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Case study

Environmental impacts of adobe as a building material: The north cyprus traditional building case

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ABSTRACT

The urgency of global climate change has drawn significant attention to the building industry over the last few years. Today, the building sector is responsible for the emission of about 23–40% of the world greenhouse gases. This is plausible owing to the various non environmental friendly materials used by modern building industry and the palpable contemporary design construct. Unlike modern buildings, traditional building materials are proven to be earth conscious and have nearly zero carbon footprints. Yet, the modernist building sector with its insatiable drive for autonomy has relegated lessons from traditional building to being primitive. Moreover, the absence of objects of industrialisation has been defined as forming conformity with poverty.

Hence, this research seeks to scientifically examine Adobe as one of the traditional building materials. In that vein, the environmental impact of the use of adobe will be studied. The study also purports to adequately examine the advantages and disadvantages of the use of adobe in modern construction.

Methodologically, owing to the aims of this research, a qualitative computer based simulation approach is adopted. A typical traditional Adobe building in Louroujina—North Cyprus, will be simulated through a parametric computer based simulation done using Revit Architecture, with a green studio plug-in. Software acknowledge by the United State Department of Energy (DOE 2015). This simulation procedure models the carbon emission of the building and the yearly energy consumption.

Summarily, this paper posits that the successful fusion of traditional building materials such as Adobe and modern design construct will not only give birth to earth conscious building, but will also be energy efficient. Moreover, it will be a substitute building material the building industry can adopt at as a contributing solution to the omniscient global warming malady.

1. Introduction

The building sector today is known to be consuming 40% of the world energy [23] and in turn, supports 23–40% of the world's greenhouse gas emission, particularly CO_2 ([10], 18). This is plausible owing to the various industrial materials employed in the building construct. Taking a more panoptic review of this state, it will be realised that albeit the building

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material types engaged by the modern building sector, the hotchpotch design construct is yet, another causative factor for the palpable greenhouse gas emission.

Today, various methodologies are currently being adopted to look into this palpable condition. Stimulatingly, the international panel on climate change (IPCC) envisaged that the CO_2 emission from the construction sector could surge from 8.6 billion tonnes in the year 2004 to 15.6 billion in the year 2030. Under the speculated rising population growth circumstance as will be contributed by the developing countries.

On the paradox, traditional building materials have been proven overtime to be earth conscious [10,17,18]. Several building materials exist in the older building industry, because of the proximity, availability and geographical location. Such material includes mud bricks (adobe), stones, cobs and wood to mention a few. Summarily, the traditional building materials are stereotypically binary: earth related material and wood related.

Today, it is obvious civilisation is to be attaining its cusp; hence, there become a pressing need to take a panoptic look at the dictates of tradition before this technological era attains its cul-de-sac. Therefore, this research aims to examine adobe as a traditional building material. The environmental impact of the use of adobe in construction will be given holistic attention. Adobe traditional building in Louroujina village, North Cyprus will be the case. Primary data for the analysis will be collected by simulating the selected building. This is done through parametric simulations using the computer software- Revit Autodesk- with Green Studio Plug-in, a program which models the yearly carbon emission of the building. The secondary data are garnered from professionals' perspective, the ongoing Tubitak research project in Louroujina, books, journals, libraries and school data bases (Figs. 1 and 2).

2. Ontology of adobe material

Historically, earthen materials have been employed as building material for thousands of years of human existence ([13,14], 13). Adobe (Mud brick) houses dated back 6000 BC when discovered in Russian Turkestan ([16], 88). It was employed as the building material in almost all ancient cultures, not only for residential buildings, but also for public structures as well.

However, adobe is generally referred in different appellations. Scientifically, the term Adobe refers to a clay mix, silt (sand with finer aggregate), sand, and sometimes coarse aggregates such as gravel. To talk of the synthetic unbaked brick typology, terms "mud bricks 'or "adobes' are usually engaged. Describing the compressed unbaked bricks, the term 'soil blocks' is commonly used.

3. The global trend

According to Novel ([15], 63–85), not all traditional structures of the same types are found in similar locations. Generally, reasons for choice of material are often governed by several deciding factors and sometimes, by just one of them. Sometimes the quality and property of the soils in a particular geographical location affect the typology of building that will be palpable there. Therefore owing to the above preambles, it can be concluded that attempting to describe adobe buildings according to geographical is a task of such encyclopaedic scope. Hence, it is streamlined under the kind of material used by each continent. However, this can be achieved by graphically illustrating the globe, showing the typology of material used by each geographical location.

4. Thermal behaviour of adobe as thermal mass

By definition, according to [9], thermal mass refers to the capacity of a material to generally absorb and store up heat and subsequently release this heat when it is necessary. This allows excess heat to be absorbed during the summer, reducing the cooling loads and also reduce the heating load in winter. It is usually measured in the number of joules (J) of thermal energy

Fig. 1. Typical moulding technique of Adobe bricks ([13,14], 63).

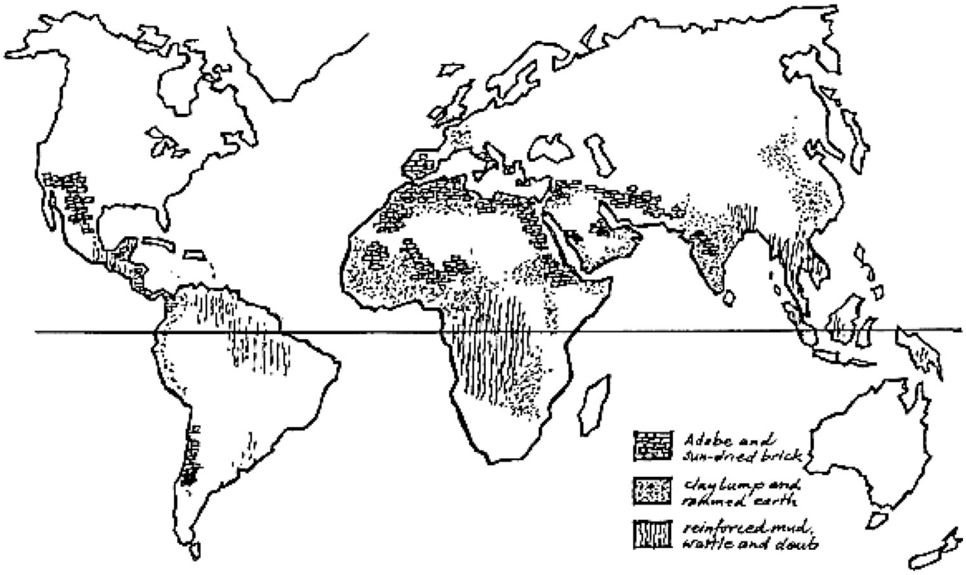


Fig. 2. Global map illustrating the locations of traditional building according to the material used. Oliver, 1983, 35, Fig. 5).

stored up per unit of mass (J/kg K) or per cubic meter (J/m^3 K) of the material in question. Generally, adobe walls are thick walls for house, usually approximately 300 mm which have a high thermal mass property. Mrema et al. 2011. The Specific heat capacity of adobe wall is 1260 J/kg K and density is 1540 kg/m [2]. Usually, adobe performs very actively, particularly in summer when the prevailing solar heat gain can be stored in the walls. Subsequently, in winter mud brick walls perform poorly because of it low thermal resistance which normally leads to heat loss through walls [21].

5. General heat loss and gain in buildings

Statistically, according to the research of Donnelly ([6], 7), usually between 10 and 15% of the total heat lost from a building is usually through the windows, owing to the combination of radiant heat loss through the members. Moreover, this palpable figure is low compared with the estimated average 25% heat loss through the roof and a sum total of 35% through external walls. The bulk of the heat loss and gain is usually through the wall. Therefore, in a scenario where the material has low insulating property as plausible by modern building materials, an alarming amount of the energy expenditure will be on heating and cooling in the respective seasons. This however, is the hypothetical reasons the modern buildings consume up to 40% of the world energy, unlike the traditional building which adopts passive design constructs.

6. Adobe as a building material in Louroujina–North Cyprus

6.1. The Cyprus case

Historically, according to Antoniadou ([1], 14), Cyprus is the third largest island in the Mediterranean Sea, after Silica and Sardinia and one of the oldest in the world.

According to archaeological excavations, the first sign of civilization was traced through date, back to the 9th millennium B.C. Louroujina, which is the subject for this research project, is one of the town located in the island-Cyprus (see Fig. 3). Geographically, it is located at longitude 350 00′ 42″ North and latitude 330 27′ 51″ East with altitude of 236 m ([12], 133).

6.2. Traditional buildings in Cyprus

There is plethora of professional perspectives on Cypriot traditional architecture [11,4,8,20,5,19,3,7]. However, despite this profusion of researches on Cypriot traditional houses, all the literature converges at a convivial point. According to [8], the classification of Cypriot traditional architecture typologies is basically under the stereotyped aegis of it modular combination of the structure. These modules however, are a function of structural type, construction materials, construction technique, and spatial features. In essence, according to the research of [7], the Cypriot architecture is divided into three basic groups:

Fig. 3. Map of Cyprus indicating the location of Louroujina [12].

- Single unit/units without hall,
- Those with outer hall,
- Those with inner hall (see Fig. 4).

6.3. The Louroujina case

Louroujina hosts some of the most relevant examples of almost-all Mediterranean typologies of traditional houses, religious buildings (chapel, mosque), social buildings (traditional cafés, market) educational buildings (primary and secondary schools), and health buildings (TÜBİTAK project 112M417 [22])

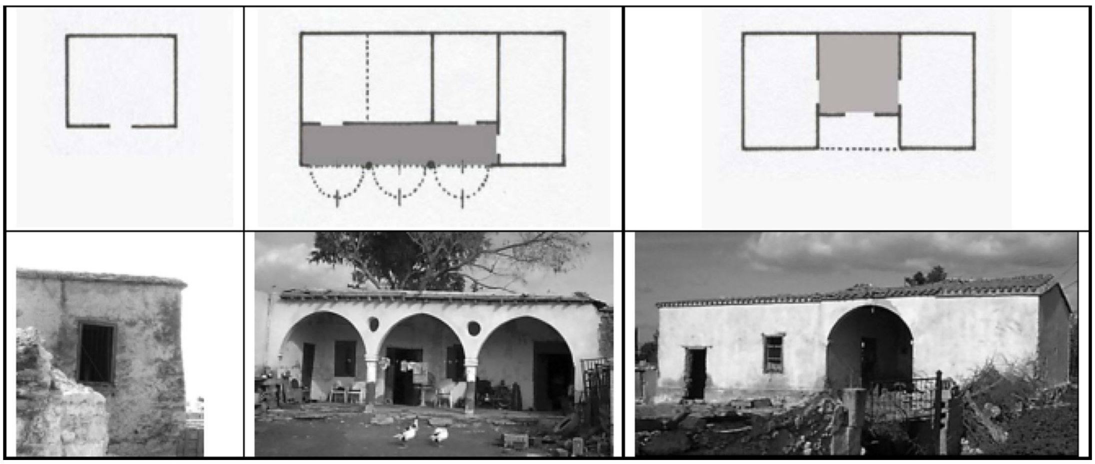


Fig. 4. The three classifications of Cypriot traditional houses [7].

The building materials used in Louroujina is generally Adobe and mortal of the same material as the adobe units (Fig. 5b), stone and timber. Moreover, the most common type of building method here is a mix manner of construction—stone and adobe (Fig. 5a).

The typical adobe masonry wall is the typology common in Louroujina. The traditional buildings are built exclusively with thick masonry (50–70 cm) which provides benefits in the sense of its thermal inertia and thermal insulation. The earthen blocks are usually produced manually and are called “adobe” or “mud brick” or “sun- dried earth block” ([12], 133).

Generally, there are four typologies of traditional buildings in Louroujina, as identified by the research of TÜBİTAK project 112M417 [22], these are

- The central hall plan
- Dichoro plan type
- The columned veranda
- Two story town house typology (see Fig. 6).

7. Methodology

The methodology aims at examining the garnered primary data to determining specific canonical summations. The summation aims to confirm if adobe buildings have any trace of carbon emission and determine their energy efficiency. It is worth stressing however, that this methodological approach used to collect the primary data is a quantitative computer based simulation procedure.

7.1. Simulation procedure

Importantly, the computer based simulation is carried out using the computer software Revit Architecture energy plug ins. It is set to simulate the following parameters for a period of one year which covers the winter, summer, spring and autumn:

- Yearly carbon emission of the building
- Yearly energy consumption of the buildings

A site inspection was initiated to measure the selected adobe building to be used for the simulation. This is subsequently drawn using AutoCAD software (see Table 1). This architectural drawing however, is a layout for the contemporary state of the buildings to be used for scrutiny and simulation. The drawings of these buildings are prepared to understand the building material, the plan form, position of the opening and the orientation of the building (see Table 2)

8. Data presentation

As shown in Fig. 7, the location of the simulation is Akincilar/Louroujina village, Cyprus. The building has a total floor area of 40 m^2 and external wall area of 73 m^2.

Therefore, owing to the above parameters, the following are the empirical data obtained from the adobe building

(A) (B)

Fig. 5. Typical building in Louroujina (Source: Authors' field work).

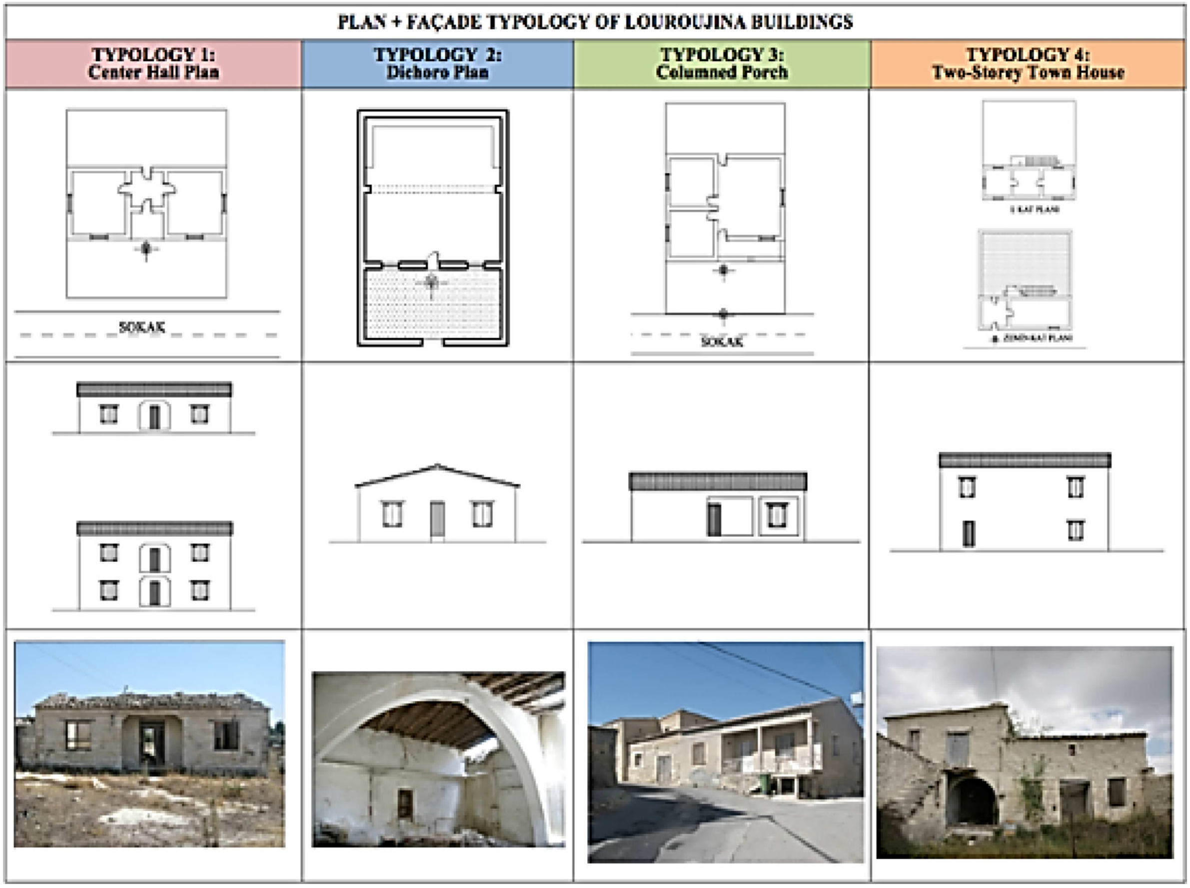


Fig. 6. Typologies of traditional buildings in Louroujina Kurt et al., 2015.

8.1. Net yearly carbon emission

As shown in Fig. 8, the result of the simulation shows the Adobe traditional building has a net zero (0) metric tonnes of carbon footprint yearly and 2 metric tonnes of electricity consumption.

Table 1
Building architectural layout.

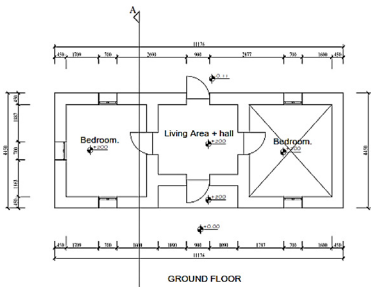
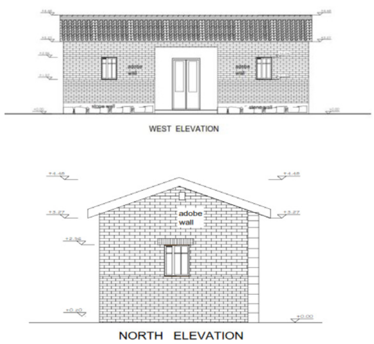
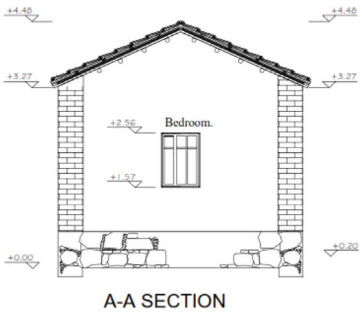
Floor Layout	Elevation	Section
		

Table 2
Building parameter Table.

Building GIS No.	Orientation	Facade	Window size and orientation	Window type	Ventilation type	Wall material	Roof material
474	South east (SE)		800 mm × 1200 mm South east	Wooden shutter	Axial corridor	Adobe	Clay tiles

8.2. The energy expenditure use

As shown in Fig. 9, only 42% of the total electric consumption goes to heating and cooling respectively, yearly in the adobe traditional building. The rest of the use goes to lighting and miscellaneous equipment like refrigerators.

9. Discussion of emperical data

According to the data collected from the parametric simulation, at this point it can be discussed that the rhetoric—that traditional buildings have zero carbon footprint—has gone beyond a mere abstraction to take its place with empirical realities. Therefore, the obtained data will be discussed under the following aegis;

- The carbon emission per year
- The energy end use

9.1. The yearly carbon emission

Owing to the rate of carbon emission per year shown in Fig. 8, it can be ascertained that, traditional buildings have zero carbon footprint. Stimulatingly, it has an empirical zero (0) metric tons of carbon footprints per year. This palpable owing to the resistance offered by the walls material in summer and winter respectively. Hence, the building is not dependent on technological comforts; rather, the adobe building adopts passive methodology of offering interior comfort.

9.2. Energy end use (electricity)

As a result of the collected empirical data, as shown in Fig. 9, it can be said that adobe buildings have good energy management irrespective of the prevailing weather condition. Adobe building uses lesser artificial heating procedure and requires lesser cooling in winter. Affirmatively, it can be confirmed that these buildings therefore offer more comfortable

Building Performance Factors

Location:	Akıncılar, Cyprus
Weather Station:	52939
Outdoor Temperature:	Max: 35°C/Min: -23°C
Floor Area:	40 m²
Exterior Wall Area:	73 m²
Average Lighting Power:	4.84 W / m²
People:	1 people
Exterior Window Ratio:	0.12
Electrical Cost:	$0.14 / kWh
Fuel Cost:	$0.14 / Therm

Fig. 7. Building performance factors (DOE-2-2-48r).

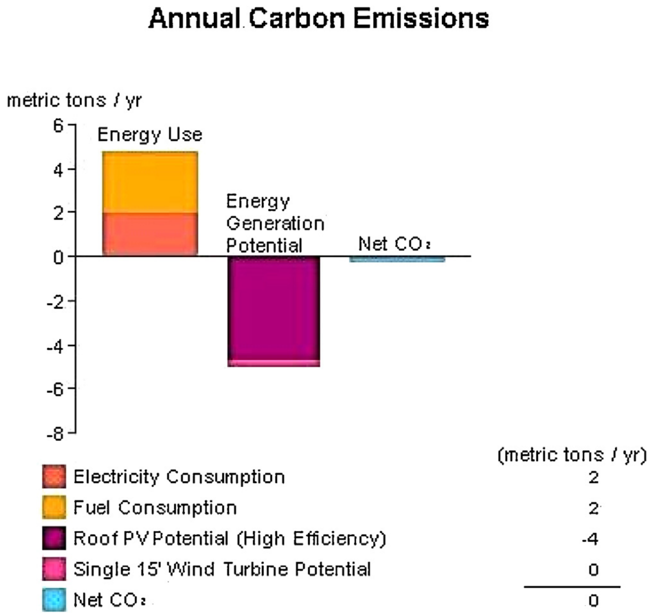


Fig. 8. The Annual carbon emission in Adobe building (DOE-2-2-48r).

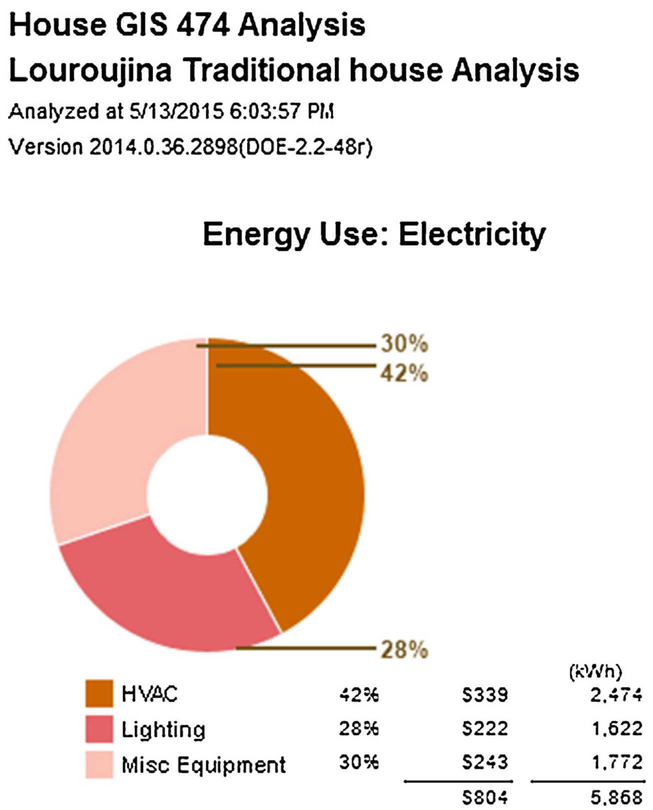


Fig. 9. Yearly energy consumption in Adobe building (DOE-2-2-48r).

interior spaces, both in winter and summer. For clearer explanation, the energy consumption will be discussed according to the following;

9.2.1. HVAC consumption

Mathematically by percentage (%), as palpable in Fig. 9, the traditional building expends a sum total of 42% of its total end use on the HVAC. Invigoratingly, 25% of the total is expended on heating in winter and 17% on cooling in summer (see Fig. 8). This is to prove the fact that adobe walls perform poorly in winter. Adobe walls are very permeable; hence, the extent of dampness makes the interior spaces colder in winter.

9.2.2. Lighting consumption

Paradoxically, however, despite the overwhelming advantages of a traditional home, the building does not have judicious use of electricity in terms of lighting energy consumption. The traditional building expends 28% of its energy on lighting system (see Fig. 10). Therefore, it can be affirmatively discussed, that, traditional buildings need to improve the existing lighting systems.

9.2.3. Advantages of adobe materials—according to simulation procedure

Within the praxis of the empirical data garnered from the simulation procedure, it can be argued that adobe buildings behave thermally efficient in summer owing to its high *R* value. It has good resistance to heat travel through the wall, owing to its thermal mass and the organic property of its constituent compositions. Consequently, lesser cooling energy is required in summer, when brought under comparison with modern building materials. On the trajectory of poor performance of the building material and energy subsequently required, this behaviour of adobe material is the most pivotal advantage of adobe buildings.

9.2.4. Disadvantages of adobe materials—according to simulation procedure

However, despite the enormous adulations accorded to Adobe buildings, they still basically have their own disadvantages. Such which capitally include its bad behaviour in winter. According to the simulation procedure, more energy (electricity) is expended on heating in winter, because of the high *U*-value and permeability of its organic constituent. Relatively, owing to the dampness it is often subjected to in winter, there is always more humidity in the internal environment and thus, more heat is lost via the heat different between the internal and external. Hence, in the context of the modern building material, this is deemed as a capital disadvantage, unless upgrade methodologies are adopted.

10. Conclusion

At this point, it will be deemed as peddling a time-worn out cliché to emphasis the rhetoric that adobe building are more earth conscious as palpable by the carbon emission rate. However, this is possible owing to the independence of the internal spaces on artificial technological comforts. As theoretically discussed, bulk of the heat loss and gain in any building is through the wall. Hence, adobe as a good earth friendly material has a counter effect on the prevailing environmental conditions. It is also noteworthy moreover, that; despite the seeming overwhelming advantages of adobe as a construction material, it still has a poor insulating property in winter. Adobe walls are very permeable; hence, the extent of dampness

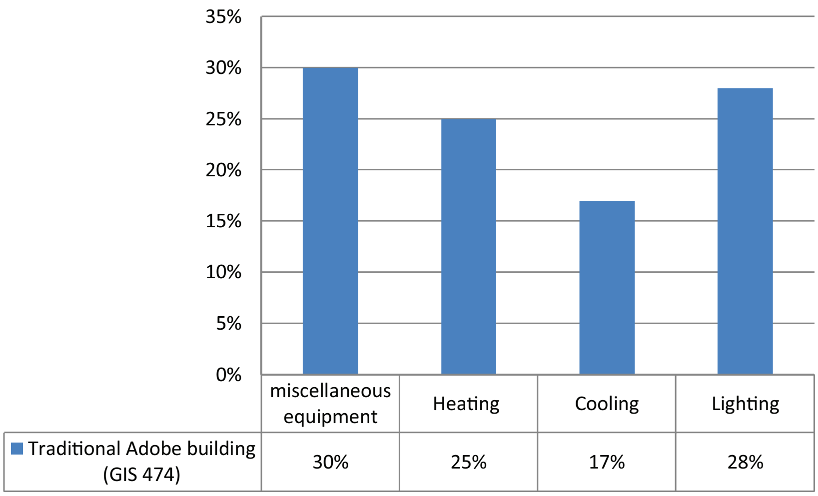


Fig. 10. Energy consumption in an adobe building.

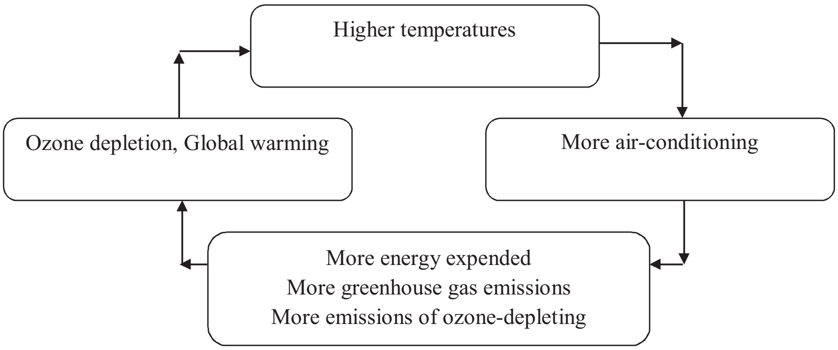


Fig. 11. The interplay between energy consumption in building and greenhouse effects.

makes the interior spaces colder in winter. Therefore, for the contemporary building industry to adopt adobe as one of its construction material, extra attention has to be drawn to this property.

Affirmatively, as seen in Fig. 11, the interplay between energy consumption and greenhouse gas emission will be an unending circle for as long as contemporary buildings continues to employ building materials with poor thermal capacity.

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