG) emission and energy use in the building's life cycle.

Keywords —Building construction, Life cycle assessment (LCA), Greenhouse gas (GHG) emission, Direct emission, Indirect emission.

I. INTRODUCTION

The greenhouse gas (GHG) is any gas present in the atmosphere which absorbs and re- emits heat and thus keeps the planet's atmosphere warmer. There are various GHG emissions used to determine the global warming potential. It is measured as the carbon dioxide equivalent (CO_2e) of greenhouse gases. Among those greenhouse gases the carbon dioxide is of greatest importance. Carbon dioxide (CO_2), emission occur in different stage of building's life cycle, which is defined as material extraction, and material processing, component fabrication process, construction and assembly, operation and service phase, and end-of-life phase. The relative contribution of embodied and operating carbon to the total life cycle carbon of buildings might vary significantly depending upon the type and function of the building, as well as factors such as location, climate, fuel type used, orientation of building, massing of building, etc.

II. IDENTIFICATION OF GHG EMISSION FACTORS FROM LITERATURE REVIEW

Gangolells M. et al (2009) introduced a systematic approach for dealing with the adverse environmental impacts during the construction stage. In this study nine categories of environmental aspects are proposed such as atmospheric emissions, water emissions, waste generation, soil alteration, resource consumption, local issues like noise, vibration, dust etc., transportation issues, effects on biodiversity and incident, accidents and potential emergency situations. In this study the construction processes considered were as follows earthwork, foundations, structures, roofs, partitions and closures, pavements, and door and window. These main construction process were again divided into smaller process steps. Major factors having significant environmental impacts are identified as GHG emissions due to construction machinery and the movement of vehicles.

Yan H. et al. (2010) describes four sources of GHG emissions in building construction, that are manufacturing and transportation of construction materials, energy consumption of construction equipment, energy consumption for processing resources and disposal of construction waste. The system boundary adopted by this method is limited to above processes. For the purpose of calculating GHG emission these are again divided into six parts as follows: embodied GHG emission of building materials which are GHG emissions due to energy consumption for manufacture of building materials before transporting to construction sites, from transportation for building materials which are GHG due to fuel and energy consumption for transporting building materials to construction materials, from fuel combustion of equipment, due to electricity used for construction equipment, due to electricity used for processing fresh water and sewage, and GHG emission from fuel combustion of transportation for

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construction waste.

Biswas W.K. (2014) limited the life cycle assessment (LCA) to three stages such as the supply of construction materials, the construction stage and finally the usage stage. The supply of construction materials stage includes the amount of GHG emissions associated with mining, processing and production of construction materials along with transportation to the construction site. The construction stage includes the GHG emission associated with the construction process, including fencing, site clearing, excavation and filling, installation of a tower crane, concrete pouring, pre-casting, shuttering, and mortar preparation. The usage stage includes the GHG emission associated with the energy consumption of end-use appliances within the building including lighting, computing, office and kitchen equipment, air conditioning, lifts, fan, and heating.

Hong T. et al (2014) done a detailed analysis on the construction phase in order to conduct a more accurate assessment of energy consumption and environmental impact of a building's entire life cycle. This study divided the construction phase into following categories such as material manufacturing, transportation and onsite construction. The construction phase for building generally proceed in the order of initially the temporary work, earth work, foundation work, frame work, finishing work and utility work. The study conducted LCA from temporary work to frame work excluding finishing and utility work in assessment model.

Hong J. et al (2014) focused on analysing the GHG emissions during the construction phase on the basis of a system boundary which have an extended focus GHG emission. Nonetheless previous studies were focused on the embodied GHG emission of building and were restricted by limited system boundaries due to lack of details and off site process data, especially for the data of assembly works as well as construction related human activities. This study covered the emission impact of all activities during the construction period of building including direct emission from fuel used in construction equipment and vehicles, onsite worker activities, construction electricity used, assembly and miscellaneous works and indirect emissions from the manufacture and transportation of building materials, transportation of construction equipment and offsite construction related staff activities.

Zhang X. and Wang F. (2015) divided the life cycle into three stages from the perspective of material and energy flow. Here the materials used are classified into structural materials that constitute the load bearing structural system, building envelope materials that constitute the non-load bearing structure system, auxiliary materials that assist in onsite construction but are not involved in building themselves, functional materials required to sustain the normal operation of building and the decorative materials that are essential to realize the architectural aesthetic requirements. The energy flow of building is divided into energy consumption for materials preparation known as embodied energy, construction machinery and conveyance, for essential building equipment, for household appliances and energy saved by using energy efficient equipment.

Sim J. et al (2016) estimated the total air emission of seven types of air pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrogen oxides (NO_x), sulphur dioxide (SO_2), non-methane organic compounds (NMVOC) and nitrous oxide (N_2O) produced during the building life cycle. It is done by considering the summation of air emission at the stage of construction material production, building construction, building operation, building demolition and building material recycling and disposal.

Wolf C.D. et al (2017) considered cradle to grave impact of buildings which includes product stage, construction process stage, usage phase, end of life stage and reuse, recovery and recycling. The product stage includes raw material supply, transport of materials from extraction to manufacturing site, and manufacturing itself. The construction process stage is divided into the transport from gate to site and the construction installation process. The usage stage includes the impacts arising from anticipated conditions of use of components, repair, replacement and refurbishment. The operational energy use and operational water use are excluded from embodied CO_2e assessment. The end of life stage comprises deconstruction and demolition, transport to landfill, incineration or recycling facilities, waste processing and disposal. Beyond these life cycle stages, potential benefits and loads of reuse, recovery or recycle is taken into account.

III. RESULTS AND DISCUSSIONS

From the literature review and questionnaire surveys, following factors are identified causing greenhouse emission from building construction sector. Among the identified factors, the GHG emission due to material production and building operation contributes greater emission rate. Buildings materials emit large amount of carbon emissions.

Table 2.1: Factors causing GHG emission

Rank	Factors
1	Material production
2	Building operation
3	Building erection
4	Transportation of materials
5	Construction machinery and movement of vehicles
6	Demolition
7	Material recycling and disposal
8	Building components assembly works

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9	Fuel combustion of construction equipment
10	Energy consuming for processing resources
11	Fuel combustion during transportation for construction waste.
12	Electricity used for construction equipment
13	Electricity used for processing fresh water and sewage
14	Soil alteration

IV. CONCLUSION

The paper identified the factors causing greenhouse gas (GHG) emission. Among the identified factors, the GHG emission due to material production and building operation (operational carbon) contributes greater emission rate. The results from literature review is confirmed by questionnaire surveys taken from construction sites. From table 2.1 it was identified that from building materials production generated the most GHG indirect emissions. The environmental impacts associated with extracting, manufacturing, and transporting materials to the construction site is the initial embodied carbon. The manufacture of building materials makes a major contribution to total global greenhouse gas emissions.

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