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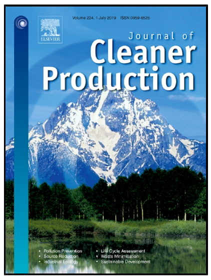

Statistical life cycle assessment of residential buildings in a temperate climate of northern part of Europe

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PII:	S0959-6526(19)31471-4
DOI:	10.1016/j.jclepro.2019.04.370
Reference:	JCLP 16726
To appear in:	*Journal of Cleaner Production*
Received Date:	11 October 2018
Accepted Date:	28 April 2019

Please cite this article as: Modeste Kameni Nematchoua, Jacques Teller, Sigrid Reiter, Statistical life cycle assessment of residential buildings in a temperate climate of northern part of Europe, *Journal of Cleaner Production* (2019), doi: 10.1016/j.jclepro.2019.04.370

Statistical life cycle assessment of residential buildings in a temperate climate of northern part of Europe.

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Abstract

Nowadays, with the new technology, the explosion of new products and the implementation of the new construction rules, it is important to evaluate the effect of the strong human pressure on nature. Thus, the analysis of the life cycle of a product (i.e., building) makes it possible to evaluate its main environmental impacts (energy demand, greenhouse gas emissions, product waste, water consumption, etc.) from raw materials manufacturing to its end of life (demolition).The purpose of this research is to carryout a meticulous statistical analysis aimed to better understand and to discern better the impact of sustainable buildings and old buildings on the environment. In addition, this research identifies the main elements that affect the environment during the construction, operation, renovation, and demolition of buildings.59 residences were analyzed (29 durable residences and 30 old residences), distributed in two districts of the Liege city. Several software tools were used(IBM SPSS statistical, ALCYONE, COMFIE-PLEIADES, and nova-EQUER) to statistically evaluate the 12 environmental impacts considered in this study .The results showed that the impacts of sustainable buildings and old buildings on the environment are very significant. Despite that, it is difficult to identify a clear difference between the environmentalimpact from old and sustainable buildings .The total lifecycle greenhouse gas(LCGHG) and energy of the whole the residential buildings represents 17.225 ktCO_2-e and 362.8TJ, respectively, over 100 years. The building operation phase (or use phase) consume significant amount of life cycle energy (from 81.0 to 94.3%), but also, the largest contribution to the life cycle greenhouse gas (between 75.6% and 91.3%).

Keywords:life cycle assessment, Statistical, residential, cold climate.

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1. Introduction

Residential buildings, transportations sector, and industries play an important role in the destruction of the ozone layer. Nowadays, in European countries almost 40% of the total energy is consumed by buildings and they generate 34% of the CO_2 emissions(European Union, 2010). The pressure on the environment has been increased with the growth of the population. It is imperative and very urgent to mitigate the undesirable effects resulting from our modern vision and our very high ecological footprint to preserve our suffering environment. The implementation of eco-design techniques for buildings makes it possible to have sustainable buildings, but the impact of these different buildings during construction, operation or renovation considerably affects the environment(Wei et al.,2011).Residential building energy consumption is often dominated by some domestic complex factors(CAE, 2009). In Belgium(Wallonia region), the total consumption of the residential sector was 31.1 TWh PCI in 2012 and consisted mainly of oil (37%), natural gas (30%) and electricity (22%). However, the average total electricity consumption per dwelling was estimated at 4,453 kWh (all uses combined) (ICEDD, 2012). Renewable energies account for more than 10% of the energy consumption of the housing sector, while wood for heating ,accounts around 80% of the renewable energy consumed by the housing sector. In addition, in Belgium, the photovoltaic energy accounted for 5.3% of the sector's final electricity consumption(ICEDD, 2012) .

At the level of buildings and cities, several methods are established, allowing the easy study of the environmental impacts. However, these different methods vary according to the built environment studied(Lotteau et al.,2015).Life Cycle Assessment (LCA) is the most widely accepted method by scientists for the quantitative analysis of a product or building throughout their life cycle among several other methods(Buyle, et al., 2012). In a study of LCA, the choice of the functional unit is essential and conditions all the continuation of the study and the possibilities of comparison with other studies. At the scale of the building, this choice is complex. Indeed, the functional unit chosen is often the entire building or the net living area. However, if we choose the complete building, then it is impossible to compare our study with another building with another function(Cuéllar and Azapagic, 2012). Regarding regional specificities, the location of the different studies does not facilitate comparisons. Local climate, comfort requirements, national norms, resident behavior are parameters that differ from a study. However, choosing a functional unit per square meter or per person greatly improves the comparability of studies(Buyle et al., 2013).According to the work of (Greening et al.,2000), the behavior of the inhabitants is a particularly difficult factor to predict which influences the energy consumptions and thus the results of an LCA, whatever the quality of this one.

(Buyle et al.,2013) found in a study that the occupancy phase generated 90% of the environmental impacts of a building, mainly due to heating and the air conditioning. Several studies show the environmental benefits of reusing end-of-life materials that would outweigh the benefits of recycling(Thormark, 2000; Blengini and Carlos, 2009). Bôrjesson and Gustavsson(2000), showed that the use of a wood structure is preferable in the context of low-energy constructions. Cole and Kerman(1996) showed that this use of wood causes, among other things, much fewer gas emissions. The greenhouse effect on its complete life cycle. Erlandsson and Levin [14] showed that renovation is generally more eco-responsible, but that urban planning standards often do not allow for optimal measures. When it comes to interventions on the exterior envelope of the building, for an addition of insulation,for example, urbanism standards are very restrictive. However, the use of renovation is rising sharply in Belgium, with an increase in permits issued of 30% between 1996 and 2010(Buyle ,2013).Whether in renovation or new construction, architectural quality is of paramount importance (orientation, solar gains, compactness)(Cuéllar and Azapagic, 2012; Greening and al.,2000).Some studies show that a change in the energy mix for renewable energies significantly reduces emissions per person nationally, even without reducing consumption(Hennicke, 2004; Marrero,2010; Rossi et al.,2012) .

The choice of the heating system has a greater influence on the primary energy consumption than the efficiency of the envelope(Gerilla et al.,2007; Gervasioet al.,2014). Rossi et al.(2012) showed that the energy mix of the country in which the building is located strongly influences emissions. By comparing four scenarios, based on different types of residential buildings, Trigaux et al.(2014), show that the contribution of road infrastructure accounts for 1% to 6% of the total impacts. Other researches on LCA were showed on(Simonen,2014; Stephan,2013; Thormark,2000; Trigaux et al.,2017a; Trigaux et al.,2017b; Wolf et al.,2012; Salomon et al.,2005; Servaes et al.,2013; Service Public de Wallonie,2018; Setac,2003; Oliver et al.,2011).The main objective of this research is to carryouta meticulous statistical analysis aimed to better understand, and to discern better, the impacts of sustainable buildings and old buildings on the environment. In addition, this research identifies us with an accuracy of more than 95%, the main elements that affect the environment during the construction, operation, renovation, and demolition of buildings.

Several researches were already carried out at building scale in several world region, but, nevertheless, some aspects evoked in this study, were not yet taken count. Indeed, this research evaluates variations coming from the size and different types of residence, in order to extract from their built environment an overview of eutrophication, the intensity of greenhouse gas emissions, energy demand, a waste product, water consumption, health damage, etc.

This research is conducted in 59 buildings, grouped into two categories (new and old residences), different ages (below 10 years and over 100 years), different microclimate and different rational development of parks, these residences are distributed in two neighborhoods representative of " building stock ", from the entire Walloon region of Belgium. Up to now, no study in the literaturewas carried out a detailed and meticulous statistical analysis of the different impacts from built-up environments.

This search is constituted of several parts. Section 2 describes the methodology used in this study, while Section 3, shows, a detailed analysis of the results. This section begins with an analysis of the different impacts, coming from the different built-up environments, and ends with an in-depth statistical analysis of 10 parameters, such as greenhouse gas emissions, energy demand and etc. regrouped in Table4. A brief discussion is conducted to compare our results with those of other LCA researches in the literature.

2. Method

This study is divided into three main parts, i.e., (a) assessment of physical and environmental parameters in sustainable and old buildings; (b)Global comparison of different environmental impacts ;(c)Statistical analysis of environment impacts.

2.1.*Studied cities*

Belgium is a federal state comprising three regions: the Walloon Region (Wallonia), the Flemish Region (Flanders) and the Brussels Region (Brussels-Capital). Liege is a city in Belgium located in the north-east of the country, in Wallonia, a few kilometers from the Dutch and German borders. This city is dominated by a temperate climate. In this city, winters are harsh and relatively wet and summers are hot and sunny. Globally, the climate of Liege is particularly favorable for outdoor activities during the five months which include the end of spring, all the summer and the beginning of autumn. However, In summer, the temperature is close to zero, at the worst times of the day.

This study is concentrated on two categories of buildings(sustainable and old).

The twenty-nine studied sustainable buildings are locatedin the neighborhood called Sart-Tilman in Liege city. This regionis one of the privileged places the country where the concept of a sustainable environment is applied. The site is strongly served by public transport linking it to the center of Liege, this because of the proximity of the university. All these residences were constitutedof apartments, and semi-detached single family homes. In these study place, we count 40 small apartments, 45 larger homes, 11 single-family duplex homes and 6 complementary functions (businesses and shopping centers). Private parking spaces are planned near the buildings. The accommodations on the ground floor have a private garden. All these buildings are constructed there is less of ten years. Only, residential buildings were studied. The thirty old buildings are located in the city center of Liege. These buildings were built in the 19th century during the period of rapid urbanization. It is well representative of the urban blocks by its high density of buildings, the little free space in the center of the block but also by its predominantly terraced dwellings. Some characteristics of these residential buildings are showed on table1.

2.2. Building analysis

The new buildings were built respecting the nearly energy zero building(NZEB)concept.

More than 50% of the dwellings are semi-detached, and the construction site has a density of 40 dwellings/hectare. Outdoor spaces are landscaped with more than 30% "green" or "blue" surfaces and separate water management for rainwater and wastewater. Valves and water recovery tanks are also implemented. The building environmental impacts were calculated on the basis of the three functional units. The gross results corresponded to the functional unit "residential eco-district of 3.5ha comprising 1ha of roads, driveways and parking lots, 17800m² of green space, 6580 m² of floor space, 13160 m² of floor space, housing around 220 people, studied on a life of 80 years and located in Liege in Belgium. Table 2 gives some characteristics of materials.

Old buildings were constructed there is more of one decade. The total population was estimated around 100, living in 30 buildings, which occupied 44% of the totalarea. Some characteristics of these buildings are shown in table2.In the majority of case, there were theWindow beats single glazed aluminum with one glass and solar factor estimated at 0.59.some characteristics of the two studied environments are showed on table3.

2.3. Data choice

The environmental data we use come from the ECOINVENT database developed by different research institutes based in Switzerland. These data include, for each process and material, a life cycle inventory that contains all material and energy flows into and out of the system(Peuportier et al.,2006) : (i) resources consumed (water, energy, etc.); (ii) emissions in the different natural environments: air, water or soils (ammonia in water, metals in the soil, CO2 etc.); (iii) waste created (inert, toxic or radioactive).

We will use version 2.2 (2012) of the ECOINVENT database. The development of this database follows processes that have been certified several times as reliable and the contents of this database have been verified and validated by international experts. The ECOINVENT Centre is recognized as an international leader in environmental sustainability data and is recognized for the transparency of these methods(Ecoinvent,2017).

2.4. Environmental indicators

In this study, we assessed twelve (12) impacts of the life cycle :the greenhouse effect(via the Global Warming Potential, GWP) ; acidification(via the Potential of Acidification, PA); Cumulative Energy Demand; the water used; Waste produced; the depletion of abiotic resources (via the Abiotic Depletion Potential, ADP); eutrophication (via the Potential of Eutrophication , PE) ; the production of photochemical ozone(via the Ozone Depletion Potential, ODP); damage to biodiversity; Radioactive waste; Damage to health(via the Disability Adjusted Life Year, DALYs); Odors(via the Odor Threshold Value, OTV).

2.5. Simulation software

In this study, statistical analysis was carried out with IBM SPSS 24.0 statistical software, The significance level was set to P-value<0.05.The repeated-measures analysis of variance (ANOVA) was applied for collecting data, even those, that were not completely normally distributed.Three othersoftware such as ALCYONE , COMFIE-PLEIADES,and novaEQUER were coupled for analyzing life cycle assessment of buildings.
These recent years, these software programs were applied in some researches which have known many success(Salmon et al.,2011; Salomon et al., 2005; Colombert et al.,2011; Tsoka,2015; Kinnan et al.,2016; Jolliet et al.,2010) .

ALCYONE is a graphical input tool. This software describesthe geometry of a building, it represents its solar masks and allows to define the composition of the walls(Solomon et al.2005). In addition, COMFIE-PLEIADEStoolsallow perform the dynamic thermal simulation for buildings(Riera et Ray,2013). Finally, nova-EQUER is the environmental quality assessment tool. The requirements calculated in COMFIE are exported and additional inputs are provided to complete the LCA.

2.6. Dynamic Thermal Analysis

For carried out a dynamic simulation of all the building, the following hypothesis was applied:

(1) implementation of occupancy scenario: from 7.00 am, to 6:00 pm, the mean residence occupancyconcentration was estimated at 25%. However, the night, from 7:00 pm to6:00am, around 90%.

(2) implementation of heating scenario: The analysis of the meteorological data explained that in the dayzone , the heating set point temperature was fixed to 16 ° C, then, to 19 ° C during the day, while in the night zone, the temperature was about 18°C between 22:00 and 7/00, then, 16°C during the day. We assume the day area occupied during the day and unoccupied at night and conversely for the night area. We found a temperature of 18 °C sufficient for the rooms in case of sleep.

(3) implementation of lightinglevel: less than 100lux from 10pm to 5:00 am(hours of sleep), more of 300lux between 6:00 am to 10 pm.

(4) implementation of other scenarios: We assume the day area occupied during the day and unoccupied at night and conversely for the night area. We judge a temperature of 18 °C sufficient for the rooms in case of sleep. The dissipated power inside the building is mainly due to the use of electrical equipment generating heat. Their values are increased during the periods of the day during which occupants' activities requesting electrical appliances are assumed to be greater. The analysis of the data obtained shows that between 7:00 am and 10:00 am, and between 6:00pm and 9:00pm, they were around 5.7W / m².The data analysis allows us to set the occupancy of our apartments at 0.033 inhabitants / m². Which corresponds to one occupant per 30 m².

2.7. Implementation of LCA–novaequer

No hypothesis was made at random, everything was planned by taking references in the safestsources, and known, to optimize the veracity of this research. Some data were implemented, after several field surveys, interview of some building owners, and analysis of the results of some researches in the literature concerning this city(Ecoinvent, 2017; HUBERT et al.,2010).

Some data were taken from dynamic thermal simulation results as: (i) The metrics of all residences constituent andtheircharacteristics;(ii) The energy and water needs and consumptions resulting from the dynamic thermal simulation. Structural and insulating materials have an age equal to that of the old building, that is to say between 50 and 200 years. The suistainable residences have between 5 and 10 years . These lifetimes allowed to calculate the impacts of the renovation phase.

The transport distances of the materials that we have taken into account in the LCA are contextualized in the case of Belgium and are the following: 100 km between the production site and the construction site, and 50 km between the construction site and the discharge concerning the end of life. In addition, a surplus of materials used on site of 5% was considered. It corresponded to the average fall rate of the different construction products.

The energy data were evaluated under the Belgian energy mix in the software. It is 52% nuclear, 27% natural gas, 17% renewable and 4% coal (International Panel of Climate Change, IPCC 2016). The production system was a natural gas condensing boiler with a 92% of Lower heating value (PCI) efficiency. The water consumption was fixed at 100L/ person/ day.

Regarding the waste use, the policy of selective sorting of waste is also taken into account (Less of waste.wallonie.be). This sorting is considered equal to 90% for glass waste and 75% for paper and cardboard. Thus, this proportion of waste will be considered recycled and not landfilled. According to Belgian statistics, 40% of the 1500g of daily household waste per person is sent to incineration with a yield of 85%. The distances from the site to the garbage dump are 10km, 100km to the incinerator and 50km to the recycling site.

We also take into account in our study the mobility component. Thus, the environmental impact of the occupants' daily trips is calculated. We consider that 60% of occupants make a daily commute. For these occupants, an average distance of 20 km is indicated for commuting to work. They are carried out 5 days a week 47 weeks a year. The trips home-trade are them of 10 km return. They are done once a week, 47 weeks a year.

1. Results and Discussions

3.1. Global comparison of different environmental impacts

Figure 1.shows the different impacts in the two kinds of building according to four phases (construction, exploitation, renovation, and demolition).

The analysis of results proof that,the impacts are higher in the old buildings than sustainable.Indeed, on the lifetime of 100 years, the emission rate of greenhouse gas was estimated to be between 13.2%(222.28teqCO2), and 86.8%(1470.72 teqCO2), in the sustainable and old buildings, respectively. The energy demand was 12.2%(3050.26GJ), in the sustainable buildings, and 87.8%(21954,12GJ) in old. The average of allthe environmental impacts was evaluated at 1.89% and 98.32 %, in sustainable and old buildings. The acidification increased from 2.8%(renovation phase) to 22.3%(demolition phase), in sustainable buildings. On the other hand, the radioactive waste was evaluatedat99.0%(renovation phase), and 77.8%(demolition), in the old buildings. Globally, during the renovation and demolition phases, the average concentration of environmental impact was between 1.7% and 22.1%(new buildings), then, from 77.8% to 98.3%(old buildings). These results were largely predictable. It is quite normal that the majority of impacts are higher in the old buildings than sustainable. In fact, the transport system, building materials, equipment, low floor etc. have significant effects on the environment in the different types of buildings. The old buildings are the most impacting. The exploitation phase showed a significant effect on the environment. Indeed, among the different phases, the 87.1% of environmental impacts on the buildings came from "Use phase". Only 0.29% from the demolition phase. These findings confirmed the results found in 2011 by Salmon et al.[35].These results also confirm the study of Sharma et al[49], who found that the use phase represents over 50% of greenhouse gas emission, but also, between 80% and 85% of energy.Herfray et al.(2011) showed that in neighborhoods with low energy consumption, neglecting energy related to mobility, in terms of primary energy consumption, the construction phase is between 7% and 13.5%, the operational phase between 85% and 92%, and the deconstruction phase between 1% and 1.5%. These confirm our results because we see the predominance of the operational phase and the low contribution of the construction and deconstruction phases.

3.2. Life cycle energy demand and greenhouse gas emissions of the residence

The life cycle energy requirements and greenhouse gas emissions of the case study sustainable and old buildings are presented in this section.

Figure 2 and 3 show the life cycle greenhouse Gas emissions (LCGHG), and energy demand(LCE). The totalLCGHG and LCE of the whole Building represent 17.225 ktCO2-e and 362.8TJ, respectively, over 100 years. This energy demand is equivalent to nearly 1.5% of the annual energy demand for residential in Australia (DEWHA ,1986).The exploitation phase signifies the largest share of the life cycle energy (represents 94.3% of the total),but, also, the largest contribution to the LCGHG (91.3%).In the old residence, the heating requirements an important rank, with nearly 61.2% and 74.3% of the LCE and LCGHG, respectively. Nowadays, in Belgium, heating accounts for 72% of total consumption[4]. In the sustainable residences, the average emissions factor is 39.2 kgCO2 per GJ, while in old residences it is estimated at 44.8kgCO2-e emitted per GJ. This one showed the lower contribution to LCGHG than LCE.

The amount of CO2 quantified in this study is very significant, so, it is interesting to reduce the emission of greenhouse gases from heating systems, electricity generation, transport,and other equipment.

3.2.1. Electricity energy and greenhouse gas emissions analysis

The electricalenergy demand of the buildings is shown in figure 3. In sustainable buildings, the maximum contribution is 55.45%, corresponding at greenhouse gas emission of 29.97%, while in the old buildings, the electrical energy demand represents 22.89%, for a greenhouse gas emission of 6.14%.Globaly, in the two residences(sustainable and old), the life cycle electricity energy demand(LCEE), and greenhouse gas emissions (LCEGHG), represent 39.2% and 18.1% of the respective totals. It is important to notice that, the greenhouse gas emissions, associated with electricity energy can be evaluated by an emissions factor of 13.9 kgCO –eq/GJ, as explained in Section 3.2. However, this increase in energy can be mitigated by more economical behavior due to high energy prices, and by improving the energy qualities of the housing stock and its equipment.

3.2.2. Operational energy and greenhouse gas emissions analysis

It is seenthat, the life cycle operational energy demand(LCOE) and greenhouse gas emissions (LCOGHG) are dominated by heating in the old residences, as showed in figures(2&3). This heating represents 61.1% of the LCOE and 74.3% of the LCOGHG. The energy performance is very high in the sustainable residence, this one explains a low contribution of heating, whom, represent 0.11% of the LCOE, and 0.17% of the LCOGHG. Energy efficiency standards are imposed by the Belgian government and respected in the design of all these buildings, this explains why the demand for heating energy, although very high during the building operation phase, is often, lower than the international average. Indeed, More than a third of the heating consumption of the Walloon housing stock is due to houses built before 1900, when they represent less than a quarter of the housing stock(ICEDD ,2012).

Water demand represents from 0.9% to 3.1% of LCOE , then, between 1.2% and 5.6% of the LCOGHG. The greenhouse gas emissions, associated with heatingenergy can be evaluated by an emissions factor of 43.9 kgCO2–eq/GJ, and 72.9 kgCO2 –eq /GJ, in old and sustainable residences, respectively. The part of the cooling demand to the LCOE and LCOGHG is very low due to the condition of temperate climate.

3.2.3. Transport energy and greenhouse gas emissions analysis

on the figures 2 and 3, it is seen that the life cycle transport energy consumption (LCTE), of the old and new residential is 10.647TJ, and 15.506TJ, over 100 years, respectively; and is associated with the emission (LCTGHG) of 656.2tCO2-e and 910.2 tCO2-e .The total direct energy demand represents 19.2%(13.08TJ), and 29.5%(0.78ktCO2-e) of the LCTE and LCTGHG, respectively. Over 70% of the transport requirements are due to the private car, it is indeed, the main transport mode utilized in this study. It is noticed that the indirect transport energy, estimated at 55.1TJ(80.8%), represents 119.8% of the heating energy demand for sustainable residences. This ratio, very important, draws our attention to the utility of always assessing the indirect requirements for transportation in the analysis of energy needs in habitats. In 2014, (Trigauxet al.,2014) found that the contribution of road infrastructures accounts for 1% to 6% of total impacts. This shows that transport mobility produces an important quantity of GHG.

3.3Life cycle related health damage and biodiversity damage

The life cycle related health damage and biodiversity damage are presented in this section.

The figures 4 and 5 show the life cycle related health damage (LCH), and biodiversity damage(LCB). The total LCH and LCB represent 11.3 DALYs and 0.4 PDF.Km², respectively, over 100 years.

The operational phase signifies the largest share of the life cycle related health damage (represents 80.7% of the total), but, also, the largest contribution to the LCB (58.03%). The average biodiversity factor is 33677 PDF.m² per DALYS. This one showed the lower contribution to LCB than LCH. It is importantto reduce biodiversitydamage from transport, electricity generation, equipment etc.

3.3.1. Electricity health damage and related biodiversity damage analysis

The electricity related healthdamage is estimated at 19.7% of total damage. This, corresponding at biodiversity damage of 11.2%.Life cycle electricity healthdamage(LCEH) and biodiversity damage(LCEB), can be associated with a factor of 15832 PDF.m²/DALYS, as explained in Section 3.3.

3.3.2. Operational health damage and related biodiversity analysis

According to figures 4 and 5, it isseenthat, the life cycle operational health demand(LCOH) and biodiversity damage (LCOB) is dominated by heating degree and water management. This heating represents 43.3% of the LCOH and 10.1% of the LCOB. While water represents 7.0% of the LCOH, and 10.1% of the LCOB. Despite the fact that the damage to health and biodiversity remains lower in the environment with sustainable residence, it is important to specify that the average of the two is below that recommended by Belgian and international standards. The heating biodiversity damage, associated withhealthdamage can be evaluated by an emissions factor of 5301.3 PDF.m²/DALYS.

3.3.3. Transport health damage and related biodiversity analysis

It is noticed that, life cycle transport health damage(LCTH) is 31.25% (0.88DALYS), associated with life cycle transport biodiversity damage(LCTB) is 3.7% (0.02 km2.PDF) , over 100 years. The average biodiversity factor is 20356 PDF.m²/DALYS.

3.4. Lifecycle waste product and related photochemical ozone

Figures 6 and 7 show the life cycle waste product(LCW), and photochemical ozone(LCP).The total LCW and LCP of the whole building represent 4893.8t and 2603.7 kg ethylene eq. , respectively, over 100 years. The construction phase of the building represents 9.6%(310.9t) of LCW and 8.2%(199.4 kg-ethylene)of LCP, while the renovation of residences contributes at 7.5%(286.9 kg ethylene)of LCP, and 7.7%(441.7t) of LCW. Globally, the transportmobilityproduces74.04t(9.41%) of waste, and 214.99kg ethylene(38.02%), of photochemical ozone, over 100 years. Meanwhile, the equipmentcontribute to7.2% of waste products and 7.9% of photochemical ozone. The high concentration of waste can facilitate the birth of several diseases and even accelerate the variation of the outside climate by the high emission of greenhouse gases.

3.5. Statistical analysis environment impacts

The significance level allows characterizing with a very high precision, the impacts of different buildings (old and sustainable), on the environment. It was estimated that Construction, use, renovation and demolition of residences, created an instability on the twelve constituents which, impacting environment, such as(greenhouse effect, energy demand, eutrophication, waste product etc.).Figure 8, is constructed with the impact data of significance level in every studied environment.

Figure8shows a comparison of environmental impacts from the sustainable and old buildings. From this figure, we can observe that there is no clear difference between the environmentalimpactfrom old residences, and sustainable residences(because the significance level is clearlyover 0.05). And consequently, both kind of buildings can be considered to reach sometimes the same impact quantity on the environment. Nevertheless, it was observed a clear difference in health damage (significance level below 0.05), in sustainable residences. Globally, there is no significant statistical on the impacts of different buildings. However, it is interesting to notice that, there is a clear, greater tendency to reach a similar environmentalimpact in sustainable buildings than in an old building, because the significance level is slightly weak in sustainable buildings.

Thereafter, a differential analysis between residences was made. Such as, in several in-depth statistical types of research(Nematchoua et al.,2017), the t-test was used in this part, all statisticalanalyseswere carried out with a 95% confidence level (CL), which was considered the level of significance equal to 5%. In both residences, a meticulous analysis of ten environmental impacts was applied at two-phases (construction and exploitation), as showed on table4. The healthdamage analysis inthe residences was applied with the Chi-Square method. This test has globally as main aim to compare two categories of measures, and easily showed the best similitude or discrepancy possible. The significance interval can be freely selected with the SPSS software. Indeed, this iscalled the p-value (observed probability for a t-test). All the statistical analyses were carried out by means of IBM SPSS 24.0 Statistical software.

In Table 4, it is seen that the statistical analysis of ten environmental impacts applied at both building kind is not significant (P-value<0.05), in all of the cases. Nevertheless, the correlation factor was important between greenhouse gas and energy demand, then, between eutrophication and waste products. Most of the means of all these impacts were higher in an environmentwith old buildings than sustainable.

The standarddeviation is lower in the construction phase than use, despite that, Mean standard error of impacts is very high during the construction phase.

Table 5, shows the Chi-Square test results for sustainable and old residences with regard to the health damage, in the differential analysis. It can be inferred from Table 5 that, health damage showed obvious differences (p-value, equal to 0.046, ($0.046 < 0.05$)).The results of the analysis shown in Table 5, justify, that there is a huge difference, between the health damage in the different categories of building. It's important to push the reflection further. It is necessary to try, by a new analysis, to understand, what are the principal elements of the different studied residences, which creates this enormous difference? Table 6 shows these results. In table 6, it was seen the mobility by private transportation (in the environmentwith sustainable residences), and heating degree(for the old residences) have the most significant effect on health.

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2. Conclusion

In this research, a thorough statistical analysis was conducted, in the purpose,for analyzing, in a meticulous and more precise way, the impacts of new and old buildings on the environment. The constituents of the various residences, that affect the environment the most are detected with an accuracy of more than 95%. The action of 59 buildings on 12 environmental impacts was evaluated. While the majority of works on LCA, at the building scale, focus on a very limited number of indicators, and often on a single parameter, we have been ambitious by studying more often indicators, applied to old and new buildings. This wide range of studied parameters, and analysis conducted, allowed us to make several interesting observations. In addition, it allowed us to understand the current climate change. The Chi-Square test applied to sustainable and old residences showedthat there is a huge difference, between the health damage in the different categories of building. Despite that, the result of the analysis of all the impacts of building on the environment was very significant. The indirect transport energy, estimated at 55.1TJ(80.8%), over 100 years, represents nearly119.8% of the heating energy demand of sustainable residences. The results reveal also, the high contribution of a public park and private garden use to the building life cycle environmental impacts, especially in a sustainableenvironment built.

In view of all the results found, it may be normal to give reason to the nature that continues to complain (natural disasters, global warming, etc.) , by following the human action.

It is important :

- raise awareness of the population to adopt more public transport modes, vehicles,and electric bikes to reduce the greenhouse gas.

- New construction techniques must be adapted to the new climate to reduce the demand for heating energy;

-Water distribution techniques and the management of public parks must be improved to reduce eutrophication,

- All waste must be recycled to reduce the proportion of odors affecting the environment and human health.

- Electricity generation techniques need to be improved to limit damage to biodiversity.

Such as, any scientific research, this work, although having several innovations, and originalities in the field of LCA, has limits. In fact, it is more focused on data analysis, neglecting the climatic aspect which is very important. Aware of this, this orientation will be the focus of the next research.

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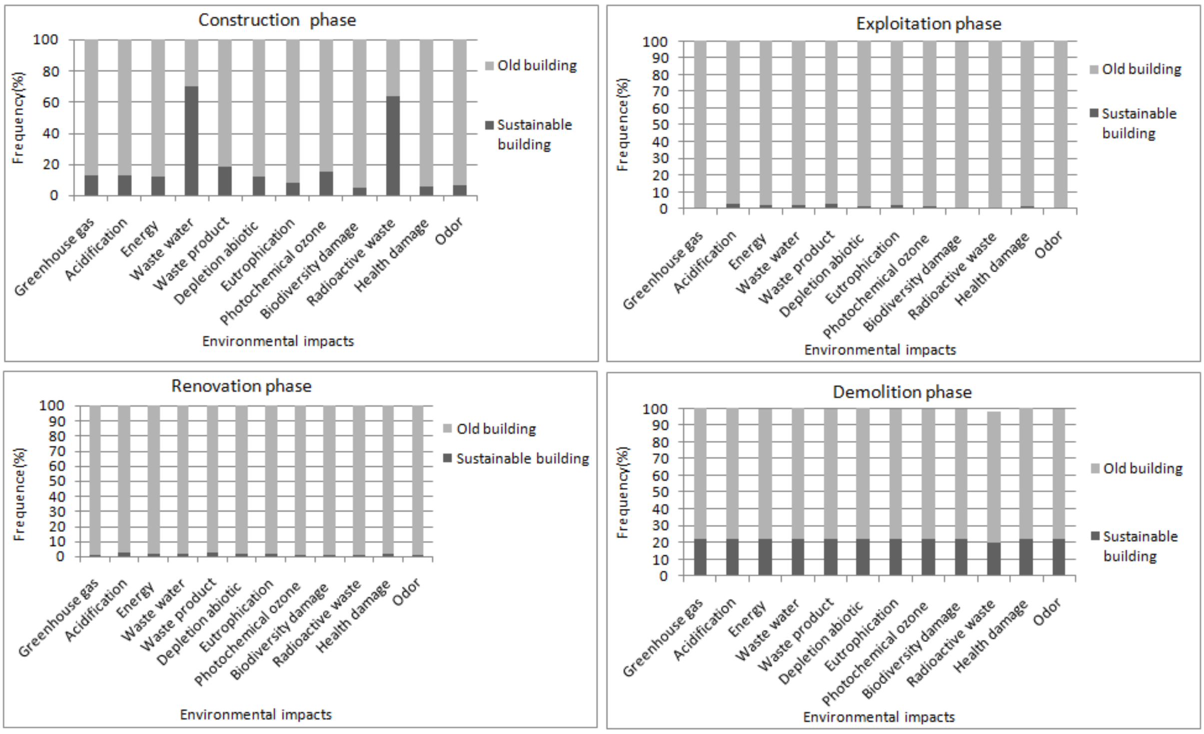


Figure1. Percentage of environmental impacts in different buildings according to phase.

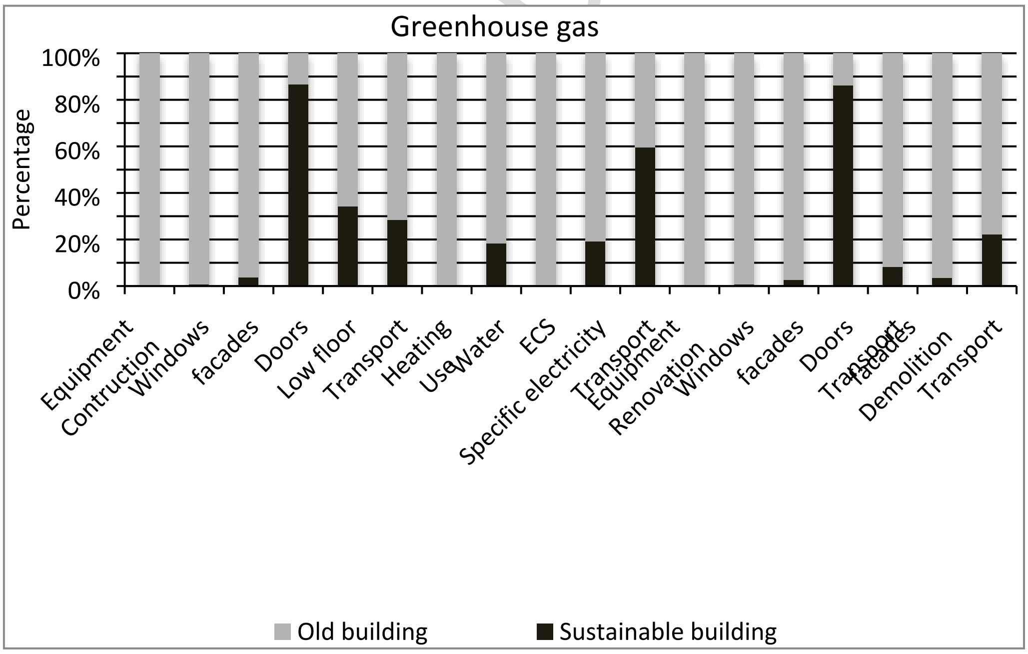


Figure2. Frequency of greenhouse gas in the sustainable and old buildings.

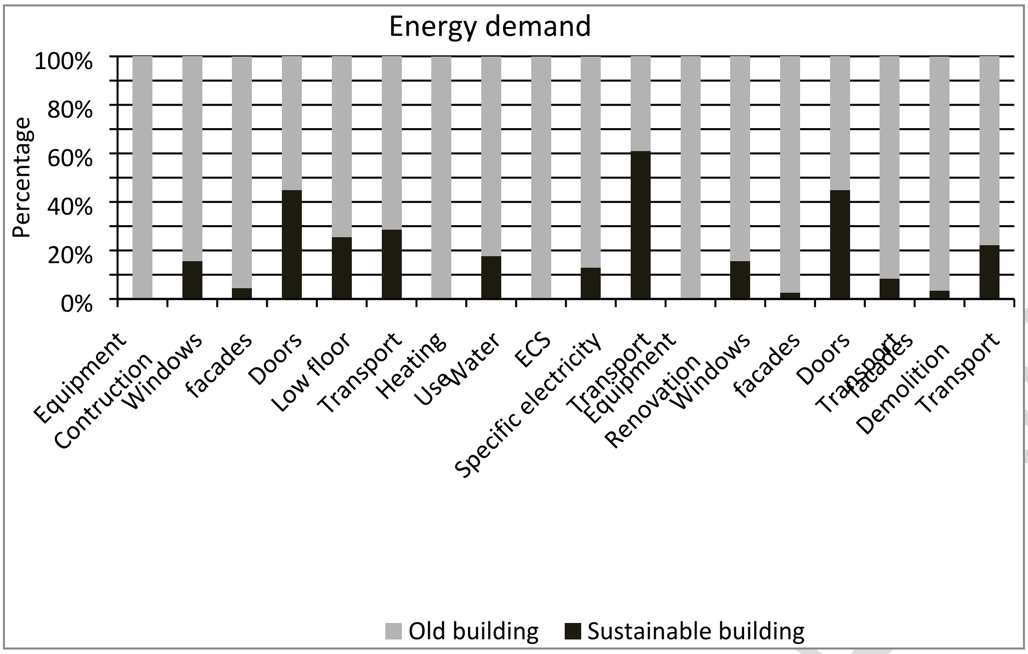
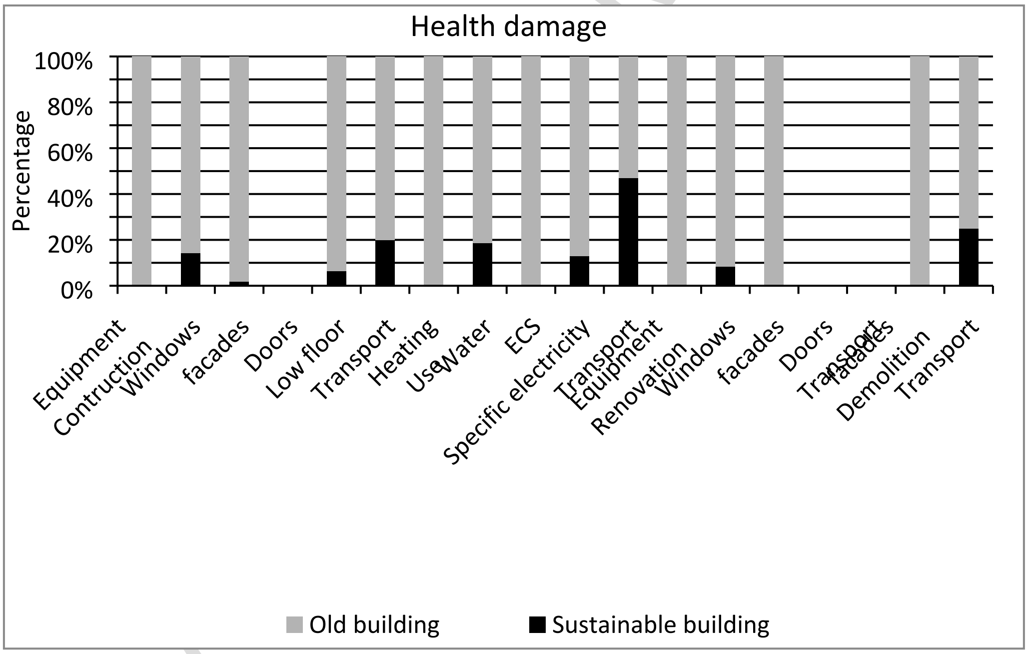


Figure3. Frequency of energy demand in the sustainable and old buildings



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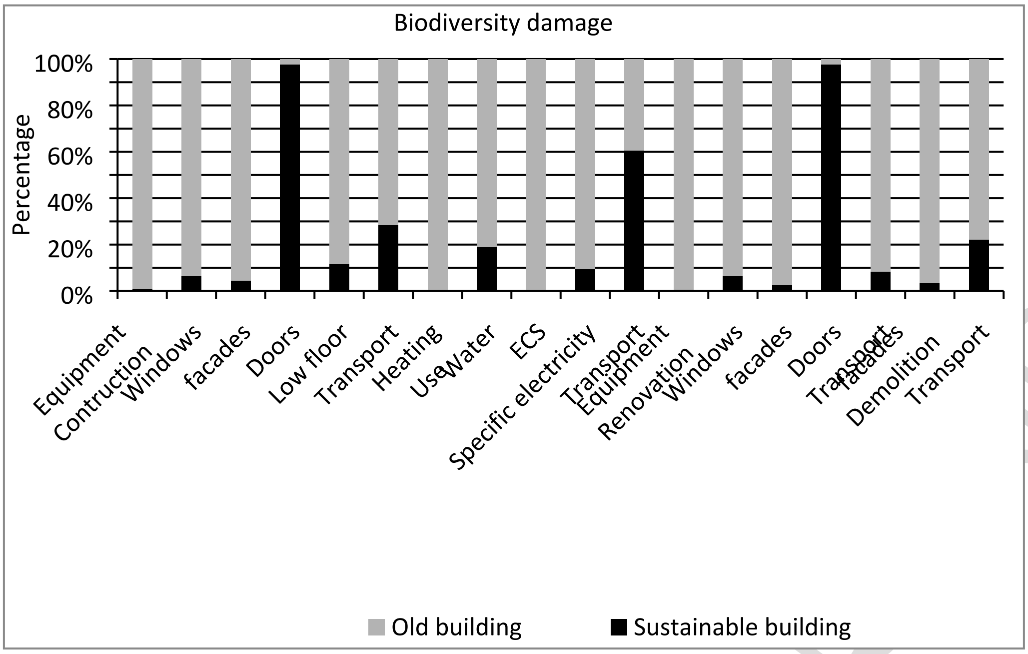

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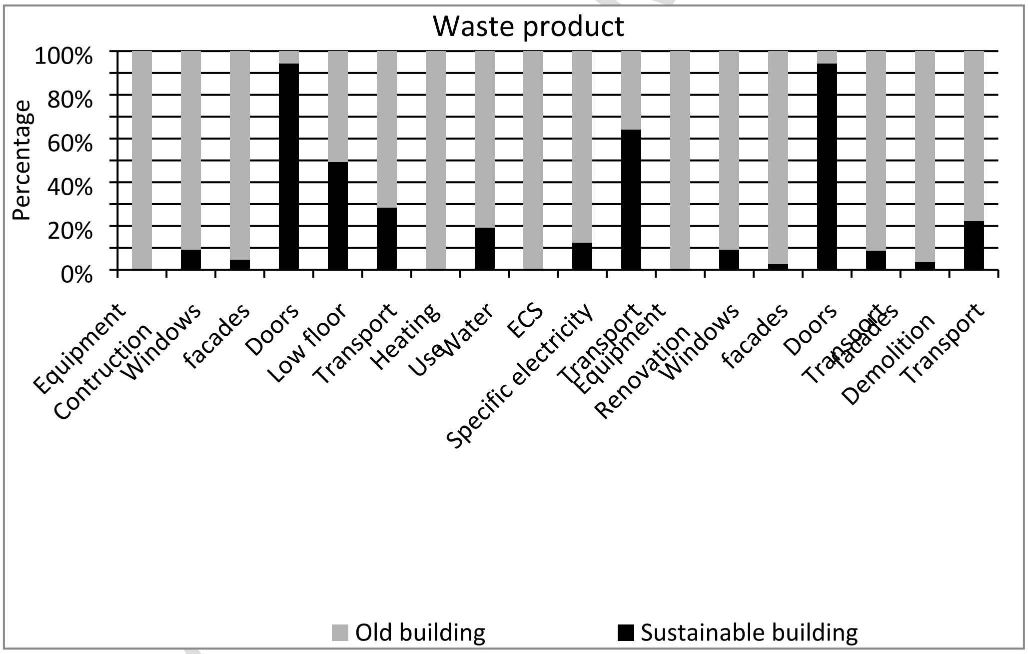

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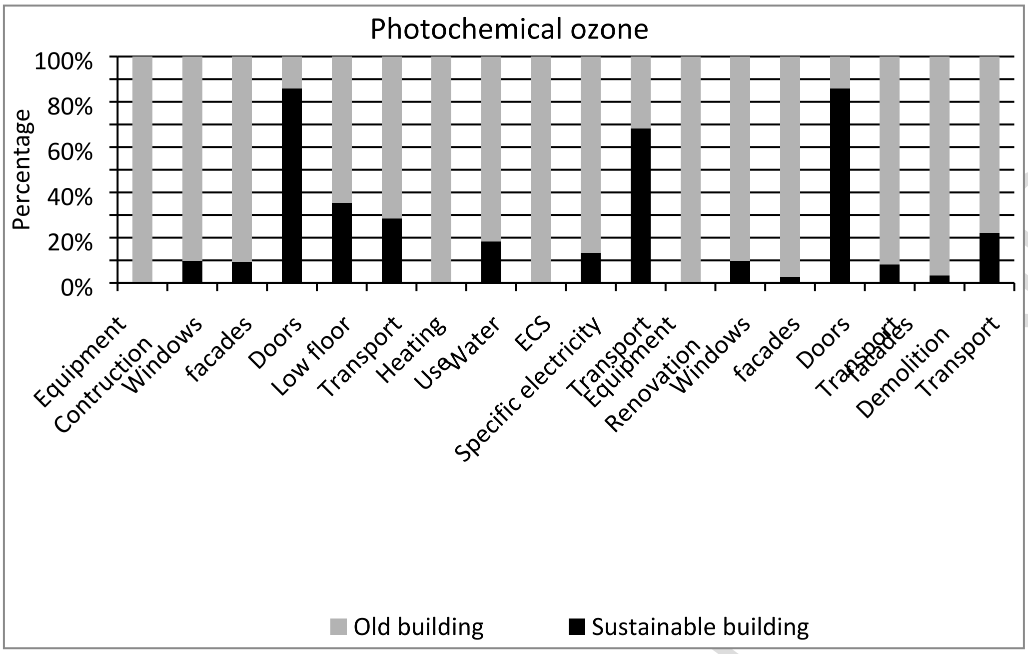

Figure7. Frequency of photochemical ozone in the sustainable and old buildings.

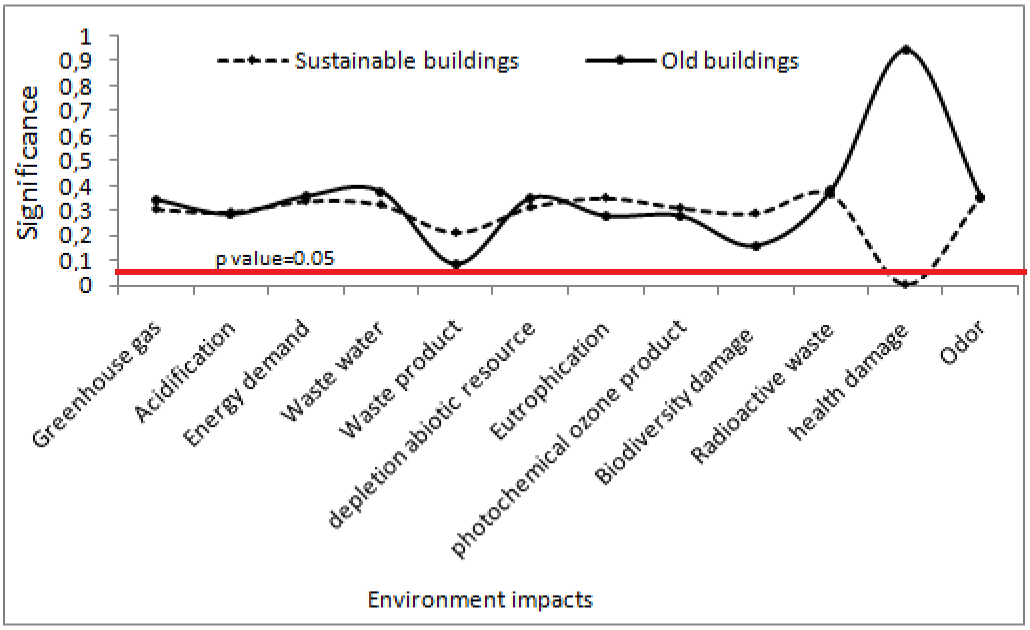

Figure8. Comparison of environmental impacts from the sustainable and old buildings.

List of table

Table1. some assessment elements .

	Sustainable buildings	Old buildings
Altitude (m)	235	59
Latitude	50°84'	50°39' N
Longitude	5°77'O	5°35' O
Number of building	29	30
Number of floor	1-3	4
Number of occupant	over 50	over 100
Seismic zone	very weak	very weak
SHON estimate(m^2)	880.00	2256.81
SHAB estimate(m^2)	0.00	4246.97
Daily water consumption(L)	90	100
Medium surface building(m^2)	304.89	134.25
Volume(m^3)	795.51	382.1
Inert waste at end of life	yes	yes
Surplus of materials(%)	5	5
Transport distance of materials(km)	100	50
Distance (site- inert discharge)(km)	50	50
Lifetime of interior windows(year)	30	30
Lifetime of interior door(year)	30	30
Lifetime of interior coating(year)	10	15
Lifetime of external windows(year)	30	30
Lifetime of external door(year)	30	30
Lifetime of equipment	20	20

Table2. List of materials

Name	Density (Kg/ m3)	Surface (m^2)	Volume (m^3)	Weight (kg)
C3-Terracotta	1900.00	653.56	222.21	422197.11
C3-Glass wool	12.00	264.32	52.86	634.37
C2-Glass wool	12.00	640.83	128.17	1 537.98
C1-Plaster + cellulose	1200.00	1803.76	23.45	28138.68
C3- Mortar	2 000.00	566.70	17.00	34 002.18
C3- Plasterboard	850.00	264.32	3.44	2 920.73
C4-Plaster + cellulose	1200.00	1073.46	13.95	16745.91
C3- Floor tile	2 300.00	566.70	11.33	26068.34
C2- Floor tile	2 300.00	1672.51	33.45	76935.67
C2- Plasterboard	850.00	640.83	8.33	7 081.12
C4-Glass wool	12.00	294.86	58.97	707.66
C4- Mortar	2 000.00	793.01	23.79	47 580.67
C2- Mortar	2 000.00	1 672.51	50.18	100 350.88
C2-Plaster + cellulose	1 200.00	2 300.85	29.91	35893.29
C4- Floor tile	2 300.00	793.01	15.86	36 478.52
C4-Terracotta	1900.00	863.51	293.59	557826.43
C2-Light wood	500.00	1672.51	41.81	20906.43
C3-Plaster + cellulose	1200.00	884.43	11.50	13797.05
C2-Terracotta	1 900.00	1 696.01	576.64	1 095624.92
C3-Light wood	500.00	566.70	14.17	7083.79

Table 3. Some analysis parameters.

	Sustainable building	Old building
Energy production		
Nuclear(%)	52	78
Hydroelectric (%)	17	07
Gas (%)	27	13
Oil (%)	0	2
Coal(%)	4	5
Loss of the electricity network(%)	9	5
Equipment		
Performance of heating equipment(%)	98.0	1.1
Performance of other equipment(%)	98.0	1.1
Water		
Network efficiency (%)	85	80
Presence of dry toilet	no	no
wastes		
Paper sorting (%)	75	50
Sorting the glass(%)	90	50
Incineration		
Incinerated waste(%)	40	50
valuation yield (%)	80	-
Transport		
Distance: Home- shops (m)	5000	500
Distance to the transit system(m)	5000	250
Distance : Home-work(m)	10000	2500
Occupants commuting daily (%)	80	100
Mode of public transportation	Bus	Bus
Presence of cycle paths	No	No

Tabe4. Statistical analysis of different environment impacts.

Datasets	Sustainable-buildings	Old- buildings	Sustainable-buildings	Old- buildings
Phase	Construction	Construction	Use	Use
(1)-Greenhouse gas(tCO2 eq.)				
Sample	06	06	05	05
Total	222.28	1470.72	1469.20	32132.56
Mean	27.51	245.12	293.84	5805.45
Standard deviation	23.32	381.96	387.89	10450.25
Mean standard error	9.52	155.93	173.47	4673.49
t-test-results	1.42		1.16	
Degree of freedom	5		4	
p-value	0.214		0.310	
(2)- Acidification(kg SO2 eq.)				
Sample	06	06	05	05
Total	687.73	4787.69	4703.86	47835. 16
Mean	180.19	797.95	940.77	6932.73
Standard deviation	255.51	1097.72	1337.91	8539.56
Mean standard error	104.31	448.14	598.33	3819.10
t-test-results	1.34		1.47	
Degree of freedom	5		4	
p-value	0.239		0.217	
(3) -Energy demand(GJ)				
Sample	06	06	05	05
Total	3050.26	21954.12	39980.74	731833.39
Mean	349.88	3659.02	7996.15	105603.14
Standard deviation	269.99	5131.11	10711.78	176029.35
Mean standard error	110.23	2094.77	4790.45	78722.72
t-test-results	1.63		1.21	
Degree of freedom	5		4	
p-value	0.163		0.293	
(4)-Waste water(m^3)				
Sample	06	06	05	05
Total	14528.17	6246.99	114932.87	698207.69
Mean	2288.78	1041.16	22986.57	119645.31
Standard deviation	3227.68	1260.64	44258.99	247688.14
Mean standard error	1317.69	514.65	19793.22	110769.51
t-test-results	-0.796		0.828	
Degree of freedom	5		4	
p-value	0.462		0.454	
(5)- Waste product(t)				
Sample	06	06	05	05
Total	114.09	507.85	304.27	3310.52
Mean	16.36	84.64	60.65	514.75
Standard deviation	15.22	114.29	59.85	653.59
Mean standard error	6.22	46.67	26.77	292.29
Correlation	-0.039		0.746	
t-test-results	1.44		1.663	
Degree of freedom	5		4	
p-value	0.2.9		0.172	
(6)- Depletion abiotic resource (kg antimony eq.)				
Sample	06	06	05	05

Total	1256.93	8996.34	10574.03	267533.57
Mean	1499.39	142.63	2114.92	48714.29
Standard deviation	2085.39	115.04	2741.78	86113.89
Mean standard error	851.36	46.96	1226.16	38511.30
Correlation	0.621		0.426	
T-test-results	-1.648		1.193	
Degree of freedom	5		4	
P-value	0.16		0.299	
(7)-Eutrophication(kg PO4 eq.)				
Sample	06	06	05	05
Total	135.65	1526.11	2669.57	16883.88
Mean	15.13	254.34	533.91	2788.12
Standard deviation	10.23	322.46	693.82	2721.14
Mean standard error	4.17	131.64	310.28	1216.93
Correlation	0.259		0.365	
T-test-results	1.831		1.976	
Degree of freedom	5		4	
P-value	0.127		0.119	
(8)-photochemical ozone product(kg of ethylene eq.)				
Sample	06	06	05	05
Total	60.82	337.98	355.16	3866.21
Mean	7.42	56.33	71.03	669.43
Standard deviation	6.73	73.57	120.94	1088.21
Mean standard error	2.75	30.04	54.08	486.65
Correlation	0.850		-0.362	
T-test-results	1.763		1.176	
Degree of freedom	5		4	
P-value	0.138		0.305	
(9)- Biodiversity damage (PDF.m².year)				
Sample	06	06	05	05
Total	3461.75	71942.83	29933.83	439322.20
Mean	420.45	11990.47	5986.77	75241.24
Standard deviation	182.79	20055.76	8495.52	132422.47
Mean standard error	74.62	8187.73	3799.31	59221.13
Correlation	0.467		-0.049	
T-test-results	1.419		1.163	
Degree of freedom	5		4	
P-value	0.215		0.309	
(10)-Radioactive waste(dm³)				
Sample	06	06	05	05
Total	19.68	11.42	73.55	761.39
Mean	3.24	1.91	14.71	14.42
Standard deviation	4.85	2.38	27.71	10.23
Mean standard error	1.98	0.97	12.34	4.58
Correlation	-0.413		-0.781	
T-test-results	-0.526		-0.018	
Degree of freedom	5		4	
P-value	0.622		0.987	

The Correlation is significant at P-value < 0.05

Table5. Chi-Square tests for health damage(sustainable and old residences) .

Confidence level (99%)	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	105,075[a]	84	0.046
Likelihood Ratio	51.915	84	0.998
Linear-by-Linear Association	0.062	1	0.804
N-observations	18		

Superscript (a) indicates that it is RC table Chi-Square Test,[a]Correlation is significant at P < 0.05, 2-tailed level.

Table 6. Quantification of the elements that most impact the health damage according to the different phases

Buildings	sustainable		Old	
Stage	Usage	Value(DALYS)	Usage	Value(DALYS)
Construction	Low floor	0.04	wall	1.56
Use	Transport	0.78	heating	7.64
Renovation	Equipment	0.01	Equipment	2.22
Demolition	Transport	0.01	Wall	0.04