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Environmental Impact Assessment as a Tool for Achieving Environmental Building Design

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ABSTRACT

This paper is concerned with the environmental impact of buildings, especially the global, and local impact and environmental building design. The study investigates two main aspects that contribute to these concerns: adverse environmental impact of energy buildings and architectural design approaches to improve the environmental quality via decreasing the buildings' energy consumptions. The investigation of the global and local environmental issues caused by the building's impact was used to define the importance of developing architectural design alternatives to reduce this impact. It is hypothesized that building design, which considers environmental aspects, particularly at the architectural conceptual design stage, can significantly reduce buildings energy consumption and CO^2 emission; and, in turn, improve the environmental quality. This design phase provides flexibility for shaping building form, applying suitable natural ventilation methods, and using recyclable construction materials, which make buildings environmentally beneficial [1]. The assessment of the environmental impact of an existing building was applied to provide evidence that natural ventilation and passive design if considered at the architectural conceptual design stage, could significantly contribute to reducing energy buildings' environmental impacts [2]. The assessment is concerned with the impact of global and local environmental issues, particularly carbon dioxide emissions. To achieve this purpose, moreover, a case study was environmentally assessed through evaluating proposed architectural design alternatives as ways of achieving environmental improvement. This assessment will also be more beneficial if it is applied to a building that has met environmental concerns during its design stage. The results emphasize that decreasing buildings' environmental impact could be achieved through considering environmental means at the architectural conceptual design stage. Eg, natural ventilation and passive design if considered as a major part of the building form and design could play a major role in decreasing buildings' energy consumption and CO^2 emission and, sequentially, achieving environmental buildings [3].

1. Introduction

Environmental issues are becoming increasingly crucial for public concern worldwide. Consequently, buildings' environmental impact, as one of the environmental issues, faces significant and intensive concerns. This is because buildings are responsible for external air pollution. In energy buildings, the use of space, water heating, lighting, and air conditioning, e.g., accounts for a considerable amount of the UK's annual emissions of greenhouse gases (GHGs). In 2019, the Department for Business, Energy and Industrial Strategy identified that "*greenhouse gas emissions for the four highest-emitting industries, including households, UK, 1990 to 2017, households have been the biggest emitter of GHGs since 2015, accounting for one-quarter of total UK GHG emissions in 2017*", Table 1 [4].

Moreover, the Department for Business, Energy and Industrial Strategy 2019 defined that the share of the business, residential and public sectors in the total amount of carbon dioxide emissions (CO^2) accounts for more than one-third of the UK's annual emissions of CO^2. The share of business, residential and public sectors in the total amount of CO^2 emissions increased from 0.342 percent in 1990 to 37.0 in 2000. This share decreased to 34.6 percent in 2010. In 2019, the share of business, residential and public sectors increased to 39.2 percent of the total amount of CO^2 emissions. During the same period, the total amount of CO^2 emissions decreased from 595.7 $MtCO^2e$ in 1990 to 558.5 $MtCO^2e$ in 2000, to 498.5 $MtCO^2e$ in 2010, and 351.5 $MtCO^2e$ in 2019. Although the total amount of CO^2 has decreased by 43.7 percent from 1990 to 2019; the share of the business, residential and public sectors of the total amount of the CO^2 emissions has increased by 14.62 percent during the same period, Table (1) [4] [5].

Table 1 Greenhouse and CO^2 Emissions in the UK during 1990-2019

	1990 $MtCO^2e$	2000 $MtCO^2e$	2010 $MtCO^2e$	2019 $MtCO^2e$
Total Greenhouse gases	793.8	707.9	600.9	435.2
Total CO2 Emissions	595.7	558.5	498.5	351.5
Business, Residential and Public CO2	203.44	206.68	172.37	137.89
Share of Business and Residential CO^2	0.342	0.370	0.346	0.392

Therefore, the public concern and international governments' commitments, made at the different Rio summits; 1992, 2002, and 2012 have combined to bring the new legislation to force building design to limit and reduce energy use in buildings and, in turn, their environmental impact. Recent planning legislation and new building regulations require that the developments and individual buildings were designed to minimize their environmental impact and energy consumption [6] [7] [8].

Future controls are likely to be more demanding and wide-ranging. The Agenda 21, Earth Summit, Rio de Janeiro stated that *"The government is committed to developing instruments which make markets work for the environment and channel development down sustainable paths. Policy directives to local authorities on Agenda 21 have farreaching implications for everyone and particularly for*

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building designers. Each local authority should adopt a 'local Agenda 21' for the community" [8].

Consequently, it is hypothesized that architectural building design, which highly considers environmental aspects at the design stage, can contribute considerably to reducing pollution and, in turn, improving the environmental quality. This is because decisions at a building design stage have long-term environmental impact consequences. Therefore, it is important to consider aspects of design which, e.g., provide flexibility for changes in use; or make use of recyclable materials as they are environmentally beneficial [9].

However, to enable designers to comply with current and future legislation, to meet international commitments, and to satisfy public concerns, effective methods for assessment of the environmental impact of buildings are required. Therefore, the Building Research Establishment Environmental Assessment Method (BREEAM) is a method devised by the Building Research Establishment (BRE) to assess the environmental impact of buildings. It was the first and is still one of only a few schemes available worldwide for assessing buildings' environmental impact. It is also described as the most broadly adopted method used until now.

BREEAM is an assessment undertaken by independent licensed assessors using scientifically based sustainability metrics and indices that cover a range of environmental issues. BREEAM types assess energy and water use, pollution, transport, materials, waste, ecology, and management processes. For evaluation purposes, BREEAM, as an assessment method, could be positioned between minimal legislative requirements and speculative standards. There are different versions of BREEAM for different building types such as offices, supermarkets, houses, and industrial units. New versions are being developed and existing versions are updated to incorporate new knowledge in the field as it becomes available. Moreover, BREEAM works by assigning credits to each of many issues that have an impact on either the global, local or indoor environment. These cover a wide variety of topics, ranging from CO^2 emissions, use of sustainably managed timber, and indoor air quality [10].

Accordingly, the purpose of this research is to assess the environmental impact of an existing building. Within this context, it is preferred to analyze a building that has met environmental concerns during the design stage. This is to evaluate how much a building is adopted with the environment. In other words, how much the environmental consideration at the design stage could decrease the negative impact of a building on the environment, global, and neighborhood? The rationale behind this assessment is to provide evidence that considering environmental issues at the design stage could lead to an environmental building, which, sequentially, is environmentally beneficial. The scope of the assessment will also include the impact of 1- global issues, where the benefits include carbon dioxide emissions; and 2- local where the benefits are to the outdoor environment near to the building [1].

Since the range of these issues is wide and the amount of required data is massive; the technical function of these issues will be examined at a conceptual level. It will be the purpose of the research to take the strategies of environmental assessment from their original level to a level where their integrity can be assessed both quantitatively and qualitatively. Within this process, the focus will be on environmental issues, which are the main current research concerns but, unfortunately, they are still out of building designs standard features [11].

The proposed case study of this research, accordingly, is called Portland Street Building, Portsmouth University, Portsmouth city, England. The Portland Street Building is selected as a case study because its design brief emphasized the necessity for environmental awareness that should be expressed in the building's form and details. Accordingly, intensive environmental concern has been provided to this building during all its design stages, including architecture, structure, mechanics, construction, etc. This building also provides a great opportunity to conceptually experiment with the ideas of passive environmental benefits. Therefore, testing how much this building is adopted with the environment. In other words, how much the environmental consideration at the design stage could decrease buildings' environmental impacts?

Therefore, the environmental impact assessment will include the building design parameters such as: first, the building impact on the global issues, in terms of its carbon dioxide emission [12]. The applied methodology, accordingly, was based on two different methods, which enabled to drive of a conclusion. The net annual primary energy consumption, thus, was measured by two different methods, LT and HTB2.

2. Literature Review

2.1. Human Comfort

Creating a thermally comfortable living environment still one of the most important required parameters of community planning and design. This depends mainly on environmental, social, and cultural aspects of location, and building technology methods, which are based mainly on decreasing the energy consumption and, in turn, environmental impact. As a result, human comfort inside buildings is one of the most important environmental concerns. Human comfort is a subjective matter and varies with individuals. It involves several environmental variables. These variables include temperature effects, air movement, and humidity [13].

Common experience shows that writing or any light work involving manual skills is not helped by cold hands. The sensations of fatigue are also aggravated if access heat can not be got rid of adequately. Room temperature, therefore, is an important physical factor influencing the performance of such. In casual summer clothing, the optimum temperature for sedentary work at 50 percent relative humidity is about 25-26° C. For more formal and winter clothing, the optimum temperature is 20-21° C. Studies have also shown that comfort levels do not just relate to air temperature, but also to mean radiant temperature [14].

The main control of internal air temperature is ventilation, which introduces fresh cooler air and removes unwanted warm air. Air movement is also associated with ventilation. Increased levels of air movements across the human body will aid perspiration and hence increase heat loss through forced convection. The use of natural ventilation in offices has shown that positively better results have been found with regards to the sense of users' wellbeing. Different architectural elements and features such as windows and stacks can play a significant role in facilitating natural ventilation requirements and, in turn, thermal comfort. Humidity, moreover, influences the rate at which moisture can evaporate from the skin. If the relative humidity values are kept within a certain range, then this evaporation process can take place readily at rates governed by air temperature and perspiration rates. This range is generally considered to be between 40 percent and 70 percent [13].

2.2. Passive Design

Passive design is the first known method for achieving human comfort, and best illustrated in ancient vernacular buildings, as a direct expression of adaptation to climate and resource constraints. In the 20th century, the man started to think of comfort as a product of energy consumption whereas building components, walls, windows, shutters, courtyards were used effectively as means of achieving comfort. Building technology that relies on passive controls for cooling and heating, may decrease the need for any mechanical controls. Building technology methods are; natural ventilation, shading control, and passive capture systems [15].

In planning and architectural design are made to achieve bioclimatic comfortable indoor spaces with the least use of energy. The emphasis is on the design of the building shell, every component of the building is used to achieve comfort. The passive cooling, shading systems, and thermal capture become very important systems of climate balanced design. Minimizing energy consumption could be achieved by interacting designs and systems with the surrounding environment, natural cooling, and heating of buildings. The potential here has always been providing adequate comfort measures for occupants of the space, as well as reducing energy consumption. Therefore, design concepts and building detailing can provide significant support during the planning and design process [16].

2.3. Stack Ventilation

Stack ventilation is one of the natural ventilation elements. It rises above the building's height level. Its mechanical technique could simply be explained by naturally using light dense warm air to rise and be replaced by heavy dense cold air. Two different air pressures are defined at the top and bottom of the stack ventilation. At the top, positive air pressure is found, as a result of natural air movements, and at the bottom, a negative pressure also occurs. This trend allows air movement through the stack ventilation without using any mechanical means. This air movement can also be applied to naturally ventilate buildings. The efficiency of stack ventilation is influenced by 1. pattern of the building's openings: size, design height, etc.; 2. stack ventilation height; and 3. difference between the bottom and top temperatures [16].

3. Portsmouth Location and Climate

Portsmouth city is located: in the south of England, in Hampshire on Portsea Island with an area of 40.25 sq km. It is located about 110 km south-west of London and 31 km south-east of Southampton, Figure 1. Its population size was 205,100 in 2011, which is projected at 238,800 in 2019.

As a result of its location, Portsmouth climate could be described as a mild oceanic climate. Comparing to the rest of England, Portsmouth has a mild microclimate. Therefore, Portsmouth temperature could be defined as follows: first, in winter: the average maximum temperature in January is 10 °C and lowest temperature in February is −8 °C; and second, in summer: the average maximum temperature in July is 22 °C, and the average minimum temperature is 15 °C. The average maximum precipitation in Portsmouth is about 700 mm per year in June, with minimum rain of 40 mm in April. The average sunshine hours per year is 1920, which is about 22.4 percent of the total sunshine of the year. The average maximum sea temperature is 17 °C, with a minimum temperature of 8 °C [17].

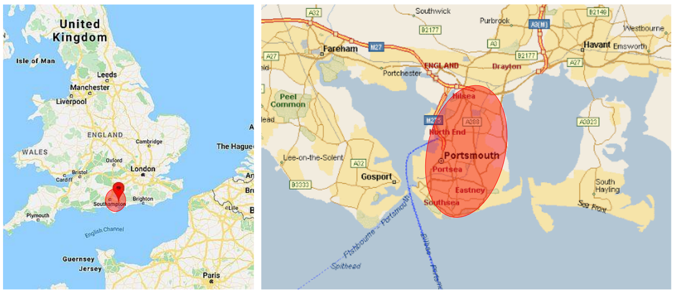

Figure 1 Location Map of Portsmouth City, England

Source http://www.worldeasyguides.com/uk/england/portsmouth/

4. Portland Street Building Design Brief and Natural Ventilation System

4.1. Portland Street Building Design Brief

The Portland Street Building, which was established during the 1990s, provided accommodation for the Faculty of Environmental Studies (FES), Figure 5. The FES accommodated the School of Architecture and the Department of Land and Construction Management. In 2014, the Portland Street Building was remodeled to house Schools for Information Services, Business, and Engineering, Figures 2, 3,4, 5, and 6 [18].

The design brief of the Portland Street Building emphasized the necessity of expressing environmental awareness in the building's form. Accordingly, intensive environmental concerns have been provided to the building during all design stages. Accordingly, the design concept has an 'E' shape which is formed in four stories and depends mainly on using five open staircases operating as stack ventilation, Figures 2, 3, and 4. The 'E' shaped plan, with the left (north), bottom (west), and top (east) wings, houses the main teaching and support facilities organized on both edges of the main corridor including studios, multi-media suits, seminar and tutorial rooms, IT centers, small lecture spaces, and administration. The bottom (west) wing is almost two times the length of the top (east) wing, Figure 2. The 'E' shape also wraps around a full-height atrium, which is covered with a glazed roof and solar shaded, Figure 5 and 6. This atrium accommodates a 200-seat-lecture theater on the first floor and a coffee area and an exhibition space on the ground floor, Figures 2, 5, 6, 7, and 8 [19].

4.2. Portland Street Building Natural Ventilation System

The design concept, except the lecture theater, provided the building with different types of natural ventilation systems, including single- and cross-sides, and stack ventilation. These ventilation types are utilized within the building as of the following. 1- The stack ventilation system is facilitated through top glazed staircases with horizontal fans to perform as solar stacks and, in turn, activate ventilation. The staircases are linked to the rooms in the lowers three floors through grills fixed in corridors false ceilings, which work as ducts, to facilitate air movement via staircases, Figure 6. The fans could be activated when the air pressure differences occurred creating needed air movement. These fans could also facilitate night ventilation when it is needed. 2- The single- and cross-sided ventilation systems were applied partially through openable wooden windows in the small offices. Most of the small offices and seminar rooms are single-side natural ventilation, in which windows open to outside. These offices also have access to forced natural ventilation through ducts in the main corridor's ceiling. 3- The third floor depends upon a mix of mechanical and single-sided ventilation, and cross ventilation linked to a stack effect in the atrium. 4- The resource center which occupies three floors in the north wing of the building, the left (north) wing, is ventilated by a stack effect that utilizes the four-story-high voids that connect the different levels. 5- The top floor, which has a timber and glazing roof, is mainly cross-sides ventilated via windows along its edges. The natural ventilation system, moreover, could facilitate internal acceptable airflow rates during winter, without increasing energy for heating fresh air and without allowing draughts. During summer, the natural ventilation system is capable to absorb the daytime high temperature by providing night ventilation to decrease building fabric temperature. Moreover, the large lecture and two small theaters are ventilated with air conditioning systems. The building was also heated by a hot water system, which applied under floors [20].

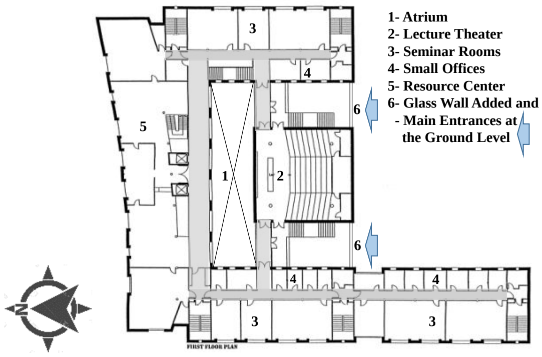

Figure 2 First Floor Plan

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Figure 3 Portland Building External Roof Details

Source Developed by the Authors

Figure 4 Portland Building External Stack Ventilation Details

Source Developed by the Authors

Figure 5 Portland Building Southern Facade Details
Source Developed by the Authors

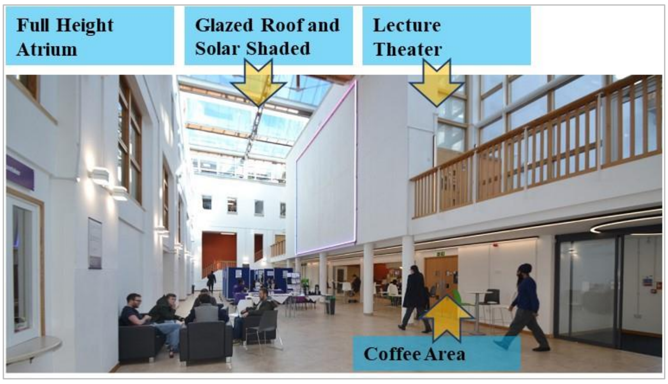

Figure 6 Portland Building Internal Atrium Details
Source Developed by the Authors

Figure 7 Portland Building Internal Atrium and Upper Floor Details
Source Developed by the Authors

Figure 8 Portland Building Upper Floor Details
Source Developed by the Authors

Figure 9 Portland Building Original External Facade Before Remodelling
Source: http://projects.bre.co1

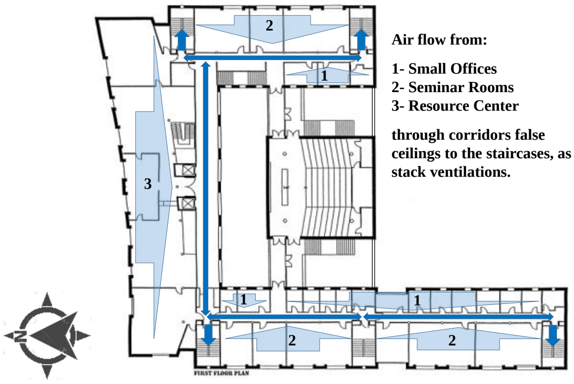

Figure 10 Portland Building: Plan of Internal Stack Ventilation System
Source: Developed by the Authors from:

Figure 11 Portland Building Internal Stack Ventilation System
Source Developed by the Authors from: https://projects.bre.co.uk/natvent/reports/monitoring/summary/gb3summ.pdf

7. Assessment Methods and Parameters

The purpose of the Portland Building assessment is to define, first, the impact of the building on the global and local environment, in terms of the production of the carbon dioxide of the building and to what extent it is an environmental building; and, second, the importance of considering the environmental aspects at the early design stages, particularly, at the architectural conceptual design stage. The assessment, therefore, is based on two different methods, LT and the building model HTB2. Both methods are capable enough to measure the net annual primary energy consumption and CO^2 emissions and to identify the conclusion.

4.3. Assessment Methods

The LT method is a broad analysis and assumption of a building's thermal performance. The purpose of LT is to give: first, a general indication of thermal performance of an existing building; second, a building net annual energy consumption kwh/m^2 and annual emission of CO^2 kg/ m^2, and third, an overall judgment for design alternatives, particularly at the building architectural conceptual design stage, in terms of form, using passive or non-passive design, and applying natural ventilation [21] [22].

To provide a more accurate indication of the thermal performance of our case study as an existing building, moreover, it was preferable to use an additional method such as the building model HTB2. The building model HTB2 is a computer program that simulates the thermal performance of an existing building. The building model HTB2, generally, is suitable for defining out internal temperature of different parts of the building in addition to measuring annual energy consumption kwh/m^2 and emission of CO^2 kg/m^2 [23] [24].

4.4. Assessment Parameters

To facilitate building assessment, according to the requirements of BREEAM and assessment methods, initial data should be identified, including urban horizon factor, buffer-space thermal saving, and passive and non-passive zones of the building, which could be defined as of the following: as stated above, the building has an E-shape with four stories. It is also located in an urban area on a site which moderately overshadowed from the west with an estimated angle of 15-45. It is slightly overshadowed from the North, East, and south with an estimated angle of less than 15. The building has an east-facing atrium with a four-stories building, with a coffee area, lecturing room, and multi-purpose space in the middle of the east side of the atrium.

The building is naturally ventilated, except for the large and two-small lecturing rooms, which are air-conditioned with air filtration. The climate zone for the building is southern England with a type C Building. It is assumed that the building is with low internal gains of 15 W/m^2 and the 300-lux lighting datum.

The passive and non-passive zones; for ground, first, and second floors; are taken off the plans, with 6.0 m wide for open spaces. The top floor is all passive zone with all side-lit and no roof-lit. The assumption includes moveable shading, clear glazing, light internal finishes, and, accordingly, an effective sky angle less than 45. Therefore, the buffer adjacent zone is 4.5 m deep. The values of the glazing ratios are calculated from the facades of the building. The actual framing obstruction for all glazing is 20 percent, except the roof; for which it is calculated as 30 percent.

The length of the separating wall, between the atrium and the resource center, is measured and the type of the atrium is defined as something between Types 1 and 2 with single external glazing of the atrium. The ventilation pre-heating is calculated in two manners modes A and C. Thus, the specific Buffer-space Thermal Saving (BTS) are 0.53 and 0.59 MWh/my, which are used in LT worksheets [24] [25].

Furthermore, the assessment parameters of the building model HTB2 includes the effect of construction materials, small power machines, small equipment, occupants' size, heat system, lighting units, ventilation system, filtration for the lecture theater, and metrology calculation through the diary of winter and summer [5].

5. Environmental Impact Assessment

5.1. LT Assessment Method

The LT assessment was based on six assumed alternatives for comparison as of the following, the building with 1- a glass-roof-covered-atrium, natural ventilation, except for the lecture theater, which is air-conditioned but without air filtration, light mechanical ventilation for the atrium, etc.); 2- a glass-roof-covered-atrium and a full air-conditioning system, light mechanical ventilation for the atrium; 3- uncovered atrium, a courtyard instead, and natural ventilation, except the lecture theater which is air-conditioned, etc.; 4- uncovered atrium, a courtyard instead, and a full air- conditioning system; 5- a solid-slab-covered-atrium and natural ventilation, except the lecture theater which is air-conditioned, light mechanical ventilation for the atrium area, etc.; and 6- a solid-slab-covered-atrium and full air- conditioning system. Additional general data also applied for all alternatives as a source of internal heat, including small power machines in offices such as computers, copiers, printers, etc, and lighting units, in terms of energy consumption [27].

5.2. HTB2 Assessment Method

HTB2 is a model that investigates buildings' thermal performance. The buildings' thermal performance utilizes or/and control occupants' interaction, solar energy, and incidental gains with buildings' systems. HTB2, moreover, determines solar and incidental gains, heating system and control responses, ventilation transport, and the operation schedules specification at short timescales. HTB2 database includes fabric temperatures, space air temperatures, net convective heat gains to internal spaces, irradiance to surfaces from incidental sources, and direct heat gains to the fabric. External driving forces; including external air temperature, solar irradiances, etc.; could be defuned from meteorological data.

The building model HTB2 assessment method is used to assess the thermal performance of the Portland Building to define its total annual energy consumption kwh/m^2, amount of CO^2 emission, and air temperature of a space, based on its energy contents. To accomplish this purpose, the building model HBT2 analysis also encompasses the effect of Portland Building small power machines, in terms of heat production and energy consumption, in offices such as computers, copiers, printers, etc.; and small equipment in the coffee area such as coffee, cooking, and food machines, refrigerators, etc.; occupants size during winter and summer, heating system, lighting units, ventilation systems, air-condition and mechanical filtration for the lecture theatre, and metrology calculation through the diary of winter and summer [23].

6. Assessment Results and Recommendations:

6.1. LT Results and Recommendations:

Tables 2 and 3; and Figures 7 and 8 show the summary results of the LT Method analysis design options as follows: 1- For the first option, the net annual primary energy consumption is 95 kWh/m2, which gives net annual CO^2 emission of 19.96 kg/m^2. According to the BREEAM criteria, this level of carbon dioxide emission is difficult to be accomplished. Once it is reached, it represents an advance on the achievement of the BREEM Low Energy Office buildings. 2- The rest of the results could be summarized, accordingly. The net annual primary energy consumption of the: second option is 219 kWh/ m^2, with 47.13 kg/m^2 of CO^2 emission; third option is 102 kWh/m^2, with 21.1 kg/ m^2 of CO^2 emission; fourth option is 226 kWh/ m^2, with 48.46 kg/ m^2 of CO^2 emission; fifth option is 191 kWh/ m^2, with 40.62 kg/ m^2 of CO^2 emission; and sixth option is 312 kWh/ m^2, with 67.28 kg/ m^2 of CO^2 emission [9].

Consequently, comparing the outcomes of the first alternative to the outcomes of the rest of the alternatives provides strong evidence that applying passive design and natural ventilation at buildings architectural design concepts decrease buildings energy consumptions and CO^2 emissions.

Moreover, comparing between the results of the first and second options, the annual primary energy consumption and CO^2 emissions of the second option are more than doubled the amount of energy consumption CO^2 of the first option. This is mainly because the second option depended on applying a fully air-conditioned building, although it also included a glass-roof-covered-atrium as a source of natural lighting.

A comparison between the outcomes of the first and third alternatives defines that the energy consumption and the amount of the annual CO^2 emission of the third alternative is a little higher than the first one. This is because the assessment of the third option is based on a courtyard rather than an atrium. Therefore, it could also be assumed that the atrium would be more suitable to the building climate zone than using a courtyard.

The outcomes of the first, third, and fifth alternatives also give the building with annual low energy consumptions and low CO^2 emissions comparing to the results of the second, fourth and sixth options. The results of the second, fourth and sixth options show that the net annual energy consumptions and CO^2 emissions increase dramatically as a result of applying air-conditioning systems for the whole building. The results, therefore, strongly support the notion of applying natural ventilation instead of using air-conditioning systems.

Moreover, the results of the fifth design option show that the net annual energy consumption is more than doubled comparing to the results of the first and third design options because it is assumed that the fifth design option includes the atrium as a non-passive zone and the building is naturally ventilated. At the same time, the outcomes of the sixth alternative are more than tripled compared to the first and third options. The results of the sixth option are also more than one and a half times the second, fourth and fifth options. This is because it is assumed the atrium is a non-passive zone, in addition to applying full air-conditioning systems to the building. In other words, the outcomes of applying full air-conditioning systems for the whole building and using a non-passive zone provide strong evidence that the net annual energy consumptions and CO^2 emissions increase dramatically. E.g., the annual energy consumption of the sixth alternative of 312 kWh/m^2 with 67.28 kg/m^2 of net annual CO^2 emission is almost 3.3 times the results of the passive atrium and naturally ventilated building of the first alternative.

Consequently, these outcomes emphasize that buildings with natural ventilation and passive design consume much less energy and produce much less CO^2 compared to buildings with non-passive design and air-conditioning systems. The results, in other words, strongly support the notion of applying natural ventilation instead of using air-conditioning systems.

Moreover, applying natural ventilation and passive design at the conceptual architectural design conceptual stage is important for decreasing energy consumption and, in turn, increasing environmental quality. The architectural conceptual stage is the right building design phase, at which, architectural design alternatives could be assessed and evaluated for identifying the most suitable environmental building.

Table 2 Net Annual Energy Consumption

Calculations	Net Annual Energy Consumption kWh/m²					
	Option (1)	Option (2)	Option (3)	Option (4)	Option (5)	Option (6)
Light	56	56	54	54	139	139
Heat	36	36	45	45	44	44
V & C	3	127	3	127	8	129
Total	95	219	102	226	191	312

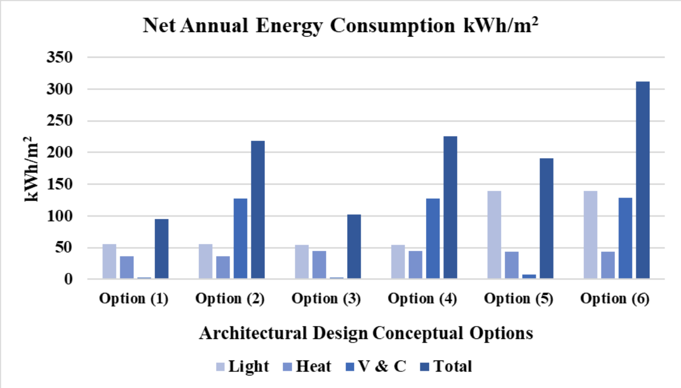

Figure 7 Net Annual Energy Consumption Chart

Table 3 Net Annual CO^2 Emission

Calculations	Net Annual CO^2 Emission kg/m²					
	Option (1)	Option (2)	Option (3)	Option (4)	Option (5)	Option (6)
Light	12.35	12.35	11.92	11.92	30.55	30.55
Heat	6.93	6.93	8.61	8.61	8.37	8.37
V & C	0.68	27.85	0.57	27.93	1.70	28.36
Total	19.96	47.13	21.1	48.46	40.62	67.28

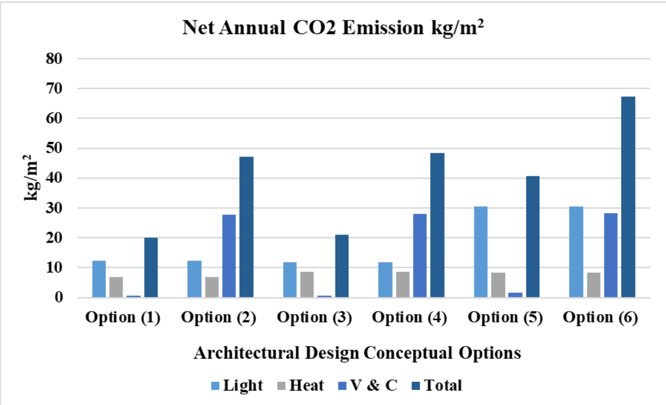

Figure 8 Net Annual CO^2 Emission Chart

6.2. HTB2 Results and Recommendations

The results of the analysis of HTB2 show that the actual annual energy consumption of the Portland Building is 312 kWh/ m². The annual emission of CO^2, thus, is 65.5 kg/m², Table 4. Comparing between HTB2 and LT assessment outcomes, particularly the first option, the differences are considerable, Table 4. The rationale behind these differences could be explained as follows: First, few additional data have been considered for HTB2 assessment, which was not applicable for LT assessment method such as 1- lecture theater ventilation system was air-conditioned with air filtration; 2- mechanical ventilation for the atrium; 3- occupants sizes were 170 during wintertime and 140 during summertime; and 4- energy consumption of small power and equipment in offices and coffee area. Despite these differences, the results of the HTB2 method, comparing to BREEAM criteria, show that the building represents a very good design for a naturally ventilated building.

Second, the purpose of the LT assessment method is to identify a general image of the appropriate architectural design concept, in terms of its expected environmental impact and the annual amount of CO^2 emission, at the architectural conceptual design stage. In contrast, HTB2 is an accurate assessment method that defines the exact annual amount of CO^2 emission of an existing building, with precise assessment parameters. To have a reasonable comparison between the results of LT and HTB2 methods, the assessment of HBT2 should have included the same options as well as LT assessment. Running such an assessment will require massive data assumptions, which would not be a practical process. Therefore, it is better off to deal with LT and HTB2 independently.

Table 4 Comparison between HTB2 and LT Assessment Outcomes

Assessment Methods	Net Annual CO^2 Emission kg/m²	Net Annual Energy Consumption kWh/m²
LT (Option 1)	95	19.96
HTB2	312	65.5

7. Conclusion

The study explains the impact of energy buildings on the environment. The outcomes of the investigation of the global and local issues provide strong evidence that buildings harm the environment. Buildings are one of the factors that increase the warmth of the Earth's surface. Buildings, moreover, are one of the main factors, which are responsible for the ozone layer depletion. In urban areas, unlimited use of energy in buildings increases the rate of pollution which adversely affects human health. Inadequate ventilation and some construction materials being used in buildings are pollutant sources, which have potential damages to human health [5].

Also, it is not only the investigation of energy building impact but also finding a formula for decreasing this impact. Developing architectural design to be compatible with the environmental aspects could play a great role in this process. The rationale behind developing the architectural design is to influence developments at an early design stage and raise the environmental profile concerns through the building design process. Architectural building design can contribute considerably to reducing building impact and, in turn, improving the environmental quality by enabling sensitive development and appropriate building designs, and operations to be recognized. [26]

The outcomes also focus on the environmental requirements and architectural approaches as factors that enhance buildings development. The requirements and approaches provide flexibility for design change according to different environments. They provide the basis, background information, design guidance, and practical assessment of adapting the natural ventilation by using natural means in building form. They are good practices to be expressed [27].

The case study, moreover, provides strong evidence that natural means, if considered at the design stage, could contribute significantly to reduce the environmental building impact. It is also emphasized that environmental impact assessment methods should be developed to enable designers to test their architectural design at an early design stage. The result could be considered as an assurance of new buildings' compatibility with the environmental requirements. Existing buildings could also be assessed in the favour of the environment [28].

Finally, in the case of Egypt and North Africa environments, unfortunately, the current environmental impact assessment methods are not suitable. Therefore, future directions for further research on decreasing the environmental building impact should focus on adapting environmental impact assessment, developed in the west, to be suitable for Egypt and North Africa environments. Although it is expensive and time-consuming, it is required to enable designers to assess their existing and future buildings.

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