Sustainable design for zero carbon architecture

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Abstract. The energy is used for construction, operation and demolition in the building sector is the most significant source of carbon dioxide (CO₂) emissions which is predicted to affect the environment. Therefore, under the Paris Convention, this paper explores the current situations and the way forward for achieving zero carbon building (ZCB). Firstly, ZCB's are expected to decrease energy requirement via effective ' passive and active design solutions ', then secondly by means of renewable energy supply systems to meet remaining energy demand. The focus would be on the ' building envelope ' that involves the shape, orientation, and building elements which usually remain unchanged throughout their life cycle. Naturally, the HVAC system and any building-integrated energy supply are going to be an integral part of the design. All of these are going to significantly reduce the demand for energy and CO₂ emissions, which are an optimized solution for a comfortable and healthy environment.

In order to move forward, this paper encourages that ZCB principles should be explicitly determined within the need for computational modelling of buildings and their energy performance throughout the life-cycle of the building. Also, technical solutions may vary, but can be clarified around passive solutions and energy efficiency, on- and off-site renewable energy technologies, and carbon offsetting measures as these are explained in the case study.

1. Introduction
The cities are in charge of more than 70% of greenhouse gases (GHG) emissions [1], standing out as the biggest contributor to CO₂ emissions, and climate change in characteristic of the global warming which leads to significant impacts on environment and sustainability. Nowadays, the worldwide transmission towards zero carbon and sustainability, as the “zero carbon building” refers to buildings using renewable sources on site to produce energy to operate, so the net energy generated on site over a year equals the net energy requirement of the building as ‘figure 1’.

Achieving that is estimated to understand zero carbon architecture design processes (ZCDP) are proposed in this paper for different the project and are applied in the case study. In accordance with low energy level design, new heating, cooling and ventilation options are in place, Efficient and comfortable cooling and surface heating systems are available (e.g. heated floors, cooled ceilings, etc.). With isolated glazing systems incorporating controlled shading layers. The main concept is to use these elements instead of treating them as a static element group but as an interactive system.

In addition to focus on the importance of using software tools. It attempts to consolidate an analytical and logical method. There are two main stages of this research: First of all, it is concentrating on the problem statement and principal consideration for (ZCB).
Secondly, it is also studying the implementation and experimentation by using different tools and software.
2. Building Emissions and Environmental Interactions

Buildings consume various of the natural resources which cause many problems such as: 40% of the total energy use worldwide; 30% of raw materials consuming; 25% of timber harvesting; 41% of the world’s CO₂ emissions; 40% of domestic solid waste intended for local landfills; 50% of ozone-depleting CFCs still in use added to bad effects for watersheds, habitat, air quality, and community transportation patterns [2]. In addition, energy is used during its lifetime causes as much as 90% of environmental impacts from buildings [3] as the direct outcome of interactions between the building and the entire environment. Figure 2 is illustrated that while some countries have been reducing their CO₂ emissions year by year, developing and developed countries, have been steadily increasing their annual rates of CO₂ emissions during the past decade.

Furthermore, building operation consumes more than 2/3 of all electricity [4]. So that, designing the best high-performance buildings based on the environmental software is critical to our future. Therefore, Roadmap 2050 tries to focus on worldwide building sector fossil fuel CO₂ emissions rapidly summit in order to acquire zero by the middle of the century which is explained in ‘figure 3’ [5].

3. Principles of Zero Carbon Building

The basis is the convert of the outdoor climate conditions to be a comfortable indoor environment, that includes temperature, relative humidity, natural ventilation, and natural lighting. For this, an integrated approach ‘figure 4’ is necessary to help the architects explain sustainable design goals and identify the passive and active solutions. The zero carbon design strategies are described in detail ‘figure 5’.

All of the following principles have to take into an account in framework of the building location and surrounding climate conditions, in addition to meet human thermal comfort requirements:

Principle (1): That is a building design to decrease the heat loads. This reduces cooling, heating and lighting energy. In order to balance good light with lower demand for cooling, particularly by facade layers, solar radiation gains should also have been controlled.

Principle (2): It is to integrate appropriate passive design strategies to enhance internal human and thermal comfort such as determine appropriate form, orientation, shading, WWR promoting the required air movement, increasing thermal mass, or introducing a cool surface are used for the second stage.
Principle (3): That is to merge high performance systems to meet the internal human thermal comfort requirements. Surface cooling and heating offers an energy-efficacy system which is comfortable.

Principle (4): Renewable energy solutions should be merged with the aim of generating energy demanded, as well as using renewable energy materials.

4. Case Study Designed: Design of a fully sustainable students’ home, Vienna 2017:
That is a new model for a sustainable building is integrated into new technologies, energy efficient and innovations with mobility and productivity. It uses passive and active climate control systems to make a comfortable and sustainable environment with a chance to minimize carbon emissions, energy costs, and improve the environment.

4.1 Site analysis and determine design strategies:
By using climate consultant software determines the major design principles and their impact on the built - up form. The aim is to make building more energy efficient and sustainable as in ‘figure 6’.
4.2 Architectural Design Concept:
For passive solar heating face most of glass area south to maximize winter sun exposure, but design overhangs terraces to fully shade in summer as in ‘figure 7’. In addition, wind catchers are integrated in the project for passive cooling.

So that, the project designed as shown in ‘figure 8’ contains on the common areas and common use like (a small shop, a cafe, a bikers’ garage and repair lab, a washing saloon, a fab lab (fabrication laboratory), a library, …… etc. From the 2nd floor to the 6th floor: students’ apartments - a larger meeting room with kitchens on every floor. The last floor: common use, offering a recreation zone and terraces for urban gardening.
4.3 Construction:
That focuses on modular units, pre-fabricated construction and designed to achieve indoor human comfort as in ‘figure 8’. It is mainly by using (timber frame -panelized façade -double glazing).

4.4 Shading design – Passive Solutions:
Based on the actual position of the sun as south east oriented large windows, surrounding buildings and shading devices (shading by adding balconies, blinds, building shape, and mass etc) in building simulations can be precisely calculated the amount of sunray coming inside the building. The designers optimize the design of the shading device for façade from comparison of solar gains for various design alternatives as well as chose the best option against overheating as ‘figure 9’. Excess sunlight however enters the rooms during the afternoon in winter time.

![Figure 9. Shading design as Passive Solutions](image)

4.5 Material Selection
It has the very isolated and air-tight building skin as in ‘figure 10’ for example facade material (brick (100mm)- rear ventilated level (outside air) (50mm) - insulation / polystyrene (eps) (150mm) - cross laminated timber (50mm) - insulation / polystyrene (eps) (50mm) - cross laminated timber (50mm), so extremely small heat convey from outdoor to indoor or versus. The external envelope decreases the solar radiation and contributes to create high-performance cooling system.

4.5 Design based on thermal mass:
The integrated design to decrease the energy and CO₂ emissions is mainly based on thermal mass capacity and different U-Values as in ‘figure 11’. The design of this building offers natural daylight and it is also utilised natural ventilation for the night cooling. This has well - isolation and moving diffuse vertical glass panels, that are controlled by sunlight and provide optimized day - long shading.
4.6 Energy concepts of the Building design:
The analysis of the building also contributes to selecting efficient construction systems in order to optimize operation, heating, cooling and ventilation of the building as described in ‘figure 12’. This building contains (a) extremely isolated façades with low rate of air infiltration, (b) the shading system that is installed against the external glazing surface with adjustable blinds, (c)Active thermal solar systems (type of collector, area, orientation, inclination, storage, distribution, etc) which characteristics by (Vacuum tubes - 120 m² - Orientation: 32° (S: 0°, E: 90°) - Inclination: 30°- Hot water storage: 7,570.8 l). (D) Photovoltaics (type, area, orientation, inclination, storage, distribution, etc) which

![Figure 11: Building U-values](image1)

**Figure 11:** Building U-values, *Source: Author*

*characteristics by Polycrystalline, two systems - 90.20 / 22.55 m² - Orientation: 23 / -49° (S: 0°, E: 90°) - Inclination: 90° - Storage: none), (E) geothermal energy, (F) recycled materials, (G) water storage systems, and (H) a green roof with rainwater harvesting system.*
4.7 Generation and demand

![Generation and demand](image)

Figure 14: Generation and demand, Source: Author

4.9 Suggestions for the future changes:
Applying double skin façade, exterior blinds, and less glazing on the ground floor.

5. Conclusion
Recently, zero carbon architecture plays an indispensable role in sustainable architectural style and displays revolutionary ecosystem-friendly approaches which lead to decrease energy consumption in buildings and overcome the climate change. The ZCA strategies are categorized to passive and active solutions. Both strategies are useful for decreasing energy consumption and declining GHG emissions. In this light, this paper is contained on the specifics of achieving (ZCB) through both ‘carbon compliance’ and ‘allowable solutions’ beside the probable use of mechanical solutions or renewable sources. It has also shown how software can support design processes.

So that, achieving the sustainable development methods needs to transform in design principals, and is based on the architect’s and the public’s awareness. That through increase the importance of architectural knowledge dramatically, through recognizing of changes in design trends. However, as a creative model of sustainability progress, ZCB keeps being more momentum. To cope with the challenges that facing architects to uptake of the ZCB model, creative study, innovation and advancement is required. Architects’d better scout the state-of-the-art technologies with public cultural awareness in delivering ZCBs. Specially, it is proven that ZCBs are technically feasible in the long term, by taking an obvious and abridged action from the government and the building industry.
References

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