A Comparative Life Cycle Assessment of Single-Family House and Multi-Storey Apartment Building in Turkey

S. Gulcimen[1], N. Uzal[1], T. Varışlı[1], M.G. Khidrah[1]

[1]Department of Civil Engineering, Abdullah Gul University, Kayseri, 38080, Turkey

Keywords: Life Cycle Assessment, Environmental Impacts, Global Warming Potential, Single-Family House, Multi-storey Building

Presenting author email: sedat.gulcimen@agu.edu.tr

Abstract

Purpose

In recent years, there has been significant transition from multi-stored buildings to single-family houses especially due to COVID-19 pandemic. Thus, people prefer to live in single-family houses or detached houses where they have more free space in outside of the house. The importance of sustainability in the building sector increases as the damage caused by the building sector to human health and the environment increases day by day in parallel with the growing sector. As environmental pollution increases in the world, environmental awareness has started to develop. Parallel to environmental awareness, the main goal of all sectors has been to enable people to live healthily and to improve environmental quality. Within the scope of this target, sectors have started to control the environmental performance of their products with some tools. The aim of this study is to quantify and compare the environmental performance of a single-family house and multi-storey apartment building in Turkey throughout their life cycle with cradle-to-grave approach.

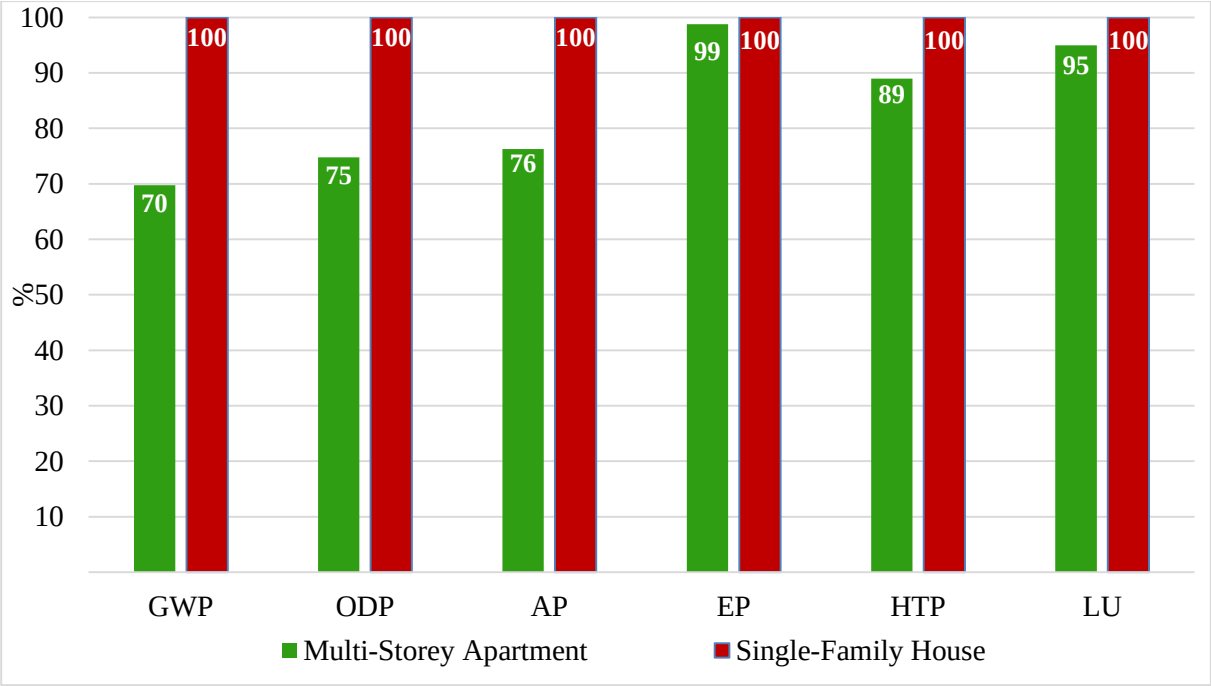
Method

Life Cycle Assessment (LCA) method based on ISO 14040 and 14044 was applied to assess the environmental impacts of the single-family house and multi-storey apartment building in Turkey for this study. The functional unit was chosen as $1m^2$ of floor area of a house over their lifespan (50 years). With cradle-to-grave approach of the LCA, the system boundaries for the environmental assessment covers the pre-operation (raw material extraction, transportation of the materials, construction), operation (use, maintenance and replacement) and post-operation (end-of-life) stages. The inventory data were gathered from a construction company in Kayseri.

SimaPro 8.4 PhD version software was used to calculate the environmental impacts of the single-family house and multi-storey apartment building within the system boundary. The IMPACT2002+ method and Cumulative Energy Demand (v1.09) was selected as impact assessment methods for this study.

Results

The results of this LCA study revealed that majority of the environmental impacts occurs at operation phase for both single-family house and multi-storey apartment. For single-family house, operation stage has highest impact with 78.5% share of the global warming potential (GWP), which is one of the selected environmental impact categories. Similarly, operation stage is responsible for 77.4% of the GWP of the multi-storey apartment. According to comparison results, GWP of the multi-storey apartment per m^2 of floor area is 30,6% lower than single-family house. The electricity consumption during the operation stage is the major contributor to the total GWP of the both single-family house (90.4%) and multi-storey apartment (87%). The main reason of this is usage of electricity from fossil-based sources, which has high negative impact on environment. Thus, usage of renewable energy sources for electricity production can reduce the environmental load of the single-family houses. The switching the energy sources to alternative renewables such as solar, wind, biogas and biomass for electricity production is not only reduce the environmental load but also contributes the circular economy by reducing both use of raw material and waste generation. The comparison of the total environmental impact of the two case studies (single-family house and multi-storey apartment building) is illustrated in Fig. 1. The single-family house shows higher impact when compared with the multi-storey apartment for all impact categories (GWP, ODP, AP, EP, HTP, and LU) primarily because its total gross area is smaller than the multi-storey apartment. Taking this building as a reference (100%), a relative comparison of its impact categories and those of the other case study was analyzed (Fig. 1).



In addition, the results clearly show that steel (32-39%) and concrete (28-30%) made the largest contribution to the environmental impacts of the both single-family house and multi-storey apartment at pre-operation stage. The main reason of this is high energy consumption and usage of raw materials with high CO_2 emission such as cement and iron in production of concrete and steel. Thus, the building industry should prefer the construction materials with low greenhouse gas emissions in their life cycle to reduce their environmental impact.

Conclusions

As conclusion, environmental impacts of the operation phase have significant importance on the overall environmental performance of both single-family house and multi-storey apartment. The usage of alternative renewable energy sources for electricity and give preference to the sustainable construction materials can help to improve the environmental performance of the buildings. To pave the way to a sustainable future, the building industry must strive to use renewable energy sources and sustainable construction materials in order to reduce their environmental impacts with a sustainable approach.