
Sustainable Architecture and Health: The Factors That Affect User's Health in Public Buildings and Sustainable Ways to Improve It

Edibe Sena ÇAKIN - Hertfordshire University

ABSTRACT

This paper explores the sustainable design strategies and the ways they can improve occupants' health. Any article or book on sustainability mentions that sustainable architecture and design provide budget and environment friendly, waste reducing and energy saving methods. These strategies are also known to have a direct link between both mental and physical health. The given topics are discussing how these design strategies can help improve health and what impacts they have on it. Sustainable architecture is one of the most discussed topics in today's world. It is not surprising that most people will think of architecture anytime they hear the word sustainability and that is because architecture is not only about buildings but also urban design and use of space. Our surrounding consists of half natural creations and half man-made products and the most space-occupying elements around us are buildings. Buildings are always in use in our everyday lives. People go to work, school, shopping centres and just staying home is also another way to use a building. If we knew that the house we live in is self-efficient, environment friendly and it minimises the amount of waste produced, by using mostly recycled resources, that would make us feel much more healthier as it would uplift our mood to see lower pricing for electricity, water and even construction costs. It is a fact that mental health has a huge impact on our physical health as well. If buildings occupy such a big space in our lives, can we use them in an efficient way which will create a healthy habitat for humanity and planet-friendly environment? A good design for a building is essential for protecting the natural environment, by following specification that will minimize the consumption of energy and environmental pollution. Buildings can be erected in such a way that it lets sufficient natural light in, and this would save on the energy that would have been used by artificial lighting. Use of the correct energy saving, lighting tools would also save a great deal of energy and money. Recycling and purifying of waste from the construction site is another way of cutting down on environmental pollution and therefore the architects and engineers should design in a way which this is achieved. More recyclable materials could also be used in the construction of structures. These factors that affect the environmental conditions also define the quality of life for users. The amount of waste produced in the construction site cause severe pollution and health issues. Using sustainable materials and adapting the design to the landscape instead of demolishing its surrounding, positioning the building and designing a façade in a way that will respond to the solar path and benefit from natural light are only a few of the ways which this can be achieved.

Keywords: *Architecture, Health, Public Buildings, Sustainable*

1. Introduction

In the simplest terms, the “green building” or sustainable architecture is environment friendly and resource efficient throughout its cycle. Through the use of these technologies, designers are making sustainable buildings and their different designs with respect to the requirements of the buildings that depends upon the environment of the surrounding areas of buildings (Pineo et al., 2018, Wang et al., 2018). After a construction has been completed it is always a good practice to clear off the site wastes and remains of concrete and iron to avoid risks of the environment getting polluted as well as protect people’s lives from the risk of the dusty nature that these materials have (Ghaffarianhoseini et al., 2018, He et al., 2018). Sick building syndrome refers to acute or comfort when working in construction site. This syndrome includes hyper-sensitive reaction or irritation (Allen and Iano, 2019). Construction sites are a major source of soil pollution especially in urban areas. Toxic substances produced at the site such as diesel and other chemicals may be absorbed into the soil (Allen and Iano, 2019). This may result in different health issues. Construction sites are responsible for producing a lot of noise from vehicles and machinery. Excessive noise can be irritating and may have health effects such as hearing loss, high blood pressure, breathing problems and stress. There is evidently a lot of waste that is being disposed at the construction site (Allen and Iano, 2019). Some of the waste include used up iron, empty material storage bags and used water and a proper waste removal plan should be considered before the beginning of construction to prevent the pollution and its harmful effects. (Allen and Iano, 2019). This prevention can be provided by recycling, reuse of materials, reducing waste, and zero waste. (Allen and Iano, 2019). Shortness of the lifecycle of the chosen building materials can also lower the sustainability of the building and will require more repairs and changes throughout the existence of the structure (Allen and Iano, 2019). Green building, which is also known as ‘sustainable building’ or ‘green construction’ refers to the structure building process and the structures that are resource and self efficient and environmentally responsible throughout the lifecycle of the structure. The lifecycle depends on the construction method, design strategies, renovations applied, maintenance of the building, operation process and choice of materials (Allam and Jones, 2018). It is stated that the correct way of using resources is known to increase good thermal performance of the material in the envelope of the building (Allam and Jones, 2018). It can reduce the amount of energy that is required to maintain the building and this is the most important factor when it comes to choosing the right material of the structure (Allam and Jones, 2018). Lifecycle assessment is known as the most important factor that can impact on deciding the building material. Quick growing materials made from agriculture waste are called ‘rapidly renewable materials’ (Allam and Jones, 2018). This essay explains the constructional methods which can prevent global warming, air and water pollution that are known to have a huge impact on the health and environment. Le Corbusier and Frank Lloyd Wright applied some of these strategies to their buildings to achieve a great design that preserves the existing landscape and similar design solutions can be used to reduce the negative impact on the environment and human health. Material usage in construction, green roofs, lighting, biophilic design and solar design planning are the other key solutions to a successful green construction design. These are the common elements that have impacts on both human health and wildlife. So, how can sustainable design help overcome these issues we are facing by following these construction methods?

Constructional Impacts on The Environment

Sustainable methods that are followed in the construction of structures and urban design have created a positive impact on the environment in two main ways. These are usage of natural and recyclable resources and preventing the emission of harmful pollutants into the environment (Altomonte et al., 2019). The prevention of these two factors can be divided into; deforestation, global warming, polluting emissions, loss of natural resources and ozone depletion (Altomonte et al., 2019). Cutting down the trees without planting new ones or replacing them in order to use the site for construction purposes cause deforestation (Altomonte et al., 2019). Greenery play a very significant role in the environment which includes providing oxygen and creating public spaces for people. Deforestation also causes loss of habitat to animals and plants species and they may end up being extinct. It is also important for maintaining the water cycle and preventing soil erosion (Altomonte et al., 2019). Forests are very important spaces which improving life quality and provide enough oxygen despite the pollution that human activities cause and deforestation causes loss of food, water and air. (Altomonte et al., 2019).

Air-Pollution

During the construction of buildings there is a lot of waste that is being released into the environment in form of gas, liquid or solid. (Altomonte et al., 2019). This emission may be harmful to the environment and also to life. Construction site vehicles take huge part in air-pollution as well, there are several substances in the fuel of car such as sulphur (Altomonte et al., 2019). There are abundant of nitrogen in the air. They all undergo oxidation process in order to form sulphur dioxide and nitrogen dioxide, which are the sources of acid rain (Altomonte et al., 2019). At the site of construction, used water should be treated before being released to the environment to prevent pollution while solid waste in form of plastic and metal should be all recycled (Carmona, 2019). Natural resources include water and energy and both of these are needed in construction of buildings (Carmona, 2019). If most of the available resources are used up in construction then other areas that also need these resources will end up suffering. The ozone is important in protecting the earth from penetration of the harmful ultraviolet rays (Altomonte et al., 2019). Depletion of this layer is mainly caused by emission of chlorofluorocarbons which can be majorly emitted from the construction sites. The alkane chain of chlorine and fluorine that will form radicals will decay the ozone layer and create a chain reaction in the environment (Altomonte et al., 2019). Construction activities release a lot of pollutants to the air. The main air pollutants include PM10, volatile organic compounds and gases like hydrogen sulphide, nitrogen oxides, carbon monoxide and carbon dioxide (Carmona, 2019). PM10 includes particles of concrete, cement, wood, stone, silica and the substances released by diesel machineries (Carmona, 2019). These pollutants are responsible for causing a wide range of respiratory illnesses.

Water Pollution

Water pollution is another major problem at a site of construction since water is mostly used at the site for varied purposes (Darko et al., 2018, Ding et al., 2018). Sixty percent of species live in water and that is why water pollution can cause serious threat on living organisms. Human beings also depend on water for survival and therefore water is very important (Darko et al., 2018, Ding et al., 2018). There is a variety of causes at a construction site that may cause water pollution such as

diesel, poisonous paint, solvents, cleaning materials, some other harmful substances and construction dirt (Darko et al., 2018, Ding et al., 2018). Water pollution may cause poisoning to human beings and to aquatic life and therefore water release from the site should be treated carefully. (Darko et al., 2018, Ding et al., 2018). Minimizing pollution by treating water before releasing it to the environment, recycling of construction products and fitting fume scrubbers to the chimney outputs to get rid of the solid pollutants. (Darko et al., 2018, Ding et al., 2018). More attention has to be given to the fact in identification removal of the false and inefficient activities that result in the loss of the clean water because this clean water can be used for so many other purposes and should also be given importance as it is the only thing that has to be present everywhere for the existence of life. (Darko et al., 2018, Ding et al., 2018) In the meantime, consideration must be made about the investigation of the new focus points and areas where the immense amounts of clean and drinking water can be created. There must be a superior control set up by the administration experts as far as the distribution and division of the essential water assets with the goal that all pieces of the populace get the equivalent offer that is additionally a fundamental right (Darko et al., 2018, Ding et al., 2018). Likewise, the increasingly effective ways that can diminish the wastage of water that is brought to the resident in their family unit offices.

Waste

Old buildings can be renovated and used again since it also saves on the use of materials and therefore reduce environmental pollution. An environmental impact assessment could enable an effective management of the environment (Darko et al., 2018, Ding et al., 2018) Some of the items which need assessments include waste disposal, thermal efficiency, water discharge, heat discharge and waste vapour discharge (Darko et al., 2018, Ding et al., 2018). An improved management system at the construction site could have a great impact in protecting the environment. For example, the site manager could set up proper guidelines and oversee the disposal and recycling of waste from the site. A clear set of policies and objectives should be set up that control wastage, recycling and pollution of the environment (Darko et al., 2018, Ding et al., 2018). It is also crucial to involve the community and to select materials that are renewable to be used at a construction site. This mainly cuts down on the wastage of the materials and hence prevent the pollution of the environment. An example is by using timber where possible then it can be made into chips for other uses or alternatively recycle used metals (Darko et al., 2018, Ding et al., 2018).

Sustainable Design Strategies of Frank Lloyd Wright and Le Corbusier

The modern building design and architecture is shaped by efforts and philosophies of many great architects of 20th century. The two of the most remarkable architectural design names who influenced modern architecture are Le Corbusier and Frank Lloyd Wright. The two architectural designers followed their particular design philosophies in designing and building residential and commercial architecture and their buildings bespeak of their particular ideologies in the field of architecture. While Frank Lloyd Wright ensued 'organic architecture' in a way he merged architecture with the surrounding landscape, Le Corbusier preferred an open style building design in which the aesthetics of the building are separated from its structural components. (Lohre, 2018) Wright believed in innovation and experimentation in building design by focusing on connecting the indoor spaces to outdoor spaces. (Kamal, 2013). He perceived buildings as an extension of nature and adopted the term 'organic architecture' which means that the buildings should have

strong connection to its site and promote flow of nature (Frank Lloyd Foundation, 2018). The green roofs and landscape are the significant characteristics of Frank Lloyd's works (Frank Lloyd Foundation, 2018). On the other hand, Le Corbusier focused on separating the building design from its structural components to allow free play of space (Kamal, 2013). Le Corbusier designed buildings with their structural skeletons in the form of columns which means that the internal space design could follow the flow of planning (Kamal, 2013). Le Corbusier's remarkable contribution makes him known as the father of modern architecture in both history and today's world. Le Corbusier and Frank Lloyd Wright both followed a unique design philosophy and their building design methods have become a signature of their architectural products (Lohre, 2018). It is clearly seen that both architects' buildings are designed in an open and sustainable way that help in protect the land they are built on and receive a huge amount of natural sunlight that provides openness to the building.

Green Roofs

Green roofs in sustainable buildings are one of the most significant developments. Green roof is the flat ground of plant developing. It can be named as 'vegetated roof', 'living roof', and 'eco roof' as well. Currently, green roof is the most substantial part of the sustainability plan, being apparent, different and natural. Biodiversity can be ignored with the use of green roofs in sustainable buildings, as it is one of the most significant way to protect the buildings from the environmental behaviors. This is due to the fact that green roofs are helpful in managing the surface of a building from water and the pollutants of air as well. Today, green roofs has become one of the most important technique for the building designers in the development of buildings and towns, as green roofs help to protect the sustainability of a building from natural crises (Pineo et al., 2018, Wang et al., 2018). Good environmental practices should be adhered to at every construction site and the same should be shared by other sites. There should be a creation of awareness to the site managers and workers on good environmental management practices. This can be achieved by way of education and involvement in policy creation. It is also crucial to involve the community. It is also crucial to select materials that are renewable to be used at a construction site. This mainly cuts down on the wastage of the materials and hence prevent the pollution of the environment. An example is by using timber where possible then it can be made into chips for other uses or alternatively recycle used metals. Green roofs are not as simple as they appear, because they have developed over the use of different steps and technologies for the protection and development of sustainable buildings (Wang, N et al., 2018). The most common technologies that are used for the proper implication of the green roofs involve root barrier, insulation, drainage layer, filter mat, growing medium, and planting (Wang, N et al., 2018). Through the use of these technologies, designers are making sustainable buildings and their different designs with respect to the requirements of the buildings that depends upon the environment of the surrounding areas of buildings. (York et al., 2018) In addition, it can be noted that there are a number of advantages of these environment friendly roofs, according to their design strategy planned by the designers. Most of the time, it becomes difficult for the owners of the buildings to finance green roofs, as the green roofs come with high amount of costage and need regular and proper maintainance. However, through the use of technologies, it has become easier even for the designers to establish economical green roofs for the building owners. Besides this, one of the most significant advantages of the green roofs is sustainable drainage. In reality, green roofs help to decrease the water of storm, through the help of plants that filter the water flows and help to longer the lifecycle of the building

from pollutants like phosphates, nitrates etc. (York et al., 2018). Another advantage of the green roofs is microclimate. In other words, green roofs help to cool down the temperature of the building, as they tend to evaporate the water flow through plants and in the meantime, they are emitting radiations of the heat of the building as well. Biodiversity is another advantage of green roofs, as they provide eco-friendly environment to the structure of the building, depending on the area of plants and the level of their development as well (York et al., 2018). It becomes clearer that green roofs are extremely beneficial and significant for the sustainability of buildings, in different ways. The first layer of the green roof provides protection to the building from water as the layer acts as a waterproof insulation (York et al., 2018). The second layer helps to protect the lower surface from water flows, as it stores water in the form of layers. (York et al., 2018) The third layer is the drainage layer that helps to control the level of water with the aim to increase the growth of plants. The fourth layer is root permeable filter layer prevents drainage issues (York et al., 2018). The fifth layer contains the nutrients and permits the roots of plants to grow (York et al., 2018). The final layer of a green roof is the vegetation. On this layer, different plants of gradual growth rates are used for the vegetation which have no deep and uncontrollable roots; such as peas, salad greens, beans, cucumbers etc. (York et al., 2018)

Lighting

For the energy efficiency the easiest way of cutting down the high cost bills through the home lighting. The revolution of the sustainable lighting industry in time has allowed energy efficiency to increase. Industries upgrade all kinds of lighting to provide the benefits of energy-efficient lighting. Sustainable lighting design offers different benefits to the environment and has so many economic advantages. It is also known that in some cases, especially in commercial buildings, the daylight is not sufficient on its own so the LED technology has been developed for minimizing energy consumption of light and improve user's life quality. (Altomonte et al., 2019). Sustainability of lighting methods does not only depend on design strategies, but also on occupant's way of using it. To improve sustainability even more, it is important to switch off the lights when they are not in active use. The key indicator starts from the right light recourse and its luminous efficacy. It is stated that the LEDs is known as the much higher luminous efficacy. Correct lighting is also very important in architectural and interior design. Wrong or too bright lighting can cause sight problems in the future and headaches in daily life of the user. (Altomonte et al., 2019)

Biophilic Design

There are many ways to interpret the definition of biophilia. Edward O. Wilson first introduced the hypothesis of biophilia in 1984 in his book, *Biophilia* (Shelton et al., 2018) According to Wilson the definition of biophilia would be "the urge to affiliate with other forms of life." (Shelton et al., 2018) Human beings are tend to be in relation with other life forms that can be found in nature. There are actually many advantages to adding a biophilic design to a public space (Shelton et al., 2018). The design patterns themselves provide many benefits. Different patterns provide a range of positive impacts on every individual that is benefiting from the biophilic design. These benefits include but are not limited to, stress reduction, cognitive performance, and better mood. Stress is reduced because a visual connection with nature lowers heart rate and blood pressure as well as mental relaxation (Siegel et al., 2018). Mental cognition is improved due to the fact that the biophilic pattern help with attention. When in the presence of this specific biophilic pattern, our mood

changes into a much calmer and happier mood (Siegel et al., 2018). Another advantage to our ideas is that they are realistic. Biophilic ideas are budget friendly as well. So, it will not only will it be cheap, but we will also be benefiting from design strategy that connects the occupant to the surrounding nature (Shelton et al., 2018). All of these ideas would provide some sort of connection with the landscape which users can benefit from. Another advantage to our ideas is that they're realistic. These ideas do not require any demolition. All you need are to buy the specific plants, pots, and to dig a little for our pond. Every individual person in the school would be capable of achieving these tasks (Shelton et al., 2018).

Solar Design Planning

In Ancient Egypt, the importance of day and night sky, and daylighting was reflected on the way Egyptian town planning (Boubekri, 2008). They were interested in the solar movement and their temples and residential areas were built in response to the sun and they made seasonal changes in design throughout the year (Boubekri, 2008). This proves that sun played an important role for all civilisations in history. It is easy to notice that it still has a huge impact on housing, public areas and public building façade design. One of the most important aspect of the sitting and orientation of the building is the sun path. The direction of the sun plays a critical role in designing and planning phase of the building. The sunlight can be both a blessing and a bane for the building, thus it is important to find the right angle for incidence of sunlight and to study the sun path along the day and the year to decide the orientation of the building (Bertone et al., 2018, Green and Thorogood, 2018). The sunlight can be the sources of lighting the rooms, lounge and other parts of the building during the day and can maximize the incidence of sunlight till the sun set (Bertone et al., 2018, Green and Thorogood, 2018). However, excessive sunlight can result in excessive heating which would require the additional artificial cooling. This is why it is important to study the sun path of the site and to orient the building to optimize the sunlight use in the building (Bertone et al., 2018, Green and Thorogood, 2018). In the passive solar design, the study of sun angle and climatic factors is utilized to plan and design the rooms, open areas and openings in the structure. The sun angle determines the number of openings and their perpetual sizes in the building and will also highlight that how the heating and cooling through the particular angle will occur throughout the day. (Bertone et al., 2018). There is excessive heat adjacent to the opening and the areas which remain under shadow are highly cool. To bridge this gap between heat wave received at particular zones, the passive design distributes the heat throughout the building (Bertone et al., 2018). Recently, technicians tend to go to sun oriented boards and twofold paned windows to gather and use sun-powered force (Ghaffarianhoseini et al., 2018, He et al., 2018). The great architect, Le Corbusier used sunlight through the openings in his buildings to create contrasts between shadows and highlights, and it inspired many forms of art, including photography. The sun and architecture intergration clearly shows in his buildings (Boubekri, 2008) Studies show that there is also direct link between vitamin D and mental health disorders. According to the data given, vitamin D intake that can be provided by the sun through the UVB interaction with human skin is used for the treatment and management of depressive personality disorder (Parker et al., 2017). Sun light and the right amount of heat increase the comfort level of the human body (Parker et al., 2017). To reduce heat related stress caused by poor solar design, these design strategies creates a thermal comfort by providing enough green spaces and shading for users (Carmona, 2019).

Conclusion

In conclusion, green buildings are environment friendly and they use safe energy produced by natural and renewable resources which will minimise the waste that is being produced by artificial instalments and lower the energy consumption inside and around the building (Bertone et al., 2018, Green and Thorogood, 2018). Green buildings also support systems that allow natural lighting, ventilation and insulation control. They have less impact on the landscape they are built on and instead of changing the surrounding they will try to blend in the context. This would result in less energy and waste consumption to build the structure by reducing the time and material used for demolishing the existing site area or landscape (Kamal, 2013). Sustainable buildings also provide rainwater harvesting systems to use natural water provided by the environment itself (Bertone et al., 2018, Green and Thorogood, 2018). The link between the materials which designers prefer to use during constructions and their impact on the environment cause a chain of reactions on the user's health as well. The way buildings and spaces are created have a huge impact on the value of the place and health conditions (Carmona, 2019). Throughout the history of civilisations, we have been attracted to sunlight and the mood-giving power it has. The warmth and light of the star gives us the mental recovery we need in our daily lives and its absence is often causing seasonal depression in some countries (Boubekri, 2008). Sunlight is the most effective way to prevent Vitamin D deficiency and this needs to be considered while designing in response to the sun path (Boubekri, 2008). The link between the construction strategy, materials and user's health are quite direct as stated in this paper. The materials and their substances' impact on the environment and pollution can result in negative impacts on physical health, such as blood pressure problems, heart diseases, asthma and fatigue therefore designers should aim an increased daily comfort and life style for the users of the proposed structures by following these sustainable design strategies. (Carmona, 2019). Designs that reduce the amount of distance that it requires its user to walk can cause physically moderate life style and this might result in less active way of living and therefore, obesity and heart rate issues. (Carmona, 2019) The positive changes in user's life quality will surely increase their physical health, mental well-being by uplifting their mood and the amount of satisfaction they get from being inside the building and its surrounding and these strategies will cure the symptoms caused by sick building syndrome. (Carmona, 2019)

References

- Allam, Z. and Jones, D., 2018, July. Promoting resilience, liveability and sustainability through landscape architectural design: A conceptual framework for port louis, mauritius; a small island developing state. *In IFLA world congress Singapore* (pp. 1599-1611).
- Allen, E. and Iano, J., 2019. Fundamentals of building construction: materials and methods. John Wiley & Sons.
- Altomonte, S., Schiavon, S., Kent, M.G. and Brager, G., 2019. Indoor environmental quality and occupant satisfaction in green-certified buildings. *Building Research & Information*, 47(3), pp.255-274.
- Bertone, E., Stewart, R.A., Sahin, O., Alam, M., Zou, P.X., Buntine, C. and Marshall, C., 2018. Guidelines, barriers and strategies for energy and water retrofits of public buildings. *Journal of Cleaner Production*, 174, pp.1064-1078.
- Boubekri, M., 2008. Daylighting, Architecture and Health : Building Design Strategies.
- Carmona, M., 2019. Place value: Place quality and its impact on health, social, economic and environmental outcomes. *Journal of Urban Design*, 24(1), pp.1-48.
- Darko, A., Chan, A.P.C., Yang, Y., Shan, M., He, B.J. and Gou, Z., 2018. Influences of barriers, drivers, and promotion strategies on green building technologies adoption in developing countries: *The Ghanaian case*. *Journal of Cleaner Production*, 200, pp.687-703.
- Ding, Z., Fan, Z., Tam, V.W., Bian, Y., Li, S., Illankoon, I.C.S. and Moon, S., 2018. Green building evaluation system implementation. *Building and Environment*, 133, pp.32-40.
- Frank Lloyd Wright Foundation., 2018. Organic Architecture and the Sustaining Ecosystem. [ONLINE] Available at: <https://franklloydwright.org/organic-architecture-and-the-sustaining-ecosystem/>. [Accessed 16 April 2020].
- Ghaffarianhoseini, A., AlWaer, H., Omrany, H., Ghaffarianhoseini, A., Alalouch, C., ClementsCroome, D. and Tookey, J., 2018. Sick building syndrome: are we doing enough?. *Architectural Science Review*, 61(3), pp.99-121.
- Kamal, M., 2017. Le Corbusier's Solar Shading Strategy for Tropical Environment: A Sustainable Approach.
- Lohre, C., 2018. The Past and Future of Sustainability - From Frank Lloyd Wright to Buildings You Can Eat [ONLINE] Available at: <http://www.lohre.com/green-cincinnati-education-advocacy/the-past-and-future-of-sustainability-from-frank-lloyd-wright-to-buildings-you-can-eat>. [Accessed 16 May 2020]
- Parker, G., 2017. Vitamin D and Depression [online] Available at: <https://www.sciencedirect.com/science/article/pii/S0165032716308928> [Accessed 12 April 2020]

Pineo, H., Zimmermann, N., Cosgrave, E., Aldridge, R.W., Acuto, M. and Rutter, H., 2018. Promoting a healthy cities agenda through indicators: development of a global urban environment and health index. *Cities & health*, 2(1), pp.27-45.

Shelton, R.C., Cooper, B.R. and Stirman, S.W., 2018. The sustainability of evidence-based interventions and practices in public health and health care. *Annual review of public health*, 39, pp. 55-76.

Siegel, B., Erickson, J., Milstein, B. and Pritchard, K.E., 2018. Multisector partnerships need further development to fulfill aspirations for transforming regional health and well-being. *Health Affairs*, 37(1), pp.30-37.

Wang, N., Phelan, P.E., Harris, C., Langevin, J., Nelson, B. and Sawyer, K., 2018. Past visions, current trends, and future context: A review of building energy, carbon, and sustainability. *Renewable and Sustainable Energy Reviews*, 82, pp.976-993.