CONGRESO
DE INGENIERÍA, CIENCIA
Y GESTIÓN AMBIENTAL
AMICA

5th International Conference of Greening of Industry Network

28, 29 y 30 de octubre de 2019
Instituto de Ingeniería de la UNAM
Ciudad de México

AIDIS · AMICA · Greening of Industry Network · Instituto de Ingeniería UNAM · University of Twente · Walmart México y Centroamérica · Red Mexicana de Análisis de Ciclo de Vida A. C.

MEMORIAS DE CONGRESO NACIONAL AMICA 2019

ISSN
04-2015-050708040300-203

ID 545 LIFE CYCLE ASSESSMENT OF TINY HOUSES IN THE NETHERLANDS

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Abstract

The main objective of this paper is to examine the impact on the global warming of construction and insulation materials which are used for a tiny house. This study consists of a life cycle assessment of three tiny houses: one built with only new materials (Case A), one built with only reclaimed materials (Case B) and one tiny house built with new and reclaimed materials (Case C). The cradle-to-gate phase enclose the raw material extraction, manufacture construction and insulation materials, transport of the raw materials to the manufacture, transport from the shop to the building site, transport from the building site to the living site and the electricity use for the used tools. The life cycle assessment was conducted in GaBi Education Software in combination with the ecoinvent Database and primary data from the interviews. The functional unit is formulated as kg CO_2 per square meter of tiny house for a lifespan of 50 years. Sheep wool has the highest impact on the global warming potential per square meter. And the result shows that the transport has a low environmental impact in comparison with manufacturing of the materials. This paper considered sheep wool as main product without taking allocation into account. Buying materials that are found locally is more environment friendly.

***Keywords**: Cradle-to-gate, Insulation materials, Construction materials, Tiny House Movement, CO2-emission*

Introduction

The building sector is the largest energy consumer and considerable constribution to environmental impacts (Scheuer et al., 2003) that is responsible for 40% energy consumption and 36% of CO2 emission in the European Union (European commission, 2018). The Dutch building sector is responsible for 40% of the energy consumption, 35% of the CO_2-emission and 50% of all raw material use (Nelissen et al., 2018). The government of the Netherlands is aware of their contribution to the CO2-emission and introduced a new legislation which came into act in January 2018: the environmental impact of the materials, MPG (in Dutch: Mileubelasting van materialen). The MPG is based on the life cycle costs of the building and has a maximum value of 1 per square meter (Veen et al., 2017). The MPG is only required for new buildings with a floor area of more than 100 m^2 (Veen et al., 2017). In 2016, the Netherlands 44% of the homes are smaller than 100 m^2 (BZK, 2016). This means the MPG would have been applicable to 56% of all the houses in the Netherlands.

Since 2015, the average living area of a house in the Netherlands is 114m^2, this is a decrease from 2005-2015 and equal to the 90s (CBS, 2018). The fastest growth of number of houses is for living areas below 75 m^2 in the last four years (BZK, 2016). Housing corporations are developing smaller houses over the years (BZK, 2018). In 2017, 10% less residences with an average living area of 100-150 m^2 were developed in comparison with 2014 (Luijkx, 2017). The decrease in average living area could be declared by housing development that is more targeted to limited budget and the life phases (Luijkx, 2017; BZK, 2018). The decrease of average living area is also related to the change of household size and composition: more single parents, more independent seniors (Lijzenga & Boertien, 2016) and the decrease of household size (Hoorn, 2016). Since 2009, the amount of people living in small houses is increasing till 40m^2 and between 40m2 and 60m2 respectively from 1.5% to 4.0% and 2.5% to 5.0% (Dopper & Geuting, 2017).

Definition of a Tiny House

A selection of tiny houses are off-grid an may be self-supporting. The last fact is important because of the goals of being CO_2 neutral in 2050 for all houses and for 2020 for new buildings in the Netherlands (European Commission, 2018). Unfortunately, there is a lack of academic papers about tiny houses and a consistent definition of a tiny house. The definition which will be used in this paper is as follows: *"A tiny house is a structure that provides everything you need to live with the focus on a smaller ecological footprint, being mobile, off-grid and a maximum ground surface of 30 m^2 and a maximum weight of 3500 kg including the trailer*." The area of 30 m^2 and the weight of the tiny house is established due to the maximum dimensions and weight of a trailer in the Netherlands. The maximum width is 2.55m, the maximum length is 12m and the maximum weight of trailer behind a car is 3500 kg. (ANWB, 2018). Nevertheless, living in a smaller house needs less construction materials and results in a decrease in carbon footprint (Carlin, 2014). The main aim of this study is to evaluate the envrironmental impacts of construction materials used in tiny house in life cycle perspective.

Methodology

The application of the global life cycle based methodologies, Life Cycle Assessment (LCA) is adopted to measure the environmental impact of construction materials in tiny house. This study focused on three types of tiny houses for this analysis.

Case A: Tiny house built with only new materials
Case B: Tiny house built with only reclaimed materials
Case C: Tiny house built with new and reclaimed materials

Life Cycle Assessment (LCA)

There are four phases in conducting LCA, which are follows:

Goal and Scope Definition

The main goal of this study is to evaluate the environmental impact of construction materials used in three tiny houses. The system boundary of this study include the manufacturing, transportation to the constrcution, i.e. cradle-to-gate as shown in Figura 1. The lifespan of the tiny houses is set to 50 years because this is average lifespan aspected in three tiny houses. In this paper the environmental impact of the floor, walls and roof will be studied and therefore the functional unit of 1 m^2 floor/wall/roof will be used as indicator for the global warming potential.

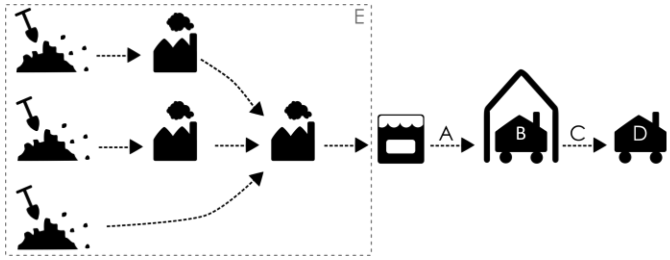

Figure 1: System boundary of the study

Lifecycle Inventory

Both primary and secondary data were used in this study. Primary data on building material type, transportation means and distance were collected. The ecoinvent database v.3 (Weidema et al. 2013) on manufacturing process of material used and their associate emission were used.

Life Cycle Impact assessment and interpretation

The lifecycle impact assessment (LCIA) is a translation of the output of the LCI. CML2001 method was chosen for the impact assessment of the three tiny houses. In this analysis only the global warming potential (kg CO_2-eq) is considered. CO_2-emission is chosen to compare the three case studies because this is one of the main pillars to adapt the climate change.

Results and Discussion

In all cases, the contribution of transport and electricity is relatively low in comparison to the other categories. Figure shows the CO_2-emission per square meter produced by the production and transport of the construction and insulation materials except for the electricity use of the tools to build the tiny house.

The roof and floor of Case A and Case B have the same area, respectively 16.83 m^2 and 16.70 m^2. In Case C, the roof has a larger area than the floor, respectively 28.08 m^2 and 24.54 m^2. Case A has the highest values of all the three cases for the production and the transport per functional unit. Based on these results, the tiny house of Case A has the most negative impact on the climate change in their production phase for the total house and per functional unit. Despite the assumption to neglect the change in CO_2-emission for the reclaimed materials of Case B and C and calculate with the reclaimed materials as they were new, Case A still has the most negative impact on the global warming. When materials are applied multiple times within or among the cases, the same source of literature or database is used.

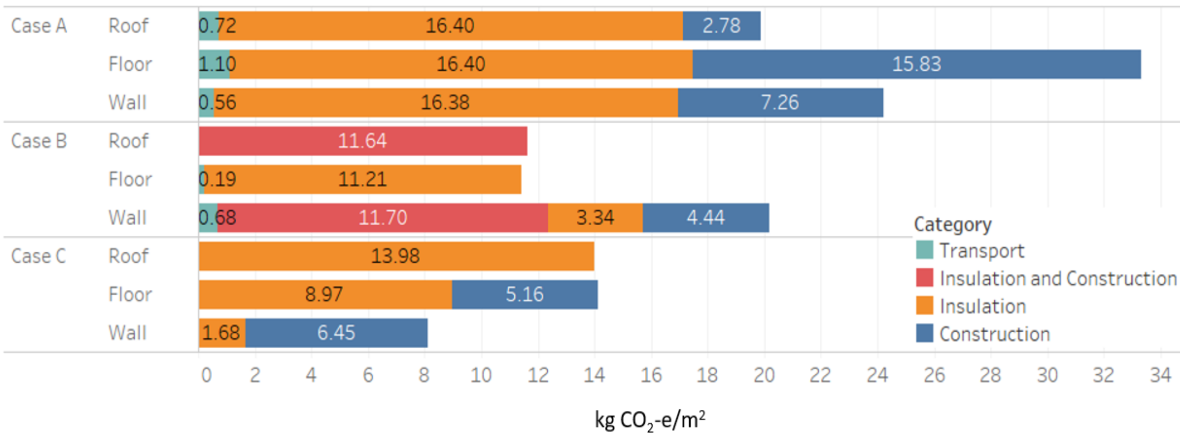

Figure 2: Carbon Dioxide of the Construction and Insulation materials used in the cases per square meter

The CO_2-emission of the Sheep Wool has, compared to other insulation materials, the most negative impact on the global warming per Case and per square meter for the wall and floor. Figure shows that the CO2-emission per square meter of Case C's roof is lower than the CO2-emission per square meter of Case A's roof. The area of the walls are almost the same for each Case (Case A 73.20 m^2, Case B 70.09 m^2, Case C 71.19 m^2) and deviate from the area of their floor and roof. The walls have the largest impact on the global warming of the whole tiny house of all the three cases and this is due to the volume of the walls.
The tiny house of Case B is built on site and the tiny house of Case C is built 5 km of the site. Compared those results to the CO2-emission of the transport of Case A, the emission of transport of Case A is 27% higher to Case B and 96% higher than Case C.

Conclusions

The life cycle analysis is done for three cases of tiny houses. The result shows that the tiny house built with only new material has the highest impact on the global warming. Despite of the fact that the materials of the other two cases were also considered as new material. The tiny house with only new materials has a higher impact on the global warming due to the use of sheep wool. Transportation has an impact as well, but the impact is lower than the impact of the production of the material itself. An important side note is that now the materials are all bought in The Netherlands. Importing materials from other countries will have a higher impact on the CO_2- emission and this is neglected in this study. Building with local products will result in a lower CO_2-emission and is therefore more environmentally friendly. The beams of Case B have had a trip of over 260 km which results in an impact of 30 kg CO_2-e. In combination with the fact that all the materials are assumed as new materials in this analysis, there can be concluded that long distances have a negative impact on the environmental friendly chosen materials.
Sheep Wool can be seen as a natural product since it can be seen as a waste product of the sheep meet production. But nowadays Sheep Wool is not a waste product anymore. Therefore, in the decision making

phase about materials coming from animals, you always have to ask yourself: "Are the materials actually a byproduct in the manufacturing process or are they main products nowadays"?

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