



# Environmental impact of building-related and user-related energy consumption in dwellings

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## ABSTRACT

Energy consumption in dwellings contributes significantly to their total negative environmental impact. This paper quantitatively assesses the environmental impact of building-related and user-related gas and electricity consumption in a Dutch apartment dwelling using life cycle assessment (LCA) methodology. Several scenarios for gas and electricity consumption are compared to assess what effect changes in building characteristics and user behaviour have on the environmental impacts of energy consumption. This study shows that gas consumption significantly contributes to four environmental impact categories, which can be most effectively countered by reducing the heat demand of the dwelling. A 23% reduction in gas consumption leads to up to 13% less overall environmental impacts. Particularly in buildings with low heat demand, electricity consumption dominates all environmental impact categories. These can most effectively be reduced by changing the electricity demand of the user: 47% less electricity consumption leads to a 9–45% reduction in the total environmental impact. However, since electricity consumption continues to rise, the environmental effects of electricity use may be better reduced by changing the environmental impact of the electricity supply. Theoretically, when electricity consumption remains the same, over 90% less environmental impact could be reached by using 100% wind power to generate electricity.

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## 1. Introduction

The largest part of energy consumption during the total service life of buildings takes place in the operational phase. In a review article that analysed 60 life cycle energy case studies of buildings, Sartori and Hestnes [1] found that in low energy [2] and conventional dwellings [3] a minimum of 54% and 62% of energy consumption respectively occurs during the operational phase. Adalberth [4] showed that as much as 85% of the total energy consumption during construction, use and demolition of a single unit dwelling with a service life of 50 years occurs in the operational phase. Additionally, a European study of the energy use of all households combined found that it constituted approximately 25% of the total annual energy use of the EU-25 countries [5].

The studies mentioned above focus on the amount of embodied and operational energy in buildings as an indicator of environmental performance. However, different types of energy will affect the environment differently. For example, gas combustion for heat will lead to the depletion of fossil fuels and the emission of CO<sub>2</sub>,

while nuclear electrical power will result in depletion of uranium and creation of radioactive waste. Therefore, this research uses LCA methodology to assess and compare different types of environmental impact related to energy consumption in dwellings. In prior research, the authors have shown that the negative environmental impact related to energy consumption for heating, ventilation and hot tap water are larger than those related to the maintenance and replacement of façade components and climate systems in the operational phase of dwellings [6,7]. The present study assesses the total energy consumption of households, which includes energy for cooking, lighting, household appliances such as washing machines and kitchen appliances, and other appliances such as televisions and computers.

The Trias Energetica theory developed by Duijvestein states that in order to decrease environmental damage as a result of energy consumption the latter should first be reduced, followed by making more use of sustainable energy resources and, finally, using less sustainable energy resources more efficiently [8,9]. However, when measures are taken to make the building more energy efficient (such as reducing consumption), more energy for other purposes may be consumed by the building user. This is called the rebound-effect [10]. Furthermore, energy demand cannot be reduced indefinitely. Therefore, to reduce the environmental impact of

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