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# Architectural Design Based on Carbon Footprint for Sustainable Cities

## *Sürdürülebilir Şehirler İçin Karbon Ayak İzine Dayalı Mimari Tasarım*

**Prof Dr. Cengiz Türe**[1]

1 Department of Biology-(Ecology), Faculty of Science, Eskisehir Technical University Eskisehir, Turkey

**Abstract**

After the industrialization of architecture, the increasing carbon footprint of the built environment requires greater consideration of small eco-design principles in architecture. Because of their role in design, architects have a decisive role in all stages of the life cycle of buildings. Therefore, for a built environment project that aims to contribute to the reduction of carbon footprint, it is of great importance to consider the direct/indirect greenhouse gas emissions originating from every stage of the life cycle of buildings. Thus, architects can make a great contribution to the sustainable architecture process by using the available options regarding material supply, energy flow, land use and ecological factors in their projects. In this study, architectural applications/eco-design methods that can be used for low environmental impact and contribute significantly to the reduction of global greenhouse gas emissions (carbon footprint) are discussed.

**Keywords:** Eco-design, Climate Change, Carbon Footprint, Sustainable Architecture, Built Environment.

**Özet**

Mimarlığın endüstrileşmesinin ardından yapılı çevre kaynaklı karbon ayak izinin giderek artması, küçük karbon ayak izini hedefleyen eko-tasarım ilkelerinin mimaride daha çok dikkate alınmasını gerektirmektedir. Çünkü tasarımdaki rolleri nedeniyle mimarlar, binaların yaşam döngülerinin tüm aşamalarında belirleyici bir role sahiptirler. Bu nedenle karbon ayak izinin küçültülmesine katkıda bulunmayı hedefleyen bir yapılı çevre projesi için binaların yaşam döngülerinin her aşamasından kaynaklanan doğrudan/dolaylı sera gazı emisyonlarının dikkate alınması büyük önem taşımaktadır. Böylece mimarlar, malzeme tedariki, enerji akışı, arazi kullanımı ve ekolojik faktörlere ilişkin mevcut seçenekleri yapacakları projelerde kullanarak sürdürülebilir mimarlık sürecine büyük oranda katkı sağlayabilmektedirler. Bu çalışmada, küresel sera gazlarının emisyonunun azaltılmasına (karbon ayak izi) önemli oranda katkı sağlayan çevresel etkisi düşük mimari uygulamalar/kullanılabilecek eko-tasarım yöntemleri tartışılmıştır.

**Anahtar Kelimeler:** Eko-tasarım, İklim Değişikliği, Küresel Isınma, Sürdürülebilir Mimarlık, Yapılı Çevre.

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**Sorumlu Yazar / Corresponding Author:**
Cengiz Türe, Department of Biology-(Ecology), Faculty of Science,
Eskisehir Technical University, Eskisehir,Turkey
Email: cture@eskisehir.edu.tr

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## 1. INTRODUCTION

Natural ecosystems are cyclical, stable and productive areas that can produce maximum output using minimum matter and energy. On the other hand, artificial ecosystems such as cities that have maximum material and energy requirements using natural ecosystem services are linearly progressive, unstable and inefficient. Because of this process, exceeding the carrying capacity of our planet has become "unsustainable" (Türe & Türe, 2021a). In order to make this effect measurable and visible, the "Ecological Footprint" indicator has been designed. The "Carbon Footprint" parameter, which expresses the amount of greenhouse gas emissions (GHC), has the largest share in this indicator (Türe, 2013). It is now a scientific fact that the large carbon footprint resulting from fossil-based energy consumption is the main cause of global warming and climate change (Eggleston et al., 2006). This situation has brought with it international initiatives (Kyoto, Paris, Sustainable Development Goals and EU Green Deal etc.) including legal sanctions for the production of goods and services with smaller carbon footprints of all sectors (Türe & Türe, 2020; Türe & Türe, 2021b).

The construction industry is also responsible for approximately 40% of world energy consumption and 1/3 of global greenhouse gas emissions (carbon footprint) during the building life cycle (Wang & Tan, 2012). This situation necessitates a holistic approach to life cycles in order to reduce the environmental impacts of buildings, especially all greenhouse gas emission sources (Türe, 2014a). The role of architects in design is decisive in all life cycle stages of buildings. Thus, the importance of architectural projects based on small carbon footprints has increased in order to reduce the negative environmental impacts caused by constructions. However, the success of this process requires not only architects and architectural design, but also all sectors and actors related to construction to adopt small carbon footprint-oriented building technologies and innovations (Türe, 2014b).

Planning the buildings according to eco-design principles will contribute to both the reduction of the carbon footprint and the construction of buildings that are resistant to climate events. In this study, architectural applications/eco-design methods that can be used for low environmental impact and contribute significantly to the reduction of global greenhouse gas emissions (carbon footprint) are discussed.

## 2. METHODOLOGY

The eco-design approach in the low-carbon built environment is the application of architectural and design principles to ensure positive social and economic development while minimizing ecological and environmental impact in their projections. The material of this study is the buildings designed with low carbon footprint and environmental impact, and the method is to evaluate the gains of these buildings throughout their life cycles according to eco-design in the light of relevant literature information (Bennett, 2007; Monahan & Powell, 2011; Türe, 2017; Fenner et al., 2018; Türe & Ar, 2019; Sipahi & Kulözü-Uzunboy, 2021).

## 3. FINDINGS AND DISCUSSION

The increasing carbon footprint of buildings after the industrialization of architecture requires a closer look at the architectural design process and a re-evaluation of eco-design principles.

### *3. a. Architectural design and ecology*

Unfortunately, it is seen that the effects of architectural design and applications on the environment have been ignored in the past. Because the ecological and environmental effects of the design have not been fully taken into account in architecture. For this reason, many applications have been made with unsustainable architectural design principles. At the end of the twentieth century, with the understanding of the power of design and its importance in terms of sustainability, an architectural design movement that makes use of ecological processes and functions has started.

Since its emergence, the science of ecology has been the basis of understanding the processes in nature, managing environmental resources and sustainable development. Expectations to find solutions to environmental problems in order to protect the ecosystem have increased the search for sustainable design and application based on ecological knowledge. Thus, while ecology knowledge provides information and guidance to this process, the creative potential of eco-design has begun to offer sustainable solutions to environmental problems.

The increasing interest in the concept of sustainability due to ecological and environmental problems in the world has found a response in the field of architecture as well as in many disciplines. All buildings, artificial landscapes and built environment elements in the world are products of architectural design. The increase in the environmental effects of buildings, especially the carbon footprint, brings with it a new definition of architecture (ecological architecture) that takes into account the climate and the local environment in the architectural design process (Sevim & Özipek, 2019).

The eco-design approach is to apply architectural and design principles in a way that will ensure positive social and economic development while minimizing the ecological and environmental impact in its projections. Thus, it can create an interface that inevitably connects culture and nature with material exchange, energy flow and land use options. In addition, turning the design into a product always requires benefiting from an ecosystem.

### *3.b. Carbon footprint assessment in architecture*

Carbon footprint assessments in architecture require preliminary assessments that consider every stage of the building's life cycle, starting from the design stage, and can shed light on the environmental performance of buildings holistically. For this, the following are necessary;

- Understanding the effects of the construction industry on climate change by researching and determining the effects of the built environment on the carbon footprint,
- Understanding and adapting to the effects of extreme weather events related to climate change on the built environment,
- Using eco-design methods and tools to build healthy, safe and durable structures that are compatible with the ecosystem.

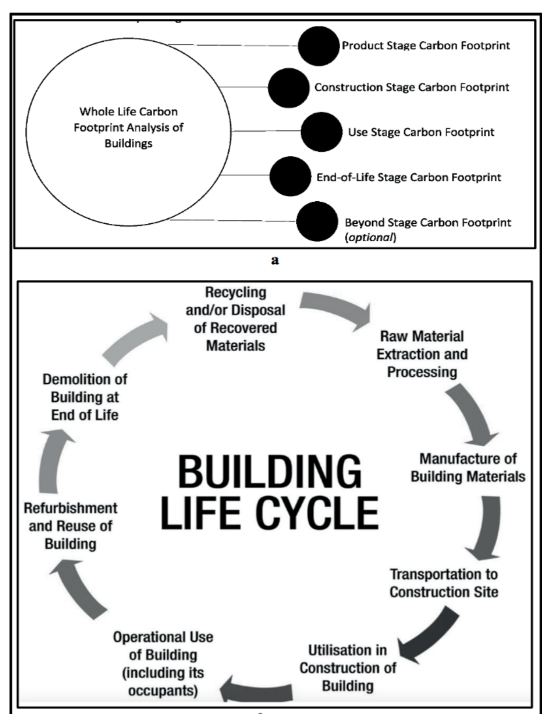
For a built environment project that aims to contribute to the reduction of carbon footprint, it is of great importance to analyze and consider direct/indirect greenhouse gas emissions and carbon sequestration capacities at all stages of the building life cycle (Table 1).

**Table 1. Greenhouse gas emission sources and capture capacities of buildings (Srinivasan & Lakshmanan, 2013)**

| | |
|---|---|
| EMISSION SOURCES IN BUILDINGS | • Energy Use<br>• Material Use<br>• Water Use<br>• Land Use<br>• Transportation Use<br>• Chemical Processes<br>• Construction Processes<br>• Fugitive Gas Leakage<br>• Storage And Distribution<br>• Waste Processing<br>• Other Sources |
| CARBON CAPTURE CAPACITY OF BUILDINGS | • Sequestration<br>• Capture and Utilization<br>• Other Sinks |

The carbon footprint analysis of buildings is the sum of the greenhouse gas emissions and removals associated with a building project over its entire life cycle (Čuláková et al., 2012). For this reason, architects should consider each stage of the building life cycle separately in their designs and choose the products and services to be used in these stages with the lowest possible carbon intensity (Figure 1a-b).

**Figure 1a-b. Life cycle stages to consider for carbon footprint analysis of buildings (Srinivasan & Lakshmanan, 2013)**



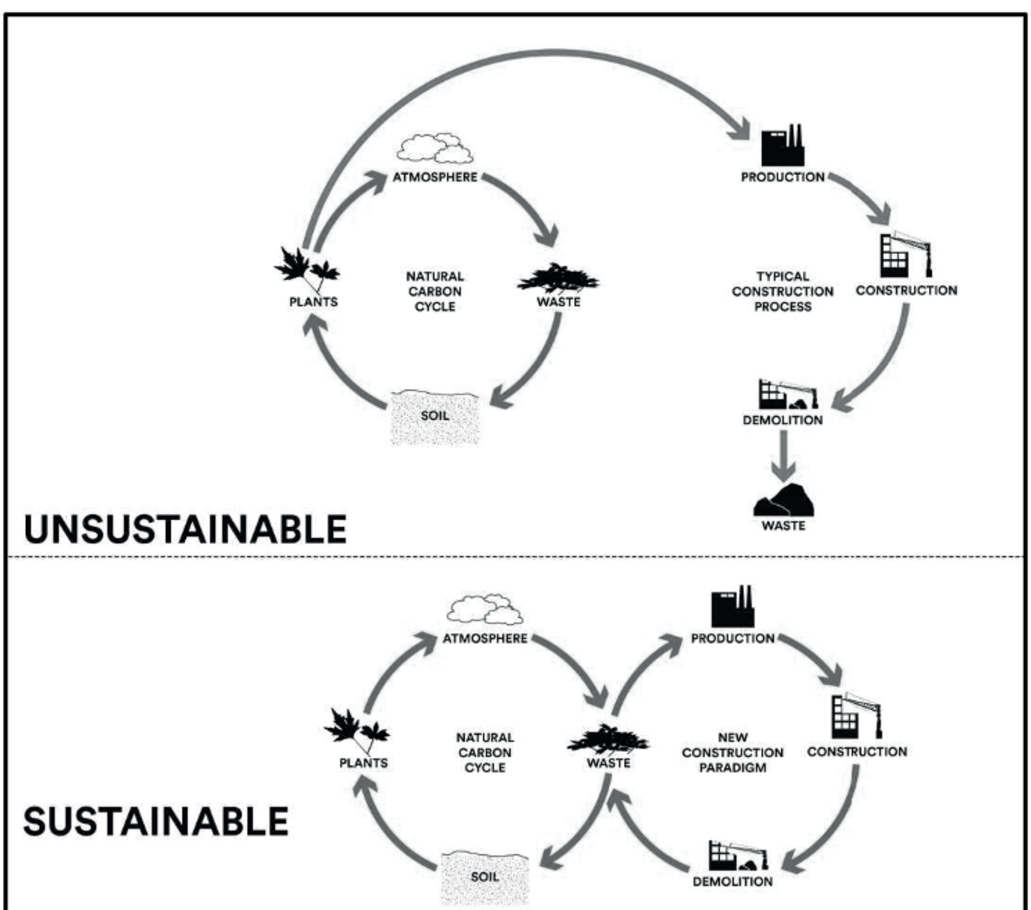
The main carbon footprint sources that architects should consider in the building life cycle in their designs are summarized in Table 2.

**Table 2. Major greenhouse gas emission sources contributing to the carbon footprint in the building lifecycle**

| | |
|---|---|
| **Product Phase** | Construction includes processes from the extraction and refining of raw materials to the manufacture of construction products. Emissions from raw material supply, transportation and manufacturing are included. |
| **Construction Phase** | It includes the processes from the factory door of construction products to the practical completion of construction works. Includes emissions from transportation and construction installation process. |
| **Usage Phase** | It includes the processes from the practical completion of construction work to the demolition or demolition of the building. It includes emissions from use, maintenance, repair, replacement, refurbishment, operational energy and water use. |
| **End of Life** | It starts when the building is decommissioned and no longer used. It includes emissions from demolition, transportation, waste treatment and disposal. |

In the light of this information, it is important for architects to design by choosing products, methods and services that can be included in the natural circular carbon flow in ecosystems, reducing the linear carbon flow that occurs during the life cycle stages of buildings. (Fig. 2).

**Figure 2. Carbon cycles for a sustainable built environment (Srinivasan & Lakshmanan, 2013)**



## 4. RESULTS

For a built environment that aims to contribute to the reduction of carbon footprint; direct/indirect GHG emissions and carbon sequestration capacities at all stages of the building lifecycle need to be analyzed and taken into account prior to the project. Particularly, the following principals are important to the adoption of eco-friendly building:

- Site analysis for effective orientation
- Passive cooling design
- Use of high thermal insulation
- Controlling heat gains
- Use of energy efficient equipment and appliances
- Reduction of water demand and consumption
- Ongoing house performance monitoring and optimization

As a result; to reduce the carbon footprint of built environment practices and minimize their impact on the climate:

- A clear goal should be defined
- A carbon budget should be determined and followed throughout the project
- The natural ecological conditions of the land (climate, aspect, watershed, soil, biodiversity, etc.) should be taken into account at the maximum level
- In practice, the project based on eco-design that will have the least impact on the environment should ensure the use of materials and energy demand
- Materials and energy sources with low climate impact should be selected
- All emissions must be balanced.

For these reasons, it is of great importance in terms of sustainable architectural practices that architects consider each stage of the building life cycle separately in their project designs and prefer low-carbon products and services.

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