THE EFFECTS OF LIFE SPAN ON ENERGY CONSUMPTION AND CO_2 EMISSIONS OF CONTAINER HOUSES

Adem ATMACA
Department of Energy Systems Engineering, Gaziantep University, aatmaca@gantep.edu.tr

ABSTRACT: Life span is an important variable in Life Cycle Assessment of buildings. The aim of this study is to make the Life Cycle Assessment (LCA) analysis of containers and to investigate the relationship between life span and consumed energy with CO_2 emission values. The proposed model in the study focused on the construction phase of the containers to estimate total energy use and CO_2 emissions for different life span years. Life span years are chosen between 5-40 years interval. Energy efficiency and emission parameters are defined for the construction per square meter. It is found that energy and emission values are decreasing with the increase of life span years in container type houses.

Keywords: Life Cycle Assessment, Life span, Energy and CO_2 consumption, Containers

INTRODUCTION

Turkey is in the top rankings in the world with regard to people affected in natural and man-made disasters. Recovery works undertaken to eliminate physical, economic, social and environmental losses caused by disasters constitute an important part of the disaster management process. AFAD has prepared a performance indicator for the improvement of recovery capacity between 2013 and 2017 years in Turkey (Table 1) (AFAD, 2012).

Table 1 Performance indicator

Indicator	2013	2014	2015	2016	2017
Capacity of established container cities (person - cumulative)	50,555	50,555	50,555	50,555	50,555
Capacity of stocked containers (person - cumulative)	19,225	32,870	32,870	32,870	32,870
Number of personnel trained on recovery processes increased yearly by	58%	58%	58%	58%	58%
Repayment ratio for disaster loans extended to	40%	45%	50%	55%	60%

eligible families					
Yearly melting rate of increasing disaster housing stock	40%	40%	40%	40%	40%
Improving the damage assessment process	20%	20%	20%	20%	20%
Realization ratio according to number of total disaster houses in the annual programme (17,535 houses in the programme at start of 2013)	40%	45%	50%	55%	60%
Ratio of cases lost in lawsuits related to Law no.7269 finalized within the year decreased by (based on 2012 figures)	5%	10%	15%	20%	25%

Table 2 shows that there is a continuing need for disaster housing stocks. The use of energy for the container houses have been increasing and can be expected to increase in the future. Therefore, container housing is an alternative area for reducing energy requirements and greenhouse gas emissions.

LCA methods have been used for environmental evaluation in many industries for a long time. The methods have been increasingly used by researchers to assist with decision-making for environment-related strategies and to reduce buildings' life cycle environmental impacts (Buyle et al. 2013).

The studies about building LCA methods mostly started after Adalberth (1997). He analysed the life cycle energy use of the construction, use and end-of-life phases of three dwellings in Sweden. It was concluded that, operating energy has a major share (80–90%), followed by embodied energy (10–20%), whereas demolition and other process energy have negligible or little share in LCEA.

Fay et al. (2000) examined the primary energy use of a detached house in Melbourne, Australia. They took advantage of alternative designs using additional insulation and found that the addition of higher levels of insulation in Australia paid back its initial EE in life-cycle energy terms in around 12 years. LCEA over lifespans of 0, 25, 50, 75 and 100 years were carried out for the base case and then with added insulation. Total energy consumption of the building is calculated to be 76 GJ/m^2 in 50 years of life span. The additional insulation decreased the total energy of the house by 3.4 GJ/m^2 of floor area.

Bastos et al. (2014) showed the linkage between building design, energy use and GHG emissions. The linkage is dependent on and sensitive to climate and sociodemographic characteristics that are geographically and culturally variable. It was also shown that larger buildings have lower life cycle energy requirements and GHG emissions on a square meter basis and reverse pattern on a per person basis.

Atmaca (2016) investigated the total energy use and CO_2 emissions over 15 and 25 year lifespans for container and prefabricated houses respectively. It was concluded that operation phase energy has a major share in both LCEA and LCCO2 on a per meter square basis.

There are also some research projects which have underlined the importance of post-disaster temporary and permanent housing in order to improve the outcomes of reuse and recycle housing projects. Arslan (2007) showed the minimum energy usage for construction should be kept for accelerating the reconstruction of the region and forming a sustainable community, which maintains itself socially, environmentally and economically over time.

There are some studies about the final energy consumption of residential buildings in Turkey. However, the studies about the life cycle energy consumption and environmental effects of container houses are limited in number and scope in literature (Atmaca, 2016). Meanwhile, there is currently very few studies about the final energy consumption of residential buildings in Turkey (Atmaca and Atmaca 2015).

The aim of this study is to make the Life Cycle Assessment analysis of containers and to investigate the relationship between life span and consumed energy with CO_2 emission values.

METHODS

Construction, operation and demolition of buildings consumes large amount of energy and produces lots of CO_2 emissions. Predictions over energy consumption during operation phase of the building life cycles and assumptions about the end of the life span of the houses are highly uncertain. Therefore, the construction phase is used for the energy and CO_2 emission analysis with different life span years in this study.

A typical container house analysed to represent the majority of the houses constructed after an unexpected disaster or natural hazard. Technical specifications of the CH are presented in Table 2. The typical CH has a gross area of 21 m^2 with one story, two rooms and a WC inside it (Figure 1).

Construction phase analysis

Construction phase analysis has two main analysis. It includes embodied energy (EE) and CO_2 emissions analysis. EE is defined as the total primary energy (MJ) required by the building materials during manufacturing phase (Hammond &

Jones 2008). Energy content of all the materials used in the building and technical installations, and energy incurred at the time of new construction and renovation of the building.

In this study, Inventory of Carbon and Energy (ICE) Version 2.0 (Hammond& Jones 2011) is used for the calculation of primary energy requirements and greenhouse gas emissions. The ICE includes the embodied energy, carbon and GHG (measured in grams of CO_2 equivalent, g CO_2-eq) for a large number of materials. Some important criteria were applied for the selection of energy and carbon values for the individual materials incorporated into the ICE database. This ensures the consistency of data within the inventory. One of the applied criteria is about the compliance of data with approved methodologies and standards (ISO 14040/ 44).

$LCCO_2A$ considers all the carbon equivalent emission output from a building over different phases of its life cycle. The "Embodied GHG" (EGHG) emissions comprise the GHG emissions from the extraction of raw materials to the building site. In the ICE, the term "embodied carbon" is used for both carbon and GHG emissions. Table 3 (Atmaca, 2016) shows the embodied energy and CO_2 intensities of some building materials.

Table 2.Technical specifications of CH

Specifications	CH
Foundation	20 cm concrete with 6x150x150 mm mesh reinforcement
Structural System	Steel profiles and wall panels
Exterior And Interior Walls	35 mm thickness sandwich plasterboard panels
Floors	16 mm thickness precast concrete panels and 3 mm PVC coatings
Roof Covering	Galvanized roller steel sheets, OSB, 80 mm thickness glass-wool
Doors	900*2100 mm steel framed for exterior door 800*2100 mm PVC framed for interior doors
Windows	100*110 mm PVC framed with single 4 mm single glazing.
Exterior surface coatings	Sandwich plasterboard panels

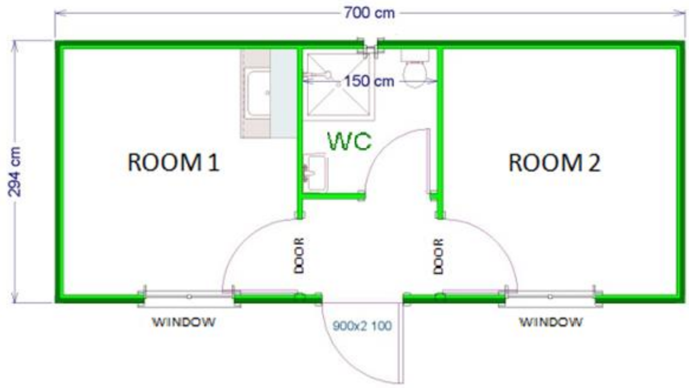

Figure 1. Floor Plan of CH (Atmaca, 2016).

Table 3 Embodied energy and CO_2 intensity ranges for different types of building materials

Type of the building materials	Embodied energy intensity (MJ/kg)*	CO_2 intensity (kg CO_2-eq /kg)*
Concrete	0.5–1.6	0.05–5.15
Galvanized steel	35.8–39	2.82
Polymer vinly siding	11.8–120	2.29
Precast concrete element	2	0.22
Wood	9.1-14.2	0.3–1.12
Thermal and acoustic insulation	3–45	0.15–1.86
Plastic, rubber and polymer	67.5–116	2.2–16.2
Purified fly ash (PFA)	<0.1	0.01
Stainless steel	51.5–56.7	6.15
Plaster, render and screed	1.4–1.8	0.12–0.16
Reinforcing bar and structural steel	9.9–35	1.72–2.82

* Intensity values were extracted from ICE.

The following assumptions were made during the LCA energy and CO_2 emission calculations:

Standard building construction methods and materials were assumed to be the same over the building life cycles.

The building design and materials were obtained mainly from original project documents.

Energy mix and intensities were considered constant over the building life cycles.

The service lives for the structural components were assumed to be equal to the service life of the house.

It was assumed that all final product manufacturing took place around the city and an average occupancy of 4 persons per container housing unit.

Finally, some environmental qualities such as indoor air quality are not included and environmental impacts were assumed to be constant over time in the analysis.
Life Span Prediction

Building life span is a variable and it is too difficult to predict. Temporary housing where optimum conditions are provided in which people can carry on their household daily activities until they move in the permanent housings. The permanent housings is a complex and time consuming process according to the size of the disaster. Therefore the life cycle of the container housing types were chosen between 5-40 years (Table 4).

Table 4 Energy and CO_2 values with different Life Spans

YEARS	ENERGY (GJ/(m^2-year))	CO_2 VALUES(kg CO^2/(m^2-year))
5	0.79	61.16
10	0.39	30.58
15	0.26	20.39
20	0.20	15.29
25	0.16	12.23
30	0.13	10.19
35	0.11	8.74
40	0.10	7.65

It can be clearly seen that the energy and emission values are decreasing with the increase of life span years in container type houses. If we show the results in a different graphical representation we can see a drastic change between 5-10 years (Figures 2).

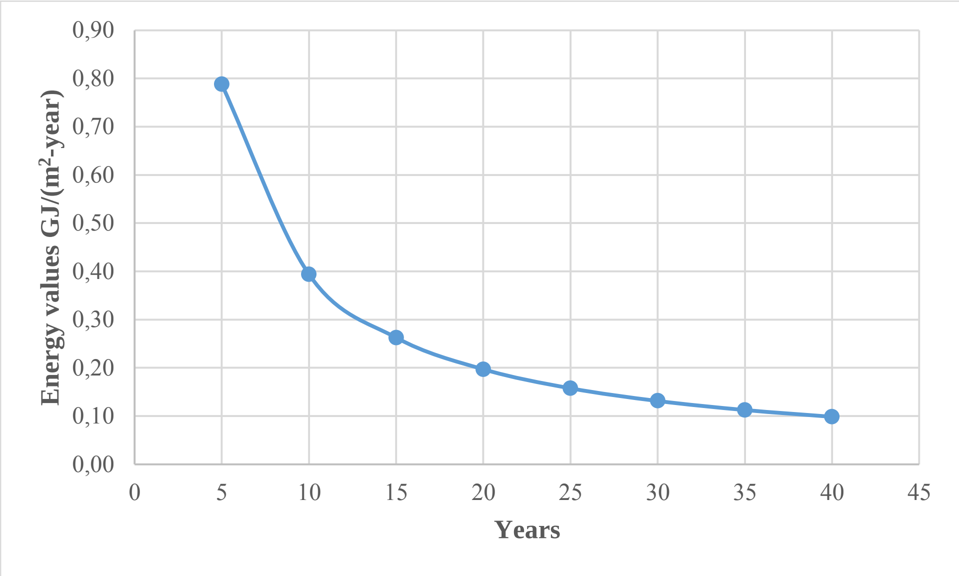

Figure 2 Energy values with different Life Spans

RESULTS AND FINDINGS

Life cycle analysis of container housings involves many assumptions, simplifications and uncertainties. The materials used in construction, life span, location and climatic conditions and building data of the houses will influence 'Cumulative Energy Demand' (CED) that is used to determine and compare the energy intensity of the houses and variations in any of these factors has the potential to vary the findings of this study.

EE must be considered over the whole life of the container housings. EE values can be reduced with a careful consideration on the design of systems and selection of appropriate building material. The results of the study show that the energy and CO_2 emission values are steadily decreasing. The rapid decrease is between 5-10 years (%50).

CONCLUSION

Life Cycle Energy analysis and Life Cycle CO_2 analysis of container houses constructed in disaster areas in Turkey are presented for different life span years. The construction phase was used for the analyses. The energy and CO_2 emission values are decreasing %50 after 5-10 years therefore, the time to make permanent housing should be chosen in this time interval. The results of the study show that for a container house to perform efficiently in terms of energy and CO_2 emissions, material selection and application of insulation and recycling facilities are important considerations. Besides that the use of area and occupancy-based functional units can give us quite interesting and important information about the life cycle analyses of container houses.

RECOMMENDATIONS

Further studies are needed to investigate more about the use of more comprehensive LCA methods. Hybrid analysis is generally considered the preferred approach for EE analysis due to its systemic completeness and use of reliable data. I–O-based hybrid analysis combines process data and I–O data to process-based hybrid analysis. The specific and wide range of data library for temporary housings may give a change to accurate prediction of the Life Span of Container houses.

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