

# Net Zero Carbon concept to create a sustainable and livable environment

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**Abstract.** Global warming and climate change have significant impacts on various sectors, including the building sector, which contributes approximately 39% to total global carbon emissions. These emissions come from operational carbon and embedded carbon in building materials. To achieve the Net Zero Carbon target by 2030 for new buildings and 2050 for all buildings, a paradigm shift is needed in building planning, construction, and operation. This study aims to examine the Net Zero Carbon concept in the context of buildings and the built environment, as well as its reduction strategies to create a sustainable and livable environment. The method used is a literature review with a narrative approach, integrating various scientific sources on carbon emissions, the building life cycle, and emission reduction technologies. The results of the study indicate that the building sector is a major contributor to greenhouse gas emissions due to high energy consumption and the use of high-carbon materials. Emission reduction can be achieved through energy-efficient building design, the selection of low-carbon materials, optimization of renewable energy, and the application of carbon capture technologies. In addition, regular monitoring of operational emissions and government policies in the form of energy regulations, emission limits, and economic incentives are important factors in supporting the implementation of low-carbon buildings. In conclusion, achieving Net Zero Carbon requires collaboration between architects, developers, building managers, and governments throughout the building life cycle to create a healthy, safe, and sustainable environment.

## 1 Introduction

The issue of global warming due to climate change has had negative impacts on various sectors, including the construction and environmental sectors. To address this, the Intergovernmental Panel on Climate Change (IPCC) issued a regulation that temperature increases in the 21st century should not exceed 1.50°C [1]. Climate change and sustainability are two key areas that have received significant attention from scientists, companies, and governments worldwide [2]. Climate change is usually defined as a significant and long-term change in global climate conditions, such as temperature or rainfall, in various regions of the world. Climate change is also largely associated with global warming and the global greenhouse effect. Global warming is usually defined as an increase in global temperatures

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due to the global greenhouse effect. GHGs are produced by various human activities, such as industrial activities and transportation. GHG emissions into the Earth's atmosphere have caused serious damage to the ozone layer. The main GHGs usually include CO<sub>2</sub>, methane, Chlorofluorocarbons (CFCs), etc. This results in the trapping of various heat emissions, which causes an increase in global temperatures and global warming worldwide.

Net Zero Carbon is a concept that refers to the balance between carbon emissions released into the atmosphere and the amount of carbon that must be absorbed or removed from the atmosphere. The Global Alliance for Building Construction (Global ABC) states that buildings are the largest contributor to carbon gas emissions, which is around 39% of total global carbon emissions. These carbon emissions consist of 28% carbon emissions when the building is operational (from design, construction, operation and demolition) and 11% carbon emissions that are already contained (embodied carbon) from the building materials that will be used. In the United States, commercial and residential buildings use 70% of total electricity and are responsible for more than 38% of total greenhouse gas emissions [3]. To accelerate the achievement of the Net Zero Carbon target for new buildings in 2030 and all buildings in 2050, efforts need to be made to reduce carbon emissions in buildings, starting from the planning, construction and operational stages as well as carbon sequestration both naturally and artificially.

Environmental management and sustainable development have become an essential part of climate change management by countries, companies, and cities around the world. The environment and sustainability first became an integral part of global climate change discussions at the first Earth Summit in Rio in 1992. The original definition of sustainable development, which remains the most frequently cited, comes from the UN Brundtland Commission, which stated that "Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [4]. The concept of sustainable development refers to principles/pillars that consider economic, social, and environmental aspects in a balanced manner [5]. Another definition of the environment and sustainable development comes from the World Commission on Environment and Development as "A process of change in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional change are all harmonious and enhance the current and future potential to meet human needs and aspirations."

A livable environment is one that provides a good quality of life for all its residents, encompassing physical, social, economic, and environmental aspects. A livable environment must be comfortable, safe, healthy, and accessible to all segments of society. The fulfillment of a livable environment is reflected in one of the indicators of the SDGs, namely sustainable cities and settlements. In the context of buildings and areas, livability includes the comfort of the physical environment, the availability and access to facilities, security and safety, affordability, social life, and community involvement.

## **2 Research theory and methods**

### **2.1 Research theory**

Global warming and climate change have become global issues today. Amidst the debate over the existence of climate change, its accompanying symptoms are already beginning to be felt. The resulting impacts have begun to affect most regions of the world, including Indonesia. Global warming and climate change are caused by greenhouse gas emissions, which largely come from the combustion of fossil fuels for energy generation. Nearly every aspect of our lives is inextricably linked to fossil fuels. Nationally, the building sector is the

largest consumer of electrical energy (41%) and the third largest consumer of final energy (including oil and gas) (27%) after industry and transportation. More than 60% of the total energy in the building sector is used for air conditioning [6].

In the field of architecture and the built environment, the concept of sustainability can be applied to various sectors such as buildings, infrastructure, outdoor/public spaces, urban and rural areas. This built environment includes all physical elements designed, constructed, and managed by humans as part of sustainability and social development. Green buildings and environments are among those that can help mitigate the problems of climate change and global warming. A building that implements sustainable and environmentally friendly (green) concepts will have a positive impact and can even reach a point of innovation in the field of economic growth. Supporting environmental development and conservation strategies will make the communities where people live more attractive, supporting a wide range of social diversity.

Green building is a constantly evolving concept that has become an integral part of contemporary architectural planning and design. This concept is rooted in efforts to create a sustainable built environment, one that takes into account not only economic factors but also environmental and social impacts [7]. It embodies the fundamental idea that buildings can be designed and managed in a more environmentally friendly and sustainable manner, reducing resource use and carbon emissions, and promoting a better quality of life for their occupants. Amidst global climate change and the depletion of natural resources, green buildings emerge as a critical response to the current architectural paradigm regarding the relationship between humans, the built environment, and nature. Most conventional approaches in architecture and development often position buildings as separate entities from the natural environment, as if buildings were structures that dominate space. However, with the emergence of the concept of green buildings, there has been a paradigm shift that leads to the unification of the built environment and the natural environment, where buildings not only stand on nature but also interact with and adapt to it. This interaction with nature includes light, air, water, landscape, vegetation, raw materials, and the surrounding climate. The surrounding climate, in particular, has a significant influence on various aspects of building design and operation, thus the concept is often associated with bioclimatic architecture, namely architecture that is responsive to climatic conditions.

Etymologically, the term carbon comes from the Latin *carbo*, meaning coal [8]. Although carbon is often associated with dark black substances, such as coal and charcoal, not all carbon compounds are black [9]. Carbon is an element that plays a crucial role as the basic building block of all organic compounds and plays a role in the transfer of energy along with other chemical elements [10]. Carbohydrates produced during photosynthesis are a form of carbon mobilization, while carbon dioxide is released along with energy during respiration. The carbon cycle is a complex representation of the mechanisms of carbon movement among various environmental components, including living things, organic matter, and the atmosphere. This cycle is closely intertwined with the biogeochemical cycle, where carbon exchange or transfer occurs between various areas: the biosphere within living things, the geosphere within the earth, the hydrosphere within water, and the atmosphere within the air. The atmosphere, as a crucial component of the carbon cycle, stores carbon dioxide (CO<sub>2</sub>) and other gases that influence climate balance. Therefore, the carbon cycle is an important part of the ecosystem and preserving environmental sustainability.

Carbon dioxide (CO<sub>2</sub>) is one of the greenhouse gases that is the main cause of global warming and the increase in CO<sub>2</sub> emissions caused by human activities. There are five main sectors that are sources of CO<sub>2</sub> emissions, namely energy use, industrial processes, product use, agriculture/forestry/land use change and waste management. The increasing amount of greenhouse gases including CO<sub>2</sub>, CH<sub>4</sub> (methane), N<sub>2</sub>O (Nitric Oxide), HFC (Hydrofluorocarbons) and SF<sub>6</sub> (Sulfur Hexafluoride) in the atmosphere will cause problems

that cause the earth's surface temperature to rise and cause climate change [11]. Each of these gases has a different Global Warming Potential (GWP), that is :

**Table 1.** Global warming potential of greenhouse gases.

<b>Types of Greenhouse Gases</b>	<b>Global Warming Potential (GWP)</b>
CO2 (Carbon dioxide)	1
CH4 (Metana)	56
N2O (Nitrat Oksida)	280
HFC (Hidrofluorocarbon)	9100
SF6 (Sulfur Heksafluorida)	16300

Net Zero Carbon is a concept that refers to the balance between carbon emissions released into the atmosphere and the amount of carbon absorbed or removed from the atmosphere. This goal is often associated with global efforts to reduce the impact of climate change, in accordance with the Paris Agreement target of limiting global temperature rise to below 2°C, with further efforts to limit the increase to 1.5°C. Net Zero Carbon for operational energy is achieved when a building's total annual net CO<sub>2</sub>e emissions are equal to zero, meaning all carbon impacts are offset by all carbon credits. The success of Net Zero Carbon Buildings is greatly influenced by collaboration with stakeholders [12]. Meanwhile, factors that hinder Net Zero Carbon Buildings include legislative (regulation, policy), economic (uncertain return on investment), and technical [13].

The net zero carbon building concept establishes definitions and principles around two equally important approaches to net zero carbon:

- Net zero carbon at construction, where the total carbon emissions associated with the building product and the construction phase through project completion are zero or negative, through the use of offsets or net exports of on-site renewable energy.
- Net zero carbon at operation, where the total carbon emissions associated with the building's operation each year are zero or negative. Net zero carbon buildings are highly energy efficient and operated by on-site and/or off-site renewable energy sources, with offsets for any remaining residual carbon.

Embedded carbon emissions refer to the total greenhouse gas emissions (primarily CO<sub>2</sub>) produced during the extraction of raw materials, production of building materials, transportation, construction, maintenance, and demolition of a building. These emissions are non-renewable and occur before the building is actively used, including:

1. The production of construction materials, namely the manufacturing of concrete, steel, stone, glass, and aluminum, requires high energy and generates significant carbon emissions [14].

**Table 2.** Embodied Carbon Factor (ECF) material.

<b>Material</b>	<b>Specification</b>	<b>ECF (kgCO<sub>2</sub>e/kg)</b>
Concrete	Unreinforced, C32/40, 50% GGBS cement replacement	0.089
Steel	Worldwide: Worldsteel LCI study data, world average	1.99
Stone	Sandstone	0.06
Glass	Generic	1.44
Aluminium	Worldwide consumption	13.2

2. Material transportation, namely the distance and mode of transportation used to transport materials from the factory to the project site, contributes to total emissions [14].

**Table 3.** Transport Emissions Factors (TEF).

<b>Mode</b>	<b>TEF mode (gCO<sub>2</sub>e/kg/km)</b>
Road transport emissions, average lade	0.10650
Road transport emissions, fully lade	0.07524
Sea transport emissions	0.01614
Freight flight emissions	0.59943
Rail transport emissions	0.02556

3. On-site construction activities, namely the use of heavy equipment, generators, and other logistical activities during the physical construction of a building, generate direct emissions from fossil fuels.

4. Maintenance and renovation, namely the replacement of building elements or periodic maintenance, also add to embedded emissions over the life of the building.

Carbon emissions during building operations consist of three scopes or areas [15], that is :

### 2.1.1 Scope 1 (direct)

Greenhouse Gas (GHG) emissions directly from the combustion process originating from sources owned or controlled by the company. Scope 1 consists of 4 sources, that is :

- Burning fuels on site are direct emissions from the combustion of fossil fuels within facilities or property owned or controlled by the company.
- Business vehicles/fleet are direct emissions from operational vehicles owned or controlled by the company that use fossil fuels, such as gasoline, diesel, or natural gas.

- Volatile gases are emissions resulting from intentional or unintentional releases, such as leaks from equipment, hydrofluorocarbon (HFC) emissions from the use of refrigeration and air conditioning equipment.
- Processes are emissions that occur during the production or processing of chemicals and materials.

### 2.1.2 Scope 2 (indirect)

Indirect greenhouse gas (GHG) emissions occur when companies consume purchased energy sources such as electricity, steam, heating, cooling, and compressed air in their own or controlled facilities or operations. These emissions physically occur at the facility where the electricity or energy is produced. Scope 2 consists of three sources:

- Purchased electricity for on-site consumption, which are indirect emissions from electricity purchased and used in company facilities, such as office buildings, factories, or warehouses.
- Purchased heat and/or cold, which are indirect emissions resulting from heating (heat) or cooling (chilled water/cooling) purchased from third parties and then used in company-owned or -controlled facilities.
- Externally generated pressure/steam, which are emissions resulting from energy in the form of pressure (e.g., high-pressure steam) or steam purchased from third parties and used by the company in its facilities

### 2.1.3 Scope 3 (indirect)

All other indirect emissions that occur in the company's supply chain and are not included in scope 2. These emissions are a consequence of the company's business activities but occur from sources that are not owned or controlled by the company. Scope 3 consists of 14 sources, that is:

- Purchased goods and services are emissions resulting from the production of goods and services purchased by an organization from external suppliers (third parties), which occur before the goods/services reach the organization.
- Capital goods are durable goods used in a company's operational processes to produce goods or services, not for resale.
- Fuel and energy-related emissions are indirect emissions originating from the production and distribution of fuel and electricity consumed by the company, but not covered by scopes 1 and 2.
- Transport and distribution are indirect emissions arising from the transportation and distribution of goods purchased, sold, or used by a company, but carried out by a third party (not the company's fleet). Transportation and distribution of goods/services to the company.
- Waste are greenhouse gas emissions originating from the management of waste generated by the company's operational activities, but managed by a third party (not managed by the company itself).
- Business travel and commuting are indirect greenhouse gas emissions arising from employee business travel using modes of transportation not owned or controlled by the company. Indirect emissions from employees' daily commutes from home to work and vice versa.
- Rented or leased property, plant, and equipment: indirect emissions from the use of leased assets, whether buildings, vehicles, equipment, or machinery that are not owned by the company but used in its operations.
- Transport and distribution: indirect emissions arising from the transportation and distribution of goods purchased, sold, or used by a company, but carried out by a third party

(not the company's fleet). Transportation and distribution of goods/services from the company to customers.

- Processing of sold products: indirect emissions arising from the further processing of products sold by the company by other parties (e.g., industrial customers) before the product reaches the end user.
- Usage of sold products: greenhouse gas emissions arising from the use of products by consumers or end users after the product is sold by the company.
- Disposal of sold products: greenhouse gas emissions arising from the end-of-life treatment of sold products after they have been used by consumers.
- Leased or rented property, plant, and equipment are indirect emissions from the use of leased assets, whether buildings, vehicles, equipment, or machinery that are not owned by the company but used in its operations.
- Franchise: greenhouse gas emissions from franchise operations that use the company's name or brand but are operated by a third party and not directly owned by the parent company.
- Investment: greenhouse gas emissions from the operational activities of entities or projects funded, partially owned, or financed by the company but not directly controlled by the company.

To achieve a Net Zero Carbon situation, efforts must be made to reduce carbon emissions from human activities. Carbon sinks are natural or artificial components that absorb and store carbon dioxide (CO<sub>2</sub>) from the atmosphere, thereby helping to reduce the concentration of greenhouse gases that cause climate change.

1. This natural carbon sequestration can help reduce CO<sub>2</sub> concentrations in the atmosphere. However, due to rapid human activity, this natural capacity is insufficient, requiring support through forest restoration, land rehabilitation, and protection of coastal ecosystems (such as mangroves and peat swamps). The extent of carbon dioxide sequestration is influenced by local conditions such as climate, vegetation type, and management practices.
2. Artificial CO<sub>2</sub> absorption can help reduce carbon dioxide emissions in the atmosphere that cannot be absorbed naturally. The most widely recognized approach and technology for reducing CO<sub>2</sub> emissions is Carbon Capture, Utilization, and Storage (CCUS) technology. This technology is a process that aims to reduce the amount of CO<sub>2</sub> released into the atmosphere and help mitigate global warming [16]. CCS plays an important role as a key abatement option in the post-2020 era, amounting to one-fifth of reductions in CO<sub>2</sub> concentrations by 2050 [17]. The process consists of three main stages: CO<sub>2</sub> capture or separation, transport to a CO<sub>2</sub> storage location, and storage in geological storage. CCS technology can allow for the continued use of fossil fuels without increasing greenhouse gas emissions. This can help protect the conventional energy sector and reduce environmental impacts. During the transition to renewable energy sources, this technology can be a temporary solution to reduce emissions from conventional energy sources.

Strategies to accelerate net-zero carbon can be implemented by reducing carbon emissions in buildings to address the challenges of climate change and simultaneously improve the quality of the urban environment. This strategy encompasses approaches from the planning, construction, and operational stages of a building. Strategies that can be implemented include:

1. Energy-efficient building design can be achieved through passive design, utilizing building orientation, cross-ventilation, natural lighting, and sun shading to reduce the need for cooling/air conditioning and artificial lighting. Active design, on the other hand, utilizes energy-efficient cooling and lighting systems, such as inverter air conditioners, LED lights with motion sensors, and elevators with regenerative braking systems.

2. The use of low-carbon and sustainable materials can be achieved by:
  - a. Selecting building materials with a low carbon footprint, such as fly ash concrete, recycled steel, bamboo, or Forest Stewardship Council (FSC)-certified wood.
  - b. Using innovative material technologies, such as geopolymers concrete or bio-composite-based materials, which have lower emissions than conventional cement.
  - c. Supply chain transparency by obtaining Environmental Product Declarations (EPDs) from manufacturers as a basis for decision-making in material selection.
3. Optimizing energy systems and smart technology by:
  - a. Using renewable energy, such as installing solar panels on roofs or building facades, to support internal electricity needs.
  - b. Building Management Systems (BMS), which use automated systems to monitor and control energy consumption, temperature, humidity, and lighting within buildings.
  - c. Internet of Things (IoT), which integrates sensors for room temperature control, presence detection, and efficient water and electricity use.
4. Policies, Regulations, and Incentives by:
  - a. Government regulations, such as issuing mandatory energy efficiency regulations for new buildings and imposing maximum operational emission limits (e.g., kg CO<sub>2</sub>/m<sup>2</sup>/year).
  - b. Economic incentives through tax breaks, easier permitting, or subsidies for buildings that meet low-carbon standards.
  - c. Implementing a Carbon Unit Price, namely developing a carbon unit price formula (Rp/kg CO<sub>2</sub>e) as an evaluation tool that links construction costs to carbon emissions to provide added value for decision-making.
  - d. A carbon tax is a tax imposed on economic activities that generate negative externalities.
5. Carbon Footprint Monitoring and Evaluation through:
  - a. Carbon emission audits by conducting regular, real-time measurements of carbon emissions.
  - b. Open reporting by producing annual carbon footprint reports and reduction strategies to increase transparency to the public and tenants.
6. Building user education and awareness by providing outreach and training for office users regarding energy savings, waste management, and efficient space use.

## **2.2 Methods**

The method used for this literature review is to collect, read, analyze, and synthesize various library sources (books, journal articles, proceedings, and official documents) relevant to the research topic. The narrative method used is to compile the literature review by summarizing, explaining, and comparing research results relevant to the topic.

## **3 Results and discussion**

Carbon emissions from the building sector continue to increase along with the pace of urbanization and economic growth. In Indonesia, buildings dominate urban spaces and generate significant carbon emissions from both construction materials (embodied carbon) and building operations (operational carbon). High energy consumption and the use of conventional materials make buildings a major source of greenhouse gas emissions. The building life cycle is a crucial concept in the construction industry, encompassing various stages from planning to demolition. One crucial stage in this cycle is planning and design, as it determines how the building will operate. One of the things that planners and architects

need to plan and design to support sustainability and address global warming and climate change is by creating energy-efficient/green buildings that produce low carbon emissions both during construction and operation. Therefore, carbon emission reduction strategies in this sector are crucial to creating a livable, healthy, and sustainable environment.

## 4 Conclusion

Net-zero carbon conditions need to be planned from the planning, construction, and operational stages, involving all stakeholders involved. Planners or architects need to create passive, energy-efficient building designs, use low-carbon and sustainable materials, optimize energy systems, and utilize smart technology. Building managers need to monitor and evaluate the building's carbon footprint during operation by regularly measuring carbon emissions in real time and publicly reporting its annual carbon footprint. The government needs to issue regulations for energy efficiency in new buildings and provide maximum operational emission limits, economic incentives in the form of tax breaks, ease of permitting, or subsidies for buildings that meet low-carbon standards and carbon taxes.

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