CO2 Emission by Different Building Materials for Walls Case: housing in Colima, Mexico

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ABSTRACT: There is a comparative analysis about CO2 emission by the extraction, transportation, manufacturing, building and demolition phases of the three wall systems more used in building of economical housing in Mexico, taking like case study houses built in the city of Colima. The studied building materials for walls are those based on traditional brick of burned clay, brick of solid cement and hollow block of concrete. The method applied was the life cycle assessment ruled by the ISO 14000 series, without considering the phase of occupation of the housing, which has not concluded. The software SimaPro 7 was used for the calculation of input and output of each system. The wall of hollow block of concrete was the most polluting due to the quantity of cement and steel for the manufacturing and construction phases, just if the traditional brick use sustainable source of biomass for the burning of the pieces in the manufacturing phase. In that case, the traditional brick is turned out to be the less polluting system during the analyzed phases.

Keywords: CO2 Emissions, Life Cycle Assessment, wall building materials, economical housing.

INTRODUCTION

The housing built in series in Mexico has not considered in its design process the environmental and energy aspects, as a result, the materials used to build are always the cheapest, and not necessarily the most appropriate to the environment and the local climate. Consequently the environmental consequences as the production of solid waste, the disposal of residual waters and the emission of gases usually go unnoticed by the authorities in the matter, thus greatly contributing to the environmental problem of the country, and very especially regarding the global warming.

For such a reason the Comisión Nacional de Vivienda CONAVI (National Commission of Housing) formulated a call for participation in order to finance research projects that could solve the omission of the environmental aspects in the housing sector in Mexico. The project "Life Cycle Assessment of Economical Housing in Mexico. Case of Study: Wall Systems in the City of Colima", which preliminary results are presented in this paper, was one of those approved. The project is based on the Life Cycle Assessment (LCA) method, since it produces reliable and objective information with scientific fundamentals and covers all the phases of the life cycle of the products to analyze [1]. In this paper only the results about the extraction, transportation, manufacturing building and demolition phases of the wall systems used for housing are reported.

OBJECTIVES

The main objective of this project is to contribute to the sustainable development paradigm of housing sector in Mexico, by means of the adaptation of the LCA methodological process, in order to ease the work of housing promoters, designers and building material manufacturers, through the knowledge of the environmental impacts caused by technologies, procedures or materials used in walls construction.

METHOD

As afore it is mentioned, this study has been based on the LCA method, according to the ISO 14000 series [2], [3], [4], [5] and [6]. The inventory of incoming and salient flows, and the identification of environmental impacts were conducted by the aid of the LCA specialized software SimaPro 7.1 and the database Ecoinvent license (v1+2). Data coming from specialized literature or even data generated as part of the research were also used.

SCOPES

Systems to analyze: The walls of the economical housings in Colima are often built with three systems based on the following materials:

Traditional burned clay brick. Size: 5x14x28cm. Weight 2.837 Kg. The burn process is carried out by the combustion of wood and waste of coconut (Fig. 1).



Figure 1: Traditional burned clay brick piece

Solid brick of cement. Monolithic piece manufactured with cement, river sand and *jal* a porous mineral commonly used in the region of Jalisco, Mexico. Size: 10x14x28 cm. Weight 5.12 Kg. Its manufacturing is carried out by electrical equipment (Fig. 2).



Figure 2: Piece of brick of cement

Hollow block of concrete. The pieces are elaborated with cement, river sand and *jal*. Size: 15x20x40 cm. Weight: 8.624 Kg (Fig. 3).



Figure 3: Piece of hollow block of concrete

Components of the systems: Besides the aforementioned pieces of masonry, it is analyzed the following components: mortar of cement-sand for bonding of masonry pieces and for the surface covering that consolidates the structural confining of the masonry; and structural columns of reinforced concrete. In this case, the horizontal structural components are not considered because the three systems are exactly the same. The energy contribution coming from the human effort is not included.

Phases of Life Cycle: Extraction of the main matter with which the construction material is manufactured, transportation to the manufacturing facilities; manufacturing of building materials; transportation to the building site; construction; and demolition. It is not considered the possible recycling and/or re-use of the materials in the end of the useful life of housing. The phase of occupation of the house is not reported here because that phase is still in progress.

Measure units: The measure unit that serves as parameter to analyze the three systems is the square meter (m2) of wall.

Environmental Impacts Category: Global warming. Accordingly only the emission of CO2 equivalent has been considered.

INFLOWS INVENTORY

In figure 4 it is presented the outline of inventories, both material and energetic, involved in the Life Cycle of the three wall systems analyzed. The inventories 1 and 2 correspond to mineral extraction in open sky mines of river sand, gravel and *jal*. Since they are local materials, they are not includes in international inventories as Ecoinvent and similar. Therefore, its corresponding data were collected in field visits.

Also, the energy inventories involved in the manufacturing of burned clay bricks, by the combustion of diverse wooden types and a by-product of the coconut bark known as "estopa", are not includes in the international inventories. So, the corresponding data were based on the values of energy capacity of wood and the emissions to the atmosphere associated to its combustion reported by Becker [7].

The inventory 5, electricity, is based in the energy mix in Mexico, which is 62% from thermoelectric plant (steam generated from combustion of fuel oil, gas and diesel), 16% from hydroelectric plant, 12% of fired coal, 6% of nuclear and 4% of geothermal (Average electricity production in Mexico 2004-2007) [8], [9]. On the contrary, the inventories 3, 4, and 6 correspond to industrialized processes, which have been generalized around the world. They are cement manufacturing and the structural steel manufacturing. In these cases, the data included in Ecoinvent that better were adjusted to the local reality, were used.



Figure 4: General outline of inflows inventories participating in the whole Life Cycle of the three wall systems.

The aforementioned inventories are necessary to develop the subsequent inventories. The inventory 8 corresponds to the manufacturing phase of the masonry products involved in the systems, incorporating the inflows of the previous phases, the primary transportation and the transportation to the worksite.

Inventory 9 integrates the implicit flows during the building phase, and inventory 11 is done with the inflows regarding to the demolition and the transportation of the rubble to their final destination. Inventory 10, regarding to the house occupation phase is not considered for the results presented in this paper.

In figures 5 and 6 it can be observed the inflows involved in hollow block of concrete and brick of cement. The most significant inflows correspond to phases that consume cement, because of the huge amount of energy required for its manufacturing. The following significant inflow corresponds to the steel production, which is used in the construction phase. The inflows for transportation are in smaller magnitude. The energy consumption for mineral extraction remains practically imperceptible, as the demolition phase.



Figure 5. Inflows inventory of hollow block of concrete.



Figure 6. Inflows inventory of brick of cement.

In the case of the inflows inventory of the traditional burned clay brick it emphasizes the energy contribution by the combustion of Biomass. The following significant inflow, as well the hollow block of concrete and brick of cement, corresponds to the cement and steel production, which is used in the construction phase. The inflows for transportation are in smaller magnitude. The energy consumption for mineral extraction remains practically imperceptible, as the demolition phase (Fig. 7).



Figure 7. Inflows inventory of brick of burned clay:

OUTFLOWS INVENTORY

The outflows inventory is based on the method IPCC 2001 GWP 100a V1.03. It is important to emphasize that the results presented in this paper can not be considered as definitive, because the assessment of the phase of house occupancy are still in progress. Also, the outflows regarding the burning of biomass are preliminary. The reported outflows are expressed in kg of CO2 equivalent by m2.

The CO2 emission by m2 of wall of hollow block of concrete reaches a CO2 emission of 17.3 Kg. Of them, 9.16 Kg (53%) correspond to processes where the cement is required. The second significant category corresponds to processes related with the use of reinforcement steel. In this case the outflow adds 6.12 Kg (35.4%). The rest of the involved processes generate an equivalent emission to 11.6% (Fig. 8).



Figure 8. CO2 outflows inventory for m2 of wall of concrete hollow block.

In turn, the CO2 emission by m2 of wall of solid brick of cement reaches 15.8 Kg. Again, the most significant processes have to do with the use of cement. In this case, that processes contribute with 9.35 Kg (59.3%). Also the second processes group most relevant is the related to the employ of the reinforcement steel. In this case they add an emission of 2.9 Kg (18.3%). The jal extraction process (including transport) generates 2.21 Kg (14%). The rest of the involved processes generate an equivalent emission to 22.4 % (Fig, 9).



Figure 9. CO2 outflows inventory for m2 of wall of cement solid brick..

Finally, the CO2 emission by m2 of wall of traditional burned clay brick reaches 38.3 kg. Contrary to the aforementioned systems, the process that generates the biggest outflow is the combustion of biomass during the burning of pieces. During this process the emissions reach 21 Kg (54.8%). In this case, the emission related to the use of cement is 15 kg (39.2%). The rest of the involved processes represent 6%, including the corresponding to the reinforcement steel which hardly represents 1.8% (Fig. 10).



Figure 10. CO2 outflows inventory for m2 of wall of traditional burned clay brick.

DISCUSSION

Independently to the values of CO2emission due to the combustion of biomass in the traditional brick manufacturing, one may ask if wood and waste of coconut employ for combustion generate a balance for zero emission. This query is based on the proposal the energy coming from the wooden combustion does not contribute to Global Warming, because when it burns it liberates the same quantity of dioxide of carbon that naturally was captured in the forest. In consequence, it is not a "new" CO_2 generated by an anthropogenic chemical reaction, but of a volume that was already in the nature. This way the carbon is recycled continuously, thus additional contributions of CO2 would not enter in the atmosphere neither to the carbon drain.

This is true regarding the combustion of coconut waste, because it is a by-product that does not imply the pruning of the palm trees. So, when the coconut burns, the palm tree remains capturing carbon from atmosphere. However, the hypothesis is questioned for the rest of wood mixture, which is utilized for the same purpose, because of the absence of sustainable practices that guarantee the controlled forest renovation.

Other subject that has to do is the length of time between the moments of capturing and emission. If the period between both moments is very short, the amount of CO2 in the atmosphere would not vary a lot and therefore, the result of wood combustion could be considered in zero balance. But if the period is prolonged too much, the accumulated amount of CO2 increases. Therefore the doubt arises if it is valid to continue considering a zero emission balance, still assuming that the forest production is sustainable.

According to data of the IPCC [10], the concentration of CO2 shows an exorbitant increment during the last years whose growing pattern spreads to an infinite slope. This indicates that the conditions of the

atmosphere at the beginning of the useful life of a tree and those at the moment of their combustion can be radically different because of this vertiginous increase of CO2. This way, the zero balance supposition loses its validity. In consequence, it could be considered that the biomass burning provides CO2 contributing to the impact of Global Warming, at least partially.

CONCLUSIONS

In figure 11, it is showed the comparison between the CO2 emissions by each wall system, considering the contribution of burned biomass. As the emission by the wall of traditional brick is the biggest, it is taken as reference; therefore it represents the 100% value. The wall of solid brick of cement registers an emission of 39% with regard to the brick, while the wall of hollow block of concrete registers only 37%. The difference is remarkable between both last wall systems and the reference system. The high volume of emissions relative to the biomass combustion is the responsible for this.



Figure 11. Comparative of CO_2 emissions by the three wall systems during the extraction, transportation, manufacturing, construction and demolition stage, considering the biomass combustion.

If the emission relative to the biomass burning is considered non-contributor to Global Warming, the corresponding CO2 volume would be eliminated. In that case, the CO2 emission by the wall system of traditional brick of burned clay would decrease to 10.8 Kg. This volume is now lower than the other two systems. Now the hollow block is the reference, represent the 100% of the value (17.3 Kg). Accordingly, the wall system of solid brick of cement emits 90% of CO₂ regarding the reference system (15.8 Kg), and the wall system of traditional brick emits 62.5% (10.8 Kg) (Fig. 12).



Figure 12. Comparative of CO_2 emissions by the three wall systems during the extraction, transportation, manufacturing, construction and demolition phases, without considering the biomass combustion.

Now, the construction phase represents the major impact for global warming in the cycle life of traditional brick, mainly because of the high consumption of cement and steel. However, the solid brick needs cement in the manufacturing phase and the hollow block of concrete needs even more of it, plus the double of steel in the construction phase than the others two wall materials. So the quantities of clinker and steel that the hollow block of concrete in the manufacturing and construction phases needs, makes that this building material for walls reaches higher levels of CO2 emissions.

Finally, and assuming that this is a preliminary conclusion, because the analysis of the occupancy phase is needed, it can be suggested that the traditional brick could represent the best environmental option for building walls in the economical housing in Mexico, just if the biomass used for the burning of bricks comes from sustainable sources.

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