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ANALYSIS OF THE EMBODIED ENERGY IN CONSTRUCTIONAL MATERIALS AND RELATED CO_2 EMISSION

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Abstract

CO_2 emissions and the energy content of building materials are important metrics to consider when assessing a building's efficiency. For the developing world in particular, there is a dearth of information about these aspects in the technical literature. It is hoped that this paper may help to remedy it. Embodied energy is calculated using a process analysis-based methodology that factors in the energy required for construction. Using a method of Intergovernmental group on climate change, it can be estimated the CO_2 emissions caused by manufacturing of constructional materials and their subsequent installation on-site. There is an analysis of water, three types of energy, eight construction materials, and three parts of the building envelope. As an illustration, It can be calculated the EE and CO_2 emissions of gravel. Due to poorer production efficiency, it was assumed that residential construction materials would have a larger embodied energy than industrialised building materials. This is likely because less machinery is used and more people are employed in manufacturing in developing nations.

Keywords: Constructional materials, EE, CO_2 emissions, process analysis,

1. Introduction

LCE use, LCC, and LCCE should be used to inform the design and performance assessment of construction projects.

Calculating how much energy a building uses and how much carbon dioxide it emits is a simple task. Calculating carbon dioxide emissions from the usage of building materials is made much more complicated by the need to know how much energy went into their production and assembly **(Augustine, et al 2019).** The lack of convenient access to such data is problematic for the design community. Whether measured in mega joules (MJ) per (kg) of material, mega joules

(MJ) per cubic metre (m^3), or mega joules (MJ) per square metre (m^2), the figures stated for particular embodied energy or energy content can vary widely..

Since the existing particular embodied energy (EE) estimates creates from data collected in industrialised nations, this creates an additional challenge for developing countries. Is it reliable to employ such information in the construction of low-income housing? This article adds to the current body of knowledge on the subject,

Categories of Building materials:

1. Materials imported from developed nations and
2. Materials manufactured in nations from raw material.

This article evaluates the EE and associated CO_2 emissions of a variety of commercial building outside envelope materials. This work is a part of a larger effort to develop decision tool to optimise structure design in preliminary stages taking into account energy use over the structure's lifetime, cost over its lifetime, and CO2 emissions over its lifetime all at once. The impact of variables like technical gaps and energy resource availability is assessed by contrasting the findings of this study with those from industrialised nations.

2. Material and Method

2.1 Analysing Energy

Analyzing how much energy a system requires in order to generate output is known as "energy analysis." The goal here is to put a numerical value on how much of an effect our individual and collective choices have on our reliance on these vital non-renewable energy sources **(Sun & Shi, 2020).** The connection between consumer products and the environment is not a focus of energy analysis.

For processing of analysing energy, a factor known as the energy content (EC) or EE of commodities is given mega joules per kilograms per square metre (MJ kg/m^2), for instance 4 MJ/kg of gravel.

The International Federation of Institutes for Advanced Study **(Kulasuriya, 2021)** advocated the usage of a number of assumptions or recommendations in order to standardise the evaluation techniques for embodied energy in goods and services. Relevant examples to the topic of this paper are provided below:

1. Due to the high degree of questionability connected with its assessment, the human energy consumed in the manufacturing process is not considered.
2. Four stages of examination should be utilised when determining the energy content of a product or service.
3. The direct energy, actually used in the production of manufactured goods or services, must be evaluated..

2.2 CO_2 Emissions

The International Panel on Climate Change (IPCC) methodology was used to estimate (CO_2) discharge attributable to the manufacture of constructional materials and their installation on-site **(GIEC 2000).** The six-step procedure involves the following (see Table 1):

This methodology is appropriate for the current situation because oil and its derivatives are the predominant source of energy. Other GHG, including CO, CH_4, N_2O, and NO, are not included in the CO_2-emission factor calculation. Indeed, as mentioned by the IPCC **(GIEC, 2000),** A multitude of factors, such as fuel type, operating conditions, combustion technology, control technology, age of equipment, and maintenance, affect these emissions. It was not possible to obtain this information. This analysis focuses solely on carbon dioxide emissions because they account for the largest portion of overall greenhouse gas emissions.

Table 1 Depicts the Analysis of the CO_2 emission factors for gas-oil, fuel-oil, and natural gas

Product	Fuel consumption (kg)	Energy equivalent (GJ/kg)	Emission (kgC/GJ)	Carbon content (kgC/kg)	Carbon oxidized (%)	Emission factor ($kgCO_2/kg$)
Gas-oil	1	0.04250	19.95	0.848	0.990	3.08
Fuel-oil	1	0.04151	21.10	0.876	0.990	3.18
Natural gas	1	0.05182	15.3	0.793	0.995	2.89

4. Results

Power, H_2O, heavy oil, and gasoline are among the most often used resources in the production of construction materials. Figure 1 shows the correlations between these four factors using average values for the country **(Samb,et al 2021).** All of the crude oil used in production comes from overseas. Gasoline and fuel-oil are two refined forms of this oil. The generation and distribution of water rely on the use of power, gasoline and chemical compounds (for treatment)..

1. Assumed that the amount of energy required to recover and transport natural gas is negligible in relation to the energy it provides. Because of this, the net calorific value (NCV), or embodied energy, of natural gas is given by CEGN = 51.82 MJ/kgr.
2. The inputs for producing and distributing water are electricity, gasoline (for pumping), and chemical compounds (for treatment). These chemical goods are imported from European countries. QELU = 0.625 kWh/m^3, QGLU = 0.0215 kg/m^3, and EDIV1 = 0.222 MJ/m^3 are the estimated amounts of energy and chemical products needed to produce and distribute 1 cubic metre of water.
3. The processing and transport of crude oil is predicted to use 3 megajoules (MJ) per kilogram. To process 1 kilogram of crude oil, the following is required: QEUP = 0.000222 m3/kg; 4.35 g gas-oil; 6.65 g fuel-oil; 0.27 g refinery gas; 0.222 l water.

The solution to equations (1) through (6) given these parameters:

"CEEL = 16.07 MJ/kWh, embodied energy of electricity

CEEU = 11.25 MJ/m^3, embodied energy of water

CEFL = 45.02 MJ/kg, embodied energy of fuel-oil

CEGL = 46.01 MJ/kg, embodied energy of gas-oil"

In addition, it was calculated that processing crude oil uses 0.51 MJ/kg of energy and that refinery gas has an embodied energy of 49.06 MJ/kg.

Gravel's estimated embodied energy (EE) and carbon dioxide (CO_2) emissions are provided. Gravel is an essential part of the cement mix. Crushing rocks like basalt, limestone, and sandstone yields this material.

Table 2 contains data collected from a gravel manufacturing firm. The company uses gasoline-powered vehicles and generators at the quarry. Table 2 depicts the daily average electricity use for the Dakar administration building. Transporting gravel to the quarry is estimated to use 108 MJ of gas-oil per tonne of gravel across a distance of 2 x 105 km. It is predicted that 28-ton trucks using 36 litres of gas-oil per 100 kilometres will carry out the transportation. (**Olagunju, & Olanrewaju, (2020**).

Table 2 one metric tonne of gravel's embodied energy (EE) and CO_2 emission factor (Crushed Basalt)

Input	**Unit**	**Quantity**	**EE (MJ/Unit)**	**Total EE (MJ)**	**CO_2 ($kgCO_2$/Unit)**	**Total CO_2 ($kgCO_2$)**
Gas-oil	kg	1.128	46.01	51.90	3.08	3.47
Electricity	kWh	0.012	16.07	0.19	1.10	0.01
Transport to Dakar	unit	1	108.08	108.08	7.23	7.23
Water	m^3	0.008	11.25	0.09	0.75	0.01
	Total by metric ton of gravel			**160.26**		**10.72**

Finally, gravel's production and transportation are estimated to result in 10.7 kg of CO2 emissions per tonne, and its embodied energy is 160 MJ per tonne (this is the CO2-emission factor of gravel).

5. Conclusion

This article provided unique data on the raw-material-derived EE and CO_2 emissions of a various constructional products. These numbers were calculated based on an examination of the process and information acquired during on-site inspections. Obtaining these figures is demonstrated. Figure 1 is especially intriguing because it shows the process analysis for creating 1 kWh of Power. One could argue that the relatively low level of automation in manufacturing processes in developing countries is compensated for by the high amount of human energy consumption.

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