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SUSTAINABLE DESIGN OF COMMERCIAL BUILDINGS THROUGH EMBODIED ENERGY OPTIMIZATION

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Sara KANBAR

ABSTRACT

SUSTAINABLE DESIGN OF COMMERCIAL BUILDINGS THROUGH EMBODIED ENERGY OPTIMIZATION

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M.Sc. in Civil Engineering

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Nowadays, buildings industry consumes large amounts of energy. The current procedures, which have been used for years, are really lack to be improved, and very important insurances and inventions are required to reduce the energy consumption.

In this study, a life cycle energy (LCEA) and carbon dioxide releases ($_{LCCO2A}$) analysis of two commercial buildings has been performed. The study involves the literature review, the records used for such an overall procedure, and approach and offers an application of the method that studies two real commercial buildings built in Gaziantep, Turkey. The intended pattern concentrated on building construction, operating and destruction stages in order to evaluate gross energy consumption and carbon dioxide throughout 50-year lifetime. Energy efficiency and emissions factors are expressed for the buildings per square meter base. The results expressed that the operating stage is prevailing in both commercial buildings and share in86-90% of the primary energy necessities and 77–86% of CO_2 releases, respectively. The embodied energy (EE) of the buildings calculated for 10–14% of the total life-cycle energy consumption.

Keywords: Commercial buildings, Life cycle, Energy, Primary energy, Embodied energy.

ÖZET

GÖMÜLÜ ENERJİ OPTİMİZASYONU İLE TİCARİ BİNALARIN SÜRDÜRÜLEBİLİR TASRIMI

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Mayıs 2018,79sayfaları

Günümüzde, yapı endüstrisi büyük miktarda enerji tüketiyor. Yıllardır kullanılmakta olan mevcut prosedürler sürdürülebilir bir yaklaşım sergilenerek geliştirilememiştir. Binalarda enerji tüketimini azaltmak için çok önemli önlemler ve yeniliklerin yapılması gerekmektedir. Bu çalışmada iki ticari binanın yaşam döngüsü enerjisi değerlendirmesi (LCEA) ve karbondioksit salınımları (LCCO_2A) analizi yapılmıştır. Çalışma, literatür taraması, genel metodoloji için kullanılan bilgiler ve söz konusu analizler için sergilenen yaklaşımı içermektedir. Bu yaklaşım ile, Gaziantep'te inşa edilen iki gerçek ticari yapıyı inceleyen bir yöntemin uygulaması sunulmuştur. Amaçlanan model, 50 yıllık ömür boyunca brüt enerji tüketimini ve karbondioksit salınımını değerlendirmek için inşaat, işletme ve bertaraf aşamalarına odaklanmıştır. Metrekare başına binalar için enerji verimliliği ve emisyon faktörleri ifade edilmiştir. Sonuçlar, işletme evresinin her iki ticari bina için en etken parametre olduğunu ve birincil enerji gereksinimlerinin % 86-90'ını ve karbondioksit salınımlarının % 77-86'sını paylaştığını ortaya çıkarmıştır. Binaların gömülü enerjisinin (EE) ise, toplam yaşam döngüsü enerji tüketiminin % 10-14'lük kısmına tekabül ettiği hesaplamıştır.

Anahtar kelimeler: Ticari binalar, Yaşam döngüsü değerlendirmesi, Enerji, Birincil enerji, Gömülü enerji.

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LIST OF SYMBOLS

LCEA Life cycle energy assessment

$LCCO_2A$ Life cycle of carbon dioxide assessment

EE Embodied energy

ASCE American Society of Civil Engineers

ISO International Organization for Standardization

CO_2 Carbon dioxide

LCI life cycle inventory

LEED Leadership of energy and environment design

AEC Architecture, engineering & construction

HVAC Heating ventilation air conditioning

GDP Gross domestic product

C & D Construction and dismantling

FT Feet

KWH Kilowatt per hour

IEQ Indoor E\environment quality

USGBC U.S. Green Building Council

ICC International code council

IGCC International green construction code

CAL Green California green building standards code

ASHRAE	American society of heating, refrigerating, and air conditioning
BREAM	Building research establishment’s environmental assessment
DGNB	German sustainable building council
EPD	Environmental product declarations
ASTM	American society for testing and materials
PCR	Product category rule
MJ	Mega joule
ICE	Inventory of carbon & energy
EGHG	Embodied greenhouse gas releases
EIA	Energy information administration
GJ	Giga joule
KG	Kilogram
NZEB	Net zero energy buildings
NPEB	Net positive energy buildings
EPA	Environmental Protection Agency

CHAPTER 1

INTRODUCTION

1.1 Background

Sustainable development has become a more explicit objective as awareness of the implications of current practices for future generations grows. In 1996, American Society of Civil Engineers (ASCE) (American Society of Civil Engineers, 2013) refined the Code of Ethics to include the principles of sustainable development in the law of civil engineering practices, demonstrating the importance of sustainable design throughout the profession. Energy is one of the general natural resources and its availability is the key to human sustainability.Structural engineers have begun to merge sustainable principles directly into their practices to reflect this awareness. While construction engineers see sustainability as a major issue, many wonder how structural design decisions can help to achieve sustainable building design. Structural engineers have given little encouragement or guidance on how to design more sustainably, as the focus is largely on reducing the use of building power. As buildings seek to become zero by generating energy, the focus will increasingly be on the environmental and environmental impacts of building materials. This shift will begin to integrate structural engineers into sustainable design discussions and promote the design of structures with low embodied environmental impacts.

1.2 Overview of LCA

One method of environmental impact assessment is embodied in the life-cycle assessment(LCA). The International Organization for Standardization (ISO) (International Organization for Standardization, 2012) defines LCA as gathering and evaluating the inputs, outputs and possible environmental impacts of the product system throughout its life cycle. LCA has been adopted primarily by the consumer products industry since the 1970s but is still in development as efforts are being made to improve the standardization of the LCA studies process. ISO has developed a set of standards on the LCA to determine the process for LCA practitioners. These standards are ISO 14040: Environmental Management - Life Cycle Assessment - Principles, Framework and ISO 14044: Environmental Management - Life Cycle Assessment - Requirements and Guidelines. ISO 14040 defines the four main stages of LCA. These are:

- Definition of Objective and Scope (Section 1.2.1)
- Inventory analysis (Section 1.2.2)
- Effectiveness estimation (Section 1.2.3)
- Explication (Section 1.2.4)

These phases are symbolized in the following format and further discussion in the following sections.

1.2.1 Definition of Objective and Scope

When we use LCA, the first step is to determine the objective of the study. The objective identifies the reasons for the implementation of the life-cycle assessment and the intended application of the results, the public's findings, and whether the results are intended to be a comparison of studies.

The scope should reflect the objective and the product to be studied and the functional unit of the study. The functional unit determines the features of the product under consideration.System boundaries should also be defined to study life cycle studies as part of the scope. Because life cycle assessment considers the overall process of creating a final product, there are several sub-processes that can eventually be included.Most activities are interdependent and interlinked; consequently it can be difficult to determine what should be included.The stages provide a general set of processes related to the product life cycle. The limits of the system determine which of these stages are included, which are usually the acquisition of raw materials, manufacturing (sometimes aggregated with the acquisition of raw materials in what is known as the pre-use phase), use / reuse / maintenance, and recycling / waste management (also known as end-of-life), as illustrated in figure 1.2 below.

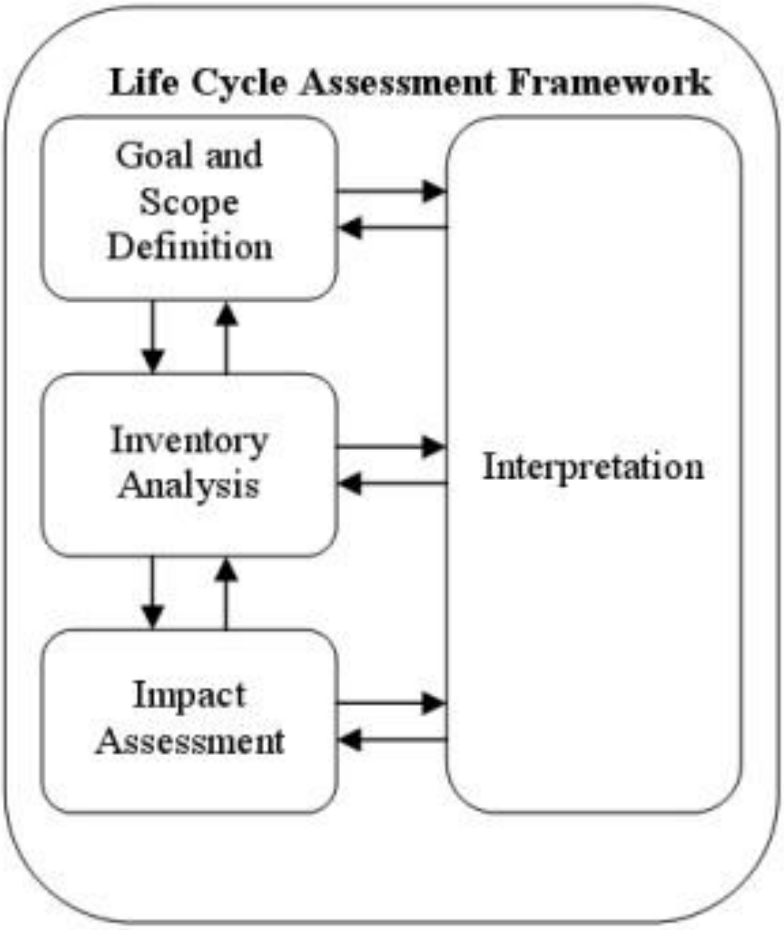


Figure 1.1 Four stages of LCA. Reprinted from "ISO 14040:2006," by International Organization for Standardization, 2006

Once the limits of the system have been determined, the quality of the required data must be determined.Life cycle assessment results depend extremely on the data used in the study.Data must be regional when available and should be constant and able to replicate between studies. As with any study, there should be clearly defined assumptions and limitations.

There may also be a need to allocate at the target definition and scope stage if the process produces more than one product.The environmental effects of the entire production process must be divided and distributed to each product of that system.Earmarking is also used in processes where the product can be recycled or reused at the end of its lifetime and LCA limits include reuse and recycling system.The impact of the reused materials should be allocated to the product under consideration. For example, for materials such as steel being recycled over and over again, allocation may need to be taken into account to properly rotate recycling after use.

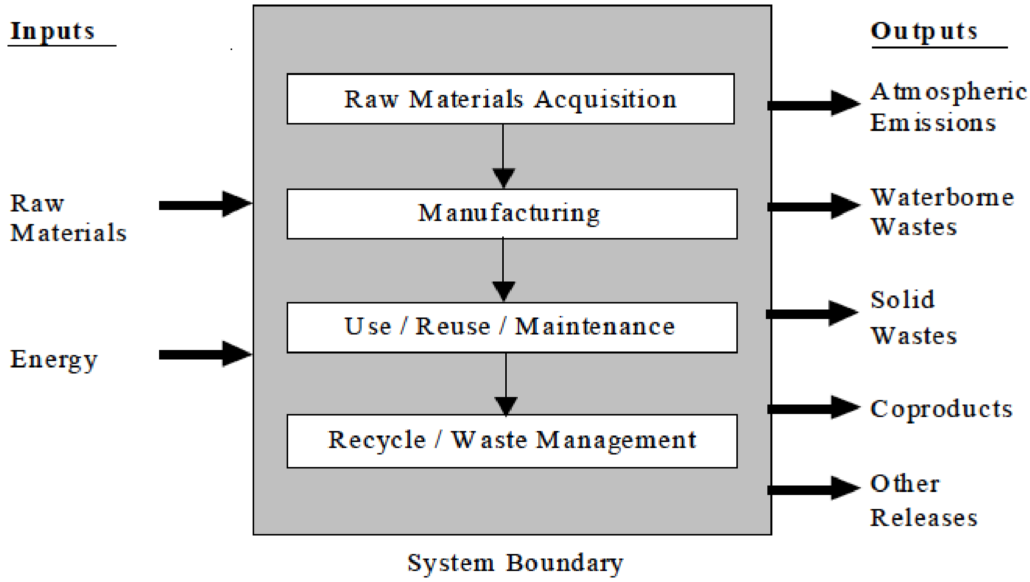


Figure 1.2 LCA system boundary. Reprinted from "Life-Cycle Assessment: Inventory Guidelines and Principles," by U.S. Environmental Protection Agency, 1993

1.2.2 Inventory Analysis

After the target setting and scope phase, inventory analysis must be performed. This phase is sometimes denoted to separately as a life cycle inventory (LCI). During the LCI stage all inputs and outputs of the product system must be determined and quantified. Inputs for each stage may involve the quantity and type of raw materials, water and energy used. The outputs may involve any emissions to air, water, and land. Figure 1.2 shows inputs and outputs with associated phases within system boundaries. Data collection to identify inputs and outputs is a major step in the life cycle assessment process.

Many LCA tools have been developed that help in conducting inventory analysis or inventory analysis built into the program, thus making easy to do the process. LCA programs differ in their focus and applicability for construction LCA. LCA Tools can be classified into three levels of intent: product concentration level, concentration level of assembly, and whole building level (Trusty, 2011).At the product concentration level, there are implements for experienced LCA practitioners to build their own LCAs and tools that have LCA built in background. SimaPro (PRé, 2013a) and GaBi (GaBi Software, 2013) are examples of the level of product focus tools that allow users to build LCA systems. With these tools, users must understand the LCA and ISO 14040 accurately in order to implement the LCA according to established guidelines.

Product concentration level tools consider one single product system and are useful for focused comparative studies.However, it cannot be applied to the entire building level. At the concentration level of the assembly, the tools are capable of performing a complete construction LCA using predefined assemblies. These assemblies can include columns, beams, panels, surfaces, and other assemblies of building elements. Athena Eco-Calculator (Athena Sustainable Materials Institute, 2013b) is the most commonly used concentration-level concentration tool for the entire LCAbuilding originally developed for use by the Green Globe environmental assessment and classification system for commercial buildings. Eco Quantum (Eco Quantum, 2013) and Envest 2 (Envest 2, 2013) are similar assembly concentration level tools.These tools have been built in the background, so that the user does not need to build system boundaries, develop the inventory, or conduct an impact assessment. The user is asked to provide design information so that the quantity of each predefined set can be determined within the tool. Using assemblies simplifies the process, but limits users to predefined assemblies, which can lead to inaccurate material quantities.The Athens Institute also makes a tool for evaluating the entire building known as the Athens Effect Estimator (Athena Sustainable Materials Institute, 2013c).Athena Impact Estimator can be conducted at the assembly concentration level using predefined assemblies to generate quantities, but users can also enter physical quantities for each pool. Allowing the user to enter quantities manually results in complete results for a more accurate construction of a particular design being considered compared to the assembly procedure.

1.2.3 Effectiveness Estimation

Effectiveness estimation follows inventory analysis and links inventory data with environmental impact categories. There are a number of environmental impact categories that can be considered and vary according to the method of effectiveness estimation and study. These categories include energy consumption, global warming potential, ozone depletion potential, acidification potential, smog potential, nutrient enrichment potential, human toxicity and environmental toxicity.

1.2.4 Explication

Explication is the final step of LCA, but all phases of the process should be considered for LCA. At this stage, the results of both inventory analysis and effectiveness estimation are quantified. The Explication provides conclusions and recommendations based on the study being developed with the public. Unlike inventory analysis and effectiveness estimation, life-cycle assessment tools do not lead to the Explication of LCA. The LCA practitioner conducting the study is responsible for providing an analysis of the results of the study.

1.3 LCA in Green Building Rating Systems and Codes

Green building classification systems typically allocate stocks of materials based on factors such as recycled and low-volatile organic compound content. In an attempt to replace these mandatory requirements with those based on performance, the classification systems and codes for LCA have been identified as a means of assessing the environmental impact of buildings and products more precisely. The level of adoption of LCA varies according to classification systems for green buildings and their codes, but life cycle assessment is not mandatory at present as part of any classification system or code. It is well recognized that the life cycle assessment has not yet been sufficiently developed for its mandatory adoption, but many classification systems and codes are currently working to strengthen LCA so that they can be fully adopted in the future.

1.3.1 General Requirements

While the details vary slightly between each code and rating system, all the requirements for LCA are based on the same concepts. First, all the codes and classification systems that have incorporated the requirements for LCA recognize that the results for LCA cannot be compared between studies and do not require results to compare with the mean or baseline value. Instead, all code and classification systems that include LCA requirements specify that the design of the intended building should be compared with the design of a reference building to show improvement. Requirements for the reference building vary, but the overall design must be the same location, size, function, orientation and energy performance. In order to ensure that the reference building is not designed to increase environmental impact.

Improvements in the design of reference buildings should be demonstrated across several categories of impact; no current requirements are required for the results of each impact category to be weighted to determine the final environmental impact. The impact categories of each classification system may vary, but fossil fuel consumption, global warming potential, acidification potential, nutrient enrichment, ozone depletion potential, and smog potential are the common impact categories considered.

1.3.2 Sustainable Rating Systems

Currently, in the practice of the United States, LEED (leadership of energy and environment design) evaluation system frequently occupies asignificant part of making decisionaround the world. Cubbison et al. (2012) in the construction engineering and construction (AEC) industry, owner often decides the initial total record due to constraints on construction cost. When they can take longer view, environmental impact LEED is considered to be a device that can be used for various kinds of projects ranging from those limited by initial costs through those that can be invested in long-term performance through various stages of certification. “LEED, parts (United States Green Building Council, 2011):

- Consumption of energy involvingefficiency of energy for lighting and heating ventilation air conditioning (HVAC) system.
- Positioning of buildings and sustainability of the environment.
- Reducing lighting costs by using indoor air quality and daylight.
- Preservationof water and decreased Mechanism.
- Usage of sustainable materials through construction.

1.4 LCA Limitations

Because LCA is a comparatively new methodology, there are several limitations, specifically when applying the full life cycle to entire buildings.While ISO 14040 unifies the properties required of LCA studies, defining those properties is a subjective task. The system limits can be easily modified, for example to include or exclude some flows if these modifications will benefit the user of LCA. For rating systems and codes that use a reference building, users can easily operate the design of the reference building to succeed better results. The tools of LCA can help remove some of this objectivity by building up the LCA and its phases, but users still have the ability to modify some inputs, such as material quantities and building lifetime, to develop their results. The tools of the LCA itself have their limits. While some life-cycle assessment tools allow the introduction of physical quantities to provide environmental impact results, others depend on the assemblies chosen by users based on their given design. These assemblies may not accurately capture the design.

Most life cycle assessment tools now assume that all materials are “cradle to grave", that the materials reach as virgin materials and are eventually disposed of LCA currently is not able to calculate design for dis-assembly or adaptability. Many structural engineers believe that this penalizes inventive designs that account for building reuse at the end-of-life. According to kestner and Webster (2010),most of buildings are designed for 50 years of building lifetime but many are demolished 50 years ago. In fact, a study conducted by the Athens Institute of Materials found that 60% of concrete buildings and 80% of steel buildings were demolished 50 years ago (Kestner and Webster, 2010).While it will be difficult for life cycle assessment tools to expect buildings that will meet their designed lifetime, this will not lead to the recognition that buildings designed to facilitate their dismantling or adaptation can produce more accurate results of the environmental impact on the life cycle.The greatest limitation to the current life cycle assessment is the lack of reliable data from the LCI. The current database in the United States of America uses industry averages for many structural building materials, which do not represent the specific materials used. The results of the LCA are only regionalized through electricity and transport networks and do not currently represent variations in manufacturing processes or mix designs.

Many LCA practitioners emphasize that the LCA has been developed to be used to compare design options for a particular product and not to provide large-scale environmental claims for performance for other products due to differences in the LCA methodology. This is particularly relevant to the entire building of LCA, where in addition to differences in methodology, construction designs can vary greatly in terms of use, area and size. Even buildings in the same area with the same use may vary due to specific loading requirements. The current requirements of LCA in various green building rules and classification systems reflect this sentiment by comparing the reference design option rather than comparing it with a separate building design. Thus, the environmental impact of the design option is compared to the impact of another design option, without making performance claims compared to other buildings.

Objective of the study

The aim of this thesis is to analyze of life cycle energy (LCEA) and carbon dioxide emissions (LCCO$_2$A) analysis of two actual commercial buildings hasbeen conducted. This study involves literature review, data used for such comprehensive analysis, and methodology, and application of methodology considering two actual commercial buildings built in Gaziantep, Turkey. The proposed model focused on the construction, operation and dismantling phases to estimate the total energy usage and carbon releases over the 50-year lifetime.

Outline of Thesis

This thesis is organized into five chapters with the following contents.

Chapter 1:presents an introduction with a brief overview of LCA stages
Moreover, the objective of the thesis is provided.

Chapter 2: contains a review of the relevant literature that covers previous studies conducted on sustainable design of buildings and international rating systems and codes.

Chapter 3: deals with the description of were studied building and LCA methodology.

Chapter 4: provides the results and discussion of the study.

Finally, **chapter 5:** summarizes the main conclusions achieved in this study.

CHAPTER 2

LITERATURE REVIEW

This chapter presents the framework of this research. It explains the application of sustainability to the building industry and the next section discusses aspects of sustainability in the constructed environment. In this chapter, outlines of research conducted by experts on the field are shown, and necessary classification is included as the basis for analyzing the evaluation system of this research.

A wide range of building LCA studies has been achieved in recent decades. These studies can give attention to building enclosure and structure assemblies over an entire building lifetime or give attention to specific subsets of building materials. Whole building LCA has been achieved on a variety to build types, including residential, institutional, and commercial buildings. LCA studies limited in range to structural materials just have been conducted more lately, often with the purpose of comparing materials to determine that includes a lesser environmental impact.

2.1 What's The Meaning of Sustainability?

In industrialized countries the concept of sustainable development has emerged over 50 years. In 1966, Kenneth Edward Boulding promoted this problem in the article "Spacecraft Economics" and is teaching the ongoing financial development process on a limited supply planet (Smith, 2010).

The concept of sustainable development has changed based on the announcement of various statements such as the World Conservation Strategy, the Brundtland Report, the Johannesburg Declaration (Smith, 2010). Following the United Nations Brundtland Report (1987), the expression "sustainable development" was increasingly used in educational activities and in government reports. As a result of advancing a somewhat uncertain explanation of flexible 'sustainable development', the report has become the most typical way to see unity between development and the environment (Baker, 2006) (Smith, 2010). The description of the Brundtland Report emphasizes the fairness of the next generation by "World Commission on Environment and Development (1987)" to satisfy current needs without compromising the ability of future generations to meet their needs There.

Nevertheless, in order to achieve sustainable development, a more perceptible explanation is required to arrive at policies that can be properly addressed. Since the term "sustainable development" was widely criticized, as the term "development" was essentially understood as growing economic development, it adopted the term "sustainability" (Smith, 2010). Sustainability was summarized as three limits on the giving of goods and services (Calvert and Calvert, 1999):

((Sustainable development does not use non-renewable resources faster than substitutes can be found, or renewable resources faster than they can be replaced; nor does it emit pollutants faster than natural processes can render them harmless)).

Sustainability, as noted previously, only asserts the significance of environmental safety and is denoted to as "ecological sustainability" (Smith, 2010).

Sustainability is also referred to as three interrelated pillars, "three ESs", economic development, stock, environmental safety (Baker, 2006;Smith, 2010; Social Watch, 2011). From this analysis perspective, sustainability is the integration of three convergence components as shown in Figure 2.1. It affects the environment, economy, and social order.

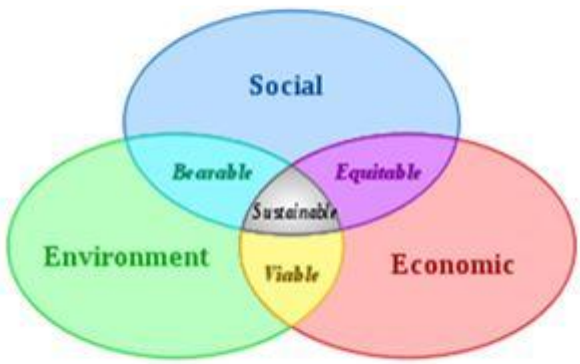


Figure 2.1 Sustainability interlocking circles model (Social Watch, 2011)

The overlapping circuit model implies that the three objectives need that they be more effective within a wide-open health state. This pattern affirms that environmental safeguard guarantees a growing and sustainable economy and those greater stages of social integrity are needed to achieve environmental safety (Baker, 2006). In order to make sustainable buildings existing, they must be achievable from the economic point of view. The further expenses incurred in the construction of these buildings must be insured by the last cash savings resulting from the energy cuts - making them achievable. Intended for sustainable buildings to be effective and typical, they must be inexpensive to all and not just an advanced product. By underlining energy preservation, sustainable buildings depend less and less on high-priced technologies to decrease greenhouse gas emissions. Reducing high-priced supplies and processes helps sustainable buildings to be dominant - and thus becomes equitable. To make sustainable buildings more available does not automatically expand the desire to be adopted by the populace. All as a priority must understand the positive impression of sustainable buildings on the environment. By offering programs to educate people about the benefits of sustainable buildings and to take the correct strategies to guarantee that the construction industry becomes sustainable, sustainable buildings are convenient to the public eye - they become endurable. Buildings should be sustainable for the protection of the environment, but also for a protectable economy and for the safeguard and security of society.

In the case of buildings that are not sustainable, they use too much energy, creating more greenhouse gases and influencing the whole situation of the model.

The notion of sustainability nowadays increases to an extensive variety of economic sections. In the next years, the notion of sustainability will remain variable, as it is progressively being used as a decision-making platform. Likewise, Community skills and mentality are also developing. However, as Yanarella et al. (2009) illustrates,the balance needed to achieve sustainability among the three columns will never attain a "fixed end state" because of the fact that the status quo in individual actions does not exist and new facts need to be reconsidered all the time to attain once more equilibrium. There are many other studies about the sustainability of residential and commercial buildings in the literature (Atmaca, 2018; Atmaca et al.,2017a,b,c; Atmaca and Atmaca, 2018; Atmaca et al., 2018; Atmaca, 2016a,b;Atmaca and Atmaca, 2016)

2.2 Sustainable Design aspects

Researchers appeared in the 1970's, the principal relationship between design and sustainability seeking an accurate equilibrium between "industrial culture and the natural environment" (Keitsch, 2012). In Martina Kitsch (2012), in her article "Sustainable design: Simple assessment of its principal concept": Under the three key principles of ethics, technology reform, and social interaction, sustainable design It defines considerations for.

Ethics is a key part in considering sustainable design considerations. Designers play a main role to influence society and environmental principles and in what way they are "modern society" (Ketsch, 2012). Technology modifications are another standard that can be used for sustainable design. This tactic began in the 1990s and is often associated with environmentally designed products and / or service solutions (Kitsch, 2012). As planners are planning for the environment at each stage of production, designers use modifications of the technology to develop product and equipment life cycle assessments.

Decisions made at that level will have a major impact on other phases of the product or service lifecycle (Rebitzer et al., 2004), but the design level of production procedures is often unimportant. For instance, residential area design determine annual energy usage and usage, and has a measurable effect on recycling choices at the end of life. Consumer's attitude has a significant impact on sustainable design. Management is more difficult as this standard tends to change over time. For example, in the 1970s and 1980s, key requirements of users were emphasized, with emphasis on meeting the social and symbolic needs of the 1990s (Kitsch, 2012). Another way is "a wide range of needs and access to society and access to goods and services as much as possible" (and still) is a very general global design in political and institutional context (Kitsch, 2012). However, EzioManzini presents one of the most appropriate design approaches for social cooperation related to sustainability (Keitsch, 2012). The point of his idea is that together with civilian life and public happiness should focus on "low material energy density" and "high regeneration effort" (closely related to the aforementioned technical modifications) (Manzini, 2003; Kitsch, 2012). In summary, a sustainable design should include all three criteria of business: ethics, technical modifications and social interactions. A common approach will share the three pillars of sustainability. Recently, the work of the designer is to take into account "what is possible in terms of both natural science and natural science, society accepts or desires" (Hermansen, 2006;Keitsch, 2012).

2.2.1 The Relation between Sustainable Design and the Built Environment

Buildings are integrated into communities and carry out a spacious range of purposes. Buildings play a dominant role whatever is household tasks, industrial processes, administrative work or leisure actions have been. They not only provide residence to public, they can also encourage social evolution (i.e., collaborations, well-being, productivity and social progress) if adequately planned and organized (Yao, 2013).

Typically, the building industry has considered the weather, which would permit for higher levels of efficiency, thereby enhancing sustainability. In a cool climate, solid structures will be used with small window spaces and dense wooden walls. The contrary was right in warm and wet climates where buildings could be used on high-roof substrates to increase natural ventilation (Lechner, 2015). The introducing of low-priced fossil fuels and related technologies has led communities to set predominantly built surroundings with respect to beauty instead of efficiency, making buildings "energy hungry" (Foskit and Mamo, 2009).

Luckily, worries about global warming have inserted a new viewpoint with regard to the built surroundings where energy use includes environmental impact estimation elements as well as cost funds plans. The number of building designs that follow "sustainable green" and "low carbon" approaches, which are primarily aimed at reducing the influence of society on the planet, is increasing (Yudelson, 2008).

Sustainability can be addressed by design for the built environment of four different viewpoints: reduction, re-use, recycling and regeneration (Lechner, 2015). The expression "reduction" may be translated in distinct methods, though, in this research, stated to as waste decrease and unnecessary practices (Lechner, 2015). For the sake of accessing sustainable designs, the principal phase that should be analyzed is decreasing. In the built surroundings, the decreasing can result in a lesser-embodied energy for each building, and will reduce the "energy craving" of the buildings.

Re-use and recycling are also essential elements of sustainable design. For example, the unusable buildings should be re-used or recycled rather than destroyed. Restoration is a usual practice and is currently available to business people aiming to build sustainable buildings. Deconstruction is also an appropriate choice. This includes recycling and reusing elements such as concrete, steel and wood, and / or reusing materials in good conditions such as windows, doors, bricks (Almusaed, 2011). When building materials are sent to the landfill site, the amount of waste will increase and the energy required for transporting and managing waste will not be consumed to the utmost. On the other hand, updating is a procedure not normally used. Regeneration develops the idea that if the earth is used and degraded, ways to restore the earth should be found out. From the viewpoint of energy use of buildings, it is possible to generate power through Net Zero Energy Buildings (NZEB), and can be played by Net Positive Energy Buildings (NPEB). NZEB can be broadly defined as "Building that sufficiently generates renewable energy on site at the same level as or higher than annual energy usage" (Cole and Fedoruk, 2015). NZEB has many similarities with NPEB but in the end it said, "It is necessary to produce more than necessary energy and export it to other buildings and systems, ie energy storage management and extra energy to the grid (Cole andFedoruk, 2015).

2.3 Sustainable Premises

Sustainable buildings are expected to produce high-performance effects within the life cycle (ie, setting, designing, construction, operating, maintenance, destruction) in the following zones (Yao, 2013):

- Effectiveness of energy and source.
- Effectiveness expenditures.
- Minimization of releases that have harmful affect global warming, interior air quality, and acid rain;
- Minimization of waste releases.

- Maximization of satisfying the needs of inhabitants' health and wellbeing.

By definition, sustainable buildings will cause fewer influence on the environment and on individual well-being, will consume fewer water and energy, reduce location effects, and increase indoor air quality (Yudelson, 2010).

For the sake of directing the growing worry about sustainability in the built environment, several organizations have appeared and have established various sustainability assessments, measures and measures that allow entities to assess their "sustainable" buildings, which are built mainly on point systems.

Different rating systems use different methodologies to determine the level of sustainability of a building, with different levels of accreditation. However, their bases are identical and include the related aspects of the various types that can be roughly summarized as exhibited in Figure 2.2.

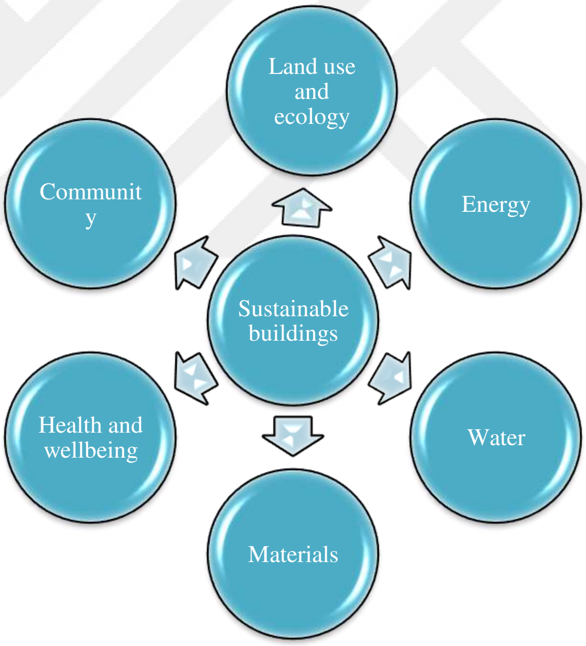


Figure 2.2 Sustainable buildings and related parts. Adjusted from (Yao, 2013)

For the purpose of achieving sustainability for a building, one should use a comprehensive method. The link to the environment should be settled within society, inhabitant good health and wellbeing. The availability and availability of materials are also taken into consideration, and questions such as "how to use materials more efficiently, how to supply them and renewable" are taken into consideration. It is part of the evaluation when design a sustainable building (Yao, 2013). Clearly, the energy use of the building's driving is an important issue and it is always low for sustainable buildings. At the design stage, all architectural styles (form, texture, framesetc), building equipment (heating and cooling systems), rural weather and thermal performance all take energy use into consideration Yao, 2013). Likewise, the use of water in buildings is also taken into account, and a way to reduce waste is involved in sustainable buildings. Land use and the environment are related to the idea of saving natural resources as much as possible.

2.4 Sustainable Design and Commercial Buildings

This part shows several points and difficulties of sustainable building design that are significant to realize.

The building manufacturing has a significant function in nation’s economy. For instance, in U.S.A the contribution of building industry in Gross Domestic Product (GDP) was 9 percent in 2005 (U.S. Department of Energy, 2008) taking into account modern construction, maintenances and improvements of residential and commercial buildings. The construction industry provides employment opportunities for 7.2 million employees and salaries in 2008 and 1.8 million self-employed workers (Labor Statistics Bureau 2011). Buildings have important influences on the environment and humanwell-being (Perez-Lombard et al., 2008; Horvath, 2004; McKinsey, 2011).

Table 2.1 shows how buildings are influenced by environment in the United States deployed between commercial buildings and residential buildings by the US Environmental Protection Agency (2009). According to the US Environmental Protection Agency (2009), building related construction and dismantling (C & D) rubble related to construction accounts for about 160 million tons each year, accounting for about 26% of entire US non-industrial waste production It is reporting. Also, according to the US Department of Agriculture (2002), the United States owns 60 million urban areas (2.6% of 2.3 billion acres in the US) and has increased 13% from 1990 to 2002.

Commercial buildings are less various in quantities than residential buildings. But, commercial buildings cause a greater environmental effect per unit for primary energy use, electricity consumption, carbon dioxide releases, and water consumption. In addition, commercial buildings showed a reduction in energy effectiveness per unit, compared with residential buildings that improved energy effectiveness during the period 1985-2004. According to the US Department of Energy (2008), energy intensity in the US construction section increased by 12%, the land area increased by more than 35%, and overall prime energy use increased by 50% during 1985-2004 (Figure 2.3). This finding presents that the design of commercial buildings has not enhanced, when estimating built on energy use point of view. The same report shows that the major use of major energy in commercial buildings is lighting (25%), cooling (13%) and heating (14%).

Table 2.1 Allocation of environmental effects on buildings (US Environmental Protection Agency 2009).

	Residential and Commercial as part of US total (1)	**Residential of (% Of (1))**	**Commercial (% Of (1))**
Units of existing buildings (millions)		128 (in 2007)	4.9 (in 2003)
Major energy use	39%	53.7%	46.3%
Electrical use	72%	51%	49%
CO2 emissions	39%	54%	46%
Water use	13%	74.4%	25.6%

Furthermore, the design of traditional buildings does not guarantee stakeholder alliances. Numerous holders are contractors, who are not influenced by the performance of the upcoming building (e.g., energy utilization). A series of publications on this issue were developed by the United Nations Environment Program (2007, 2008a, 2008b, and 2008c).

Traditional practices in planning and construction of buildings cause a significant effect on human good health and environment such as causing weather alteration, urban air contamination, water use, waste generation and the devastation of wildlife habitats.

Junnila and Horvath (2003) performed an LCA of 168,000 square foot (15,600 square meter) office building in Southern Finland with a 50-year building lifetime. Data of Life Cycle Inventory (LCI) was obtained from real constructors in Finland, to the expansion possible. The effect classifications chosen were global warming (indicated to in the report as climate change), acidification potential, smog potential (indicated to in the report as summer smog), nutrient enrichment and dispersal of dangerous materials (also indicated to as heavy metals).

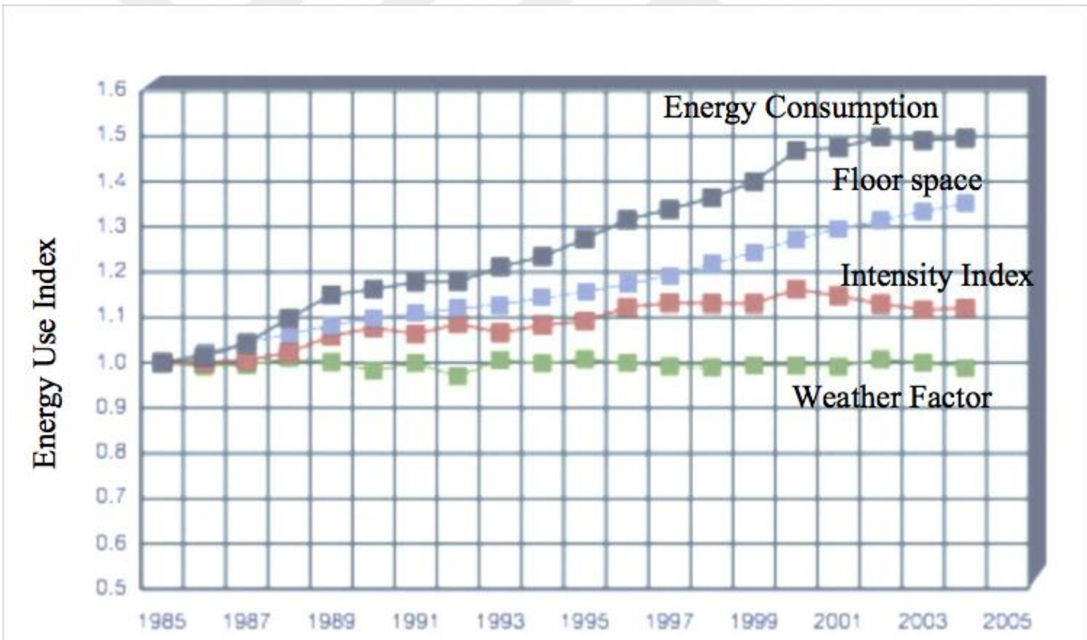


Figure 2.3 Commercial buildings, energy use, and intensity factors (US Department of Energy 2008, Figure 30)

The structural framework was cast-in-place reinforced concrete. The feasible unit involved building location materials, structure, fencing, finishes, lifts, and mechanical and electrical facilities throughout the whole life cycle. The limits of the system involved pre-use, industrialization process, use, repairing and end-of-life phases. In the study, the pre-use and industrialization stages were combined together, indicated to as the "building materials" stage. Construction was taken into account and operational power was involved in the study.

During the construction phase and the maintenance stage, the structure, enclosure and finishes were considered to have an effect. The combined environmental impact of these two phases of structure and enclosure was taken into account only in comparison with the environmental effects of the structure alone. The results are presented in Figure 2.4. The end-of-life phase was not included because the study combined the effects of the demolition of all materials and processes and did not provide individual effects at the individual end of life. Structural materials were considered steel, concrete, and reinforcing steel bars. Elements of the enclosure were construction, insulation and glass.

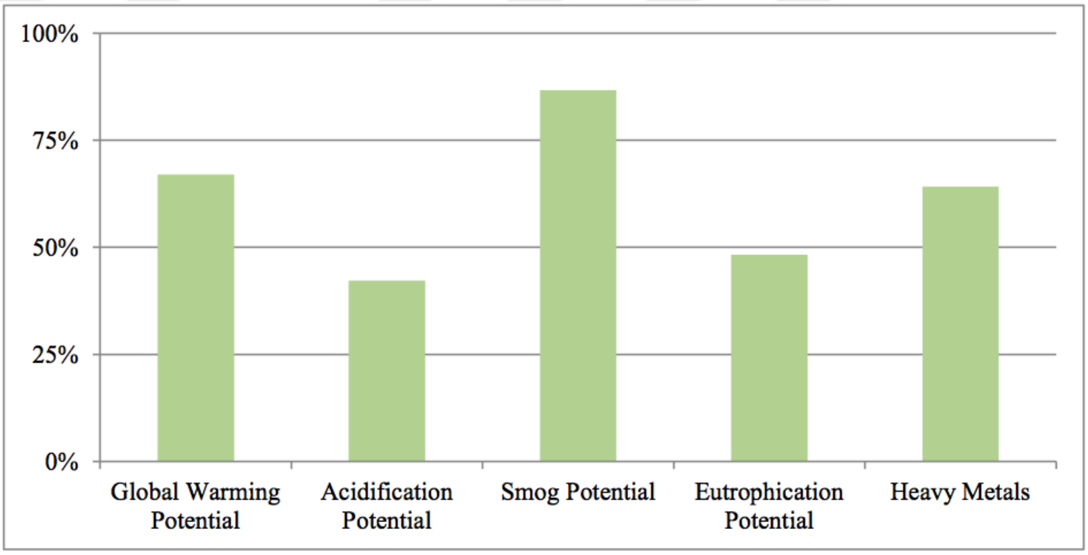


Figure 2.4 Contribution of structure relative to embodied environmental impacts of an office building in Southern Finland. Adapted from “Life-Cycle Environmental Effects of an Office Building,” by S. Junnila and A. Horvath, 2003, Journal of Infrastructure Systems, 9, p. 162-163

When considering structure and enclosure alone, the structural materials contributed around 50% in most impact categories, with the highest contribution being to summer smog (86.7%). In the climate change (global warming) impact category, structural materials contributed 67.0% to overall impacts. Embodied energy consumption was not an impact category considered in this study.

(Junnila, Horvath and Guggemos, 2006) added to existing LCA studies by evaluating two office buildings: one located in Southern Finland and one located in the U.S. Both were assumed to have a 50-year building lifetime and 47,400 ft^2(4,400 m^2) floor area. The system boundaries of the study were pre-use, manufacturing, use, maintenance, and end- of-life phases. The pre-use and manufacturing phases were grouped together as a “materials” phase, similar to the Junnila and Horvath study.

A construction phase was also included. Structure, enclosure, internal finishes, and mechanical and electrical equipment were part of the functional unit. The office building in Southern Finland was a reinforced concrete structure. The U.S. building was of the same size as the Southern Finland building, and the location was selected in a climate that was as close to the European conditions as possible. The U.S. building was also a reinforced concrete structure.

Like other LCA studies that include the operating energy of a building, a large portion of the environmental impact results were attributed to the use phase. The results were presented by life cycle phase, allowing for the combined effects of only the materials, maintenance, and end-of-life phases to be considered. Embodied effects of structural materials were shown separately only in the materials and maintenance phases. The end-of-life phase included effects of transportation of all materials combined and equipment required during that phase for both the Finland and U.S. case studies.

The environmental impacts during the materials, maintenance, and end-of-life phases were considered when calculating the overall embodied environmental impacts of the structure and enclosure, from which the contribution of structure was calculated for both study locations. These results are shown in Figure 2.5. The construction phase and use phase is excluded. The results from the literature were presented by impact measure and are shown in the figure as the related impact category: $CO_2$was used as a measure for global warming potential, $SO_2$for acidification potential, $NO_x$for smog potential, and $PM_{10}$for human health respiratory effects potential.

Structural materials for the Finland building were considered to be concrete, steel reinforcing bars, and cast-iron steel. Enclosure elements were considered to be nonferrous metals, masonry, timber, insulation, waterproofing, and glass. Structural elements for the U.S. building were considered to be concrete and steel reinforcing bars; enclosure elements are considered to be bitumen, glass, and insulation.

The structure had a lower contribution to the embodied environmental impact of the U.S. building when compared to the Finland building, except in the acidification potential impact category. Overall, structural materials had a contribution of approximately 50% in many impact categories. For the energy and CO_2 impact categories, structural materials contributed approximately 50% or more for both building.

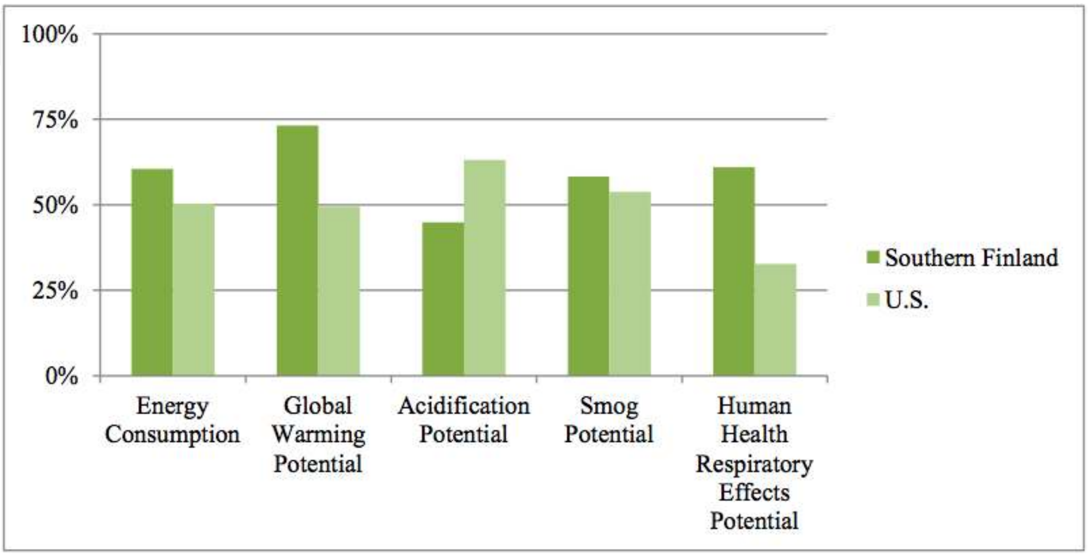


Figure 2.5 Contribution of structure relative to embodied environmental impacts of an officebuilding. Adapted from "Life-Cycle Assessment of Office Buildings in Europe and the United States," by S. Junnila, A. Horvath, and A. A. Guggemos, 2006, Journal of Infrastructure Systems, 12, p. 13

Ryerson University conducted a study comparing two framing options in the Canadian context: steel and concrete. The building studied was a 94,100 ft^2 ($8,740 m^2$) six-story office building located in Toronto with a 60-year assumed building lifetime. As part of the study, several LCA tools were used to evaluate the differences between results. Athena Eco-Calculator, Athena Impact Estimator, and GaBi were all used. Additionally, the author of the paper compared the material quantities estimated from the pre-defined assemblies built into Athena Impact Estimator to manual take-off material quantities. The manual take-off bill of materials is used later in this paper for purposes of conducting an LCA case study within the context of the draft LEED v4 requirements. The functional unit of the LCA included both structure and enclosure elements. Some interior finishes were also included, such as gypsum board and paint, but the environmental impact associated with these materials are considered to be minimal relative to the combined impacts of structure and enclosure elements.

Pinto's results included the environmental impact of the whole building, as well as the impact of the structure alone. Out of the LCA tools used, only Athena Impact Estimator was able to provide impact results for the structure of each framing option. Additionally, the Athena Impact Estimator results using manual take-offs were likely to be more accurate than results taken from estimated pre-defined assemblies. From these values, the contribution of structure can be determined for both framing options, which is shown in Figure 2.6.

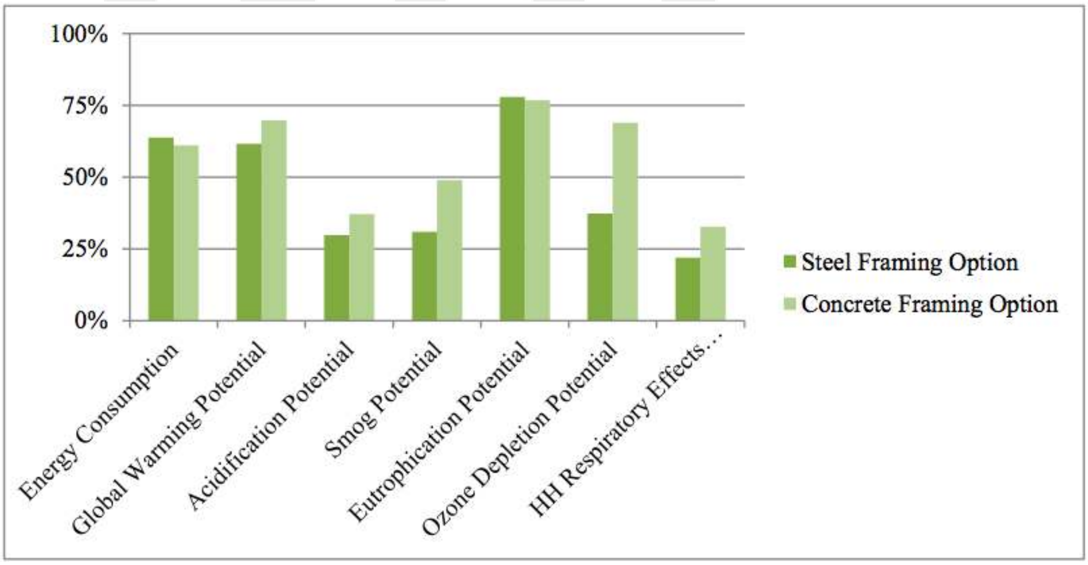


Figure 2.6 Contribution of structure relative to embodied environmental impacts of an office building in Toronto. Adapted from "LCA comparison of structural frame alternatives for office buildings," by I. L. Pinto, 2011

For both framing options, structure accounted for over 50% of the environmental impact in most categories. Over 60% contribution to global warming potential was shown for both framing options. Generally, the structural materials used in the concrete framing option had a higher contribution to the overall embodied impact when compared to the steel framing option. Because the same enclosure and finish elements were used in both framing options, this indicates that the concrete framing option had an increased embodied environmental impact.

(Yang, 2011) used bills of materials available from a Concrete Centre cost study of 20 different structural solutions to three building types: commercial (177,389 ft2, 16,480 m^2), hospital (115,734 ft2, 10,752 m^2), and school (145313 ft2, 13,500 m^2). The framing options for each building type are shown in Table 2.2. The system boundary of the LCA did not include maintenance or end-of-life phases. The functional unit included structure, enclosure, and finishes. Construction related impacts and miscellaneous impacts categorized as "other" were also included.

Table 2.2 Framing options used by Yang, 2011 for commercial, hospital, and school buildings

	Commercial Building	Hospital Building	School Building
Concrete Flat Slab	X	X	X
Cast-in-Place Concrete with Precast Concrete	X	X	X
Post-Tensioned Concrete Flat Slab	X	X	X
Steel with Composite Reinforced Concrete Slab	X	X	X
Steel with Precast Concrete Slab	X	X	X
Slimdek®	X	X	X
Post-Tensioned Concrete Band Beam	X		
Long Span Steel with Composite Reinforced Concrete Slab	X		

Global warming (CO_2) was the only environmental impact considered. Yang studied embodied CO_2 using industry figures of the materials considered, when available, data directly from manufacturers, and LCI data from LCA tools. The results concluded that structure accounted for 50% or more of the whole building embodied CO_2 in all cases. Yang found that there was no clear preference of steel over concrete, or vice versa, in terms of embodied CO_2. Instead, Yang found that the least material efficient framing option was also the option with the highest embodied CO_2 impact and that specifying low cement concrete had the ability to greatly reduce embodied CO_2 in all scenarios. Additionally, Yang suggested that the design of the structure alone could be improved to reduce the associated embodied CO_2 without adversely affecting other building components, such as enclosure elements.

As part of Yang's study, the effect of varying LCA methodology was applied to each framing option. The results indicated that changes to methodology have as much of an impact on the embodied CO_2 values as changes to design, indicating that regardless of discrepancies in methodology, structural engineers still have an ability to make an impact on the overall environmental impact of a building.

The results of the study are shown in graphical form in Figure 2.7. Shown in the figure is the embodied CO_2 of each framing option and the variance in values due to changes in LCA methodology, as well as changes to design (in this case, varying the concrete specification. In each framing scheme, it is apparent that structure accounts for more than 50% of embodied CO_2, when considering structure, enclosure, floor finishes, construction activities, and other uncategorized components. When attempting to compare structural material choices, the sensitivity of results to the assumption and methods of calculating impacts is significant.

(Atmaca and Atmaca, 2015) conducted a study comparing two actual residential buildings built at Gaziantep in Turkey. In this study, they focused on construction at the construction, operation and dismantling stage and estimated total energy consumption and carbon emissions for 50 years. The first building is built in urban areas and the second building in rural areas. The building's life expectancy was considered 50 years. The first building has a floor area of 260 m 2, a floor area of 13 m 2, two residences per floor, four bedrooms, and a large salon per dwelling. The second building is a small building with a total area of 110 m 2, with 3 stories, 4 stories residences, and stairs. Each residential unit has two bedrooms and a salon.

The operating phase is dominant in both urban and rural housing and shows that it contributes 76 to 73% of primary energy demand and 59 to 74% of CO_2 emissions. The building's total energy (EE) accounts for 24 to 27% of the energy consumption of the entire lifecycle. The result shows that the lifecycle energy demand of rural houses is 18% lower than urban areas due to differences in the structure, living standards and air conditioning habits of buildings. The results of the study are shown in Figure 2.8 and Figure 2.9.

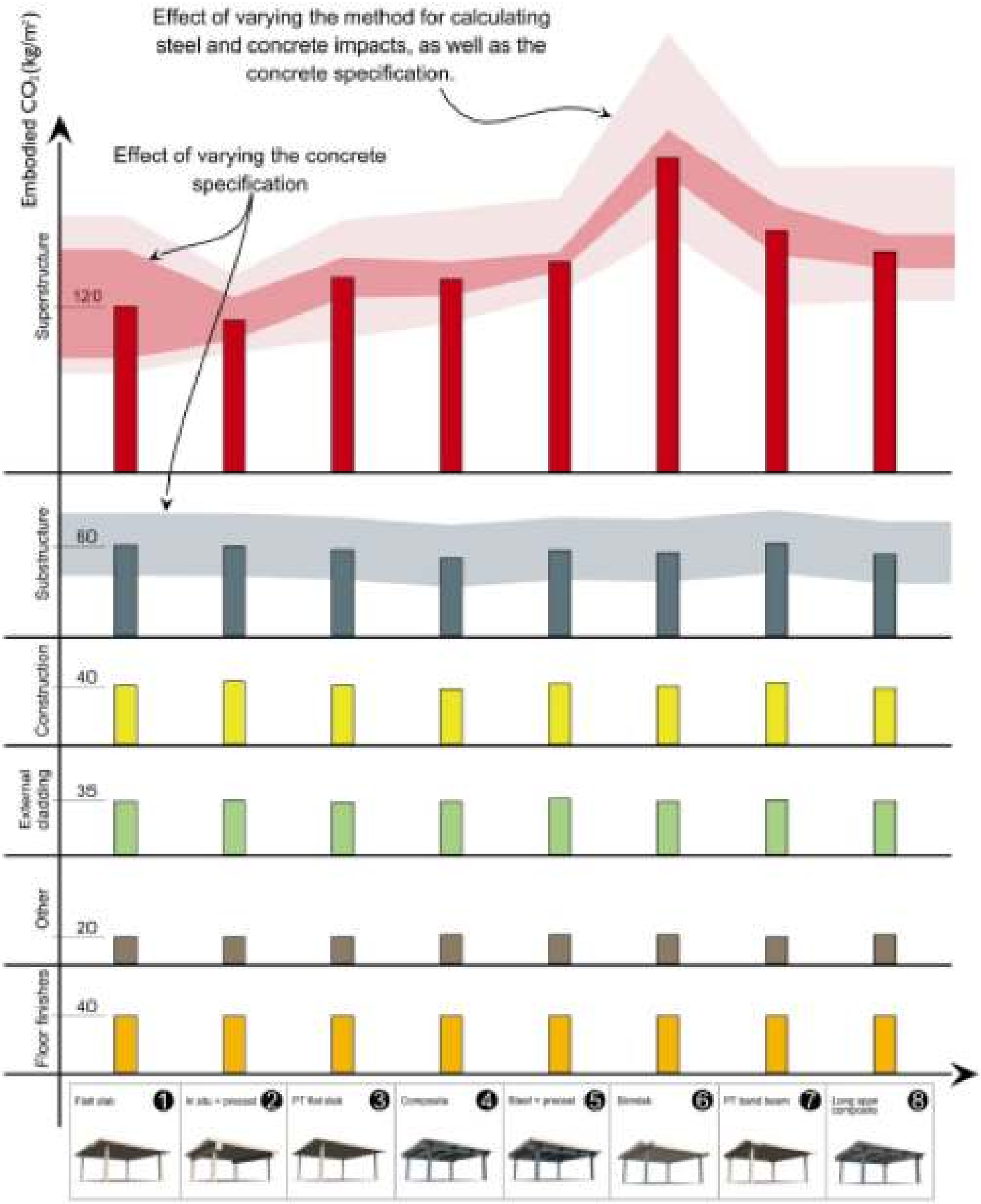


Figure 2.7 Embodied CO_2 of eight framing options. Reprinted from "What Life Cycle Assessment Can Teach Structural Engineers about Design and Specification," by F. Yang, 2011

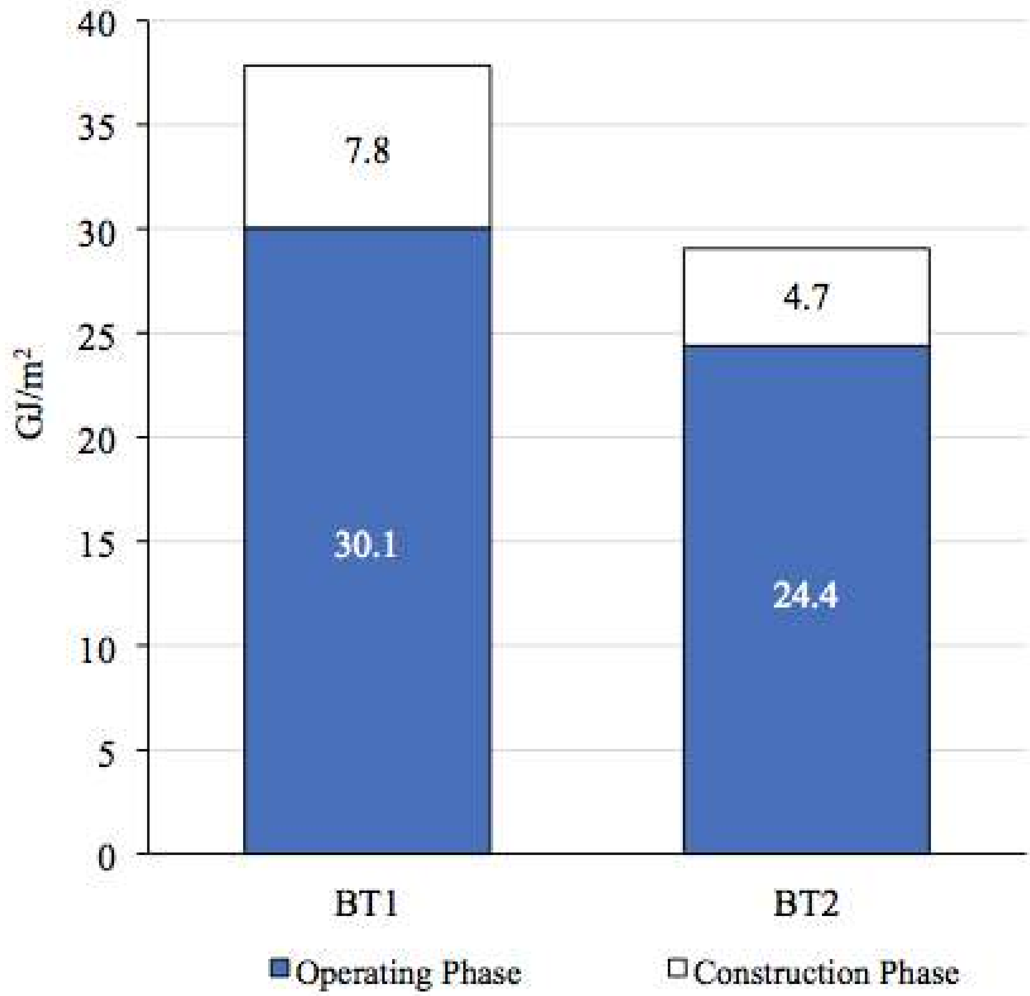


Figure 2.8 Primary energy necessities of the two residential buildings (BT1) and the (BT2) reprinted from "Life cycle energy (LCEA) and carbon dioxide emissions (LCCO_2A) assessment of two residential buildings in Gaziantep, Turkey" By Atmacaand Atmaca, 2015

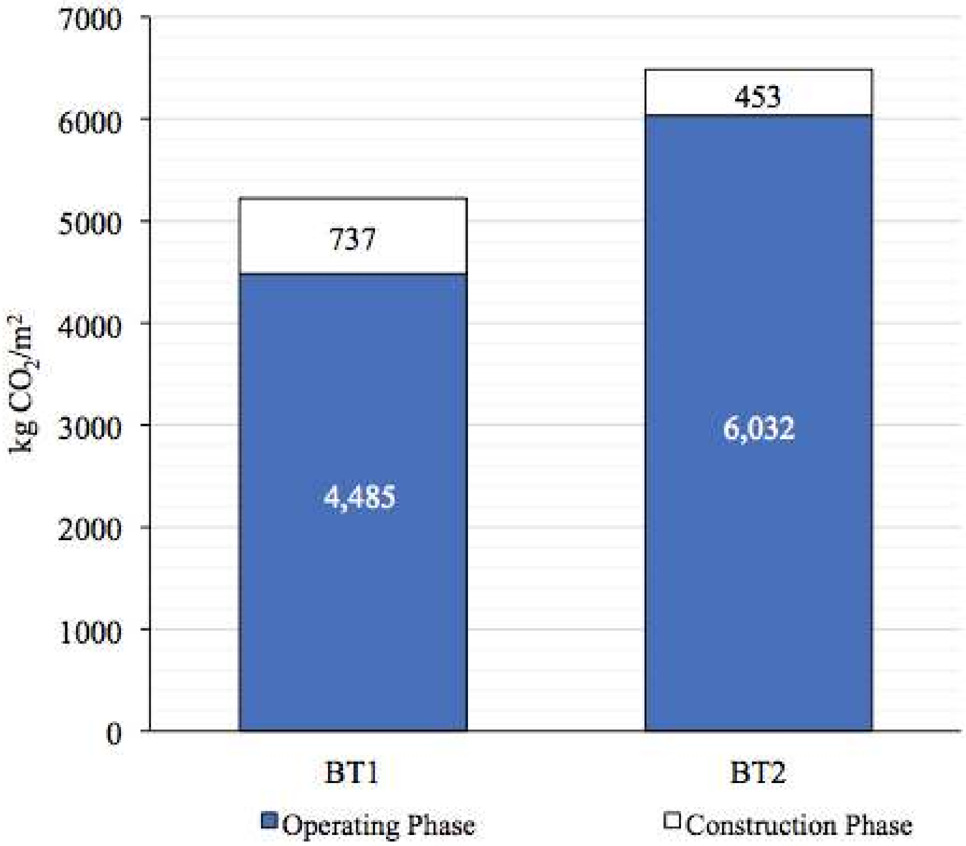


Figure 2.9 The CO_2 releases of two residential buildings BT1 and BT2 reprinted from "Life cycle energy (LCEA) and carbon dioxide emissions ($LCCO_2A$) assessment of two residential buildings in Gaziantep, Turkey" By Atmaca and Atmaca, 2015

Hence, there is a need for sustainable design of buildings to decrease the influence of buildings on the ecosystem and individual health. Sustainable building design considerations for:

1. Sustainable location planning
2. Water Protection and efficiency
3. Energy efficiency and renewable energy
4. Preservation of materials and resources
5. Best indoor environmental quality
6. User and stakeholder comfort

In this study, several elements were used to evaluate options. The elements considered in case studies take into account most sustainable design procedures (American Institute of Architects, 2012).Total of these procedures must be taken into consideration altogether. The significance of the element depends on the difference between the decision framework and options. By way of example, when estimating two materials, if they have equal embedding energy, but have separate emission characteristics that influence the internal air's excellence, the internal air quality factor is embodied It has a big influence on energy resolution. The next section explains the details of specific sustainable design methods related to the background of case studies advanced in this study.

2.4.1 Sustainable Location Planning

In this section, the designer must consider the location design. For example, this project draws and calculates a weather-friendly architecture. Figure 2.10 (Milne and Givoni, 1979) shows planning techniques that best correspond to biomechanical schemes at specific locations (eg high mass, evaporative cooling, humidification and nocturnal ventilation). Furthermore, it is essential to consider various design methods according to the dominant weight of the building.

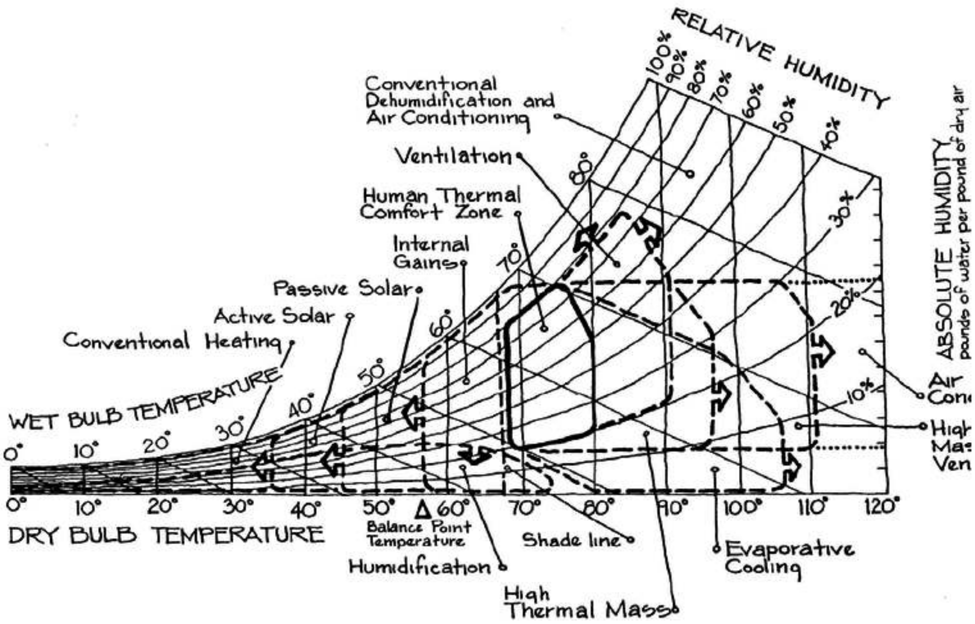


Figure 2.10 Bioclimatic chart (Milne and Givoni, 1979)

The external climate usually dominates residential buildings. On the other hand, internal weights command commercial buildings, which denotes that the external weather does not have any effect on the well-being of inhabitants as much as the amount of individuals or equipment used into the building (internal weights).

2.4.2 Water Protection and Efficiency

In sustainable buildings, designers should consider the water usage throughout the construction process;decrease the total of drinking water consumed by the building for the requirements of the system (such as heating and cooling) and the residents there is. Commercial buildings usually include internal water for toilets and kitchens, external water for landscaping, processed water and construction systems for industrial purposes.

Due to the necessity of modernized wastewater flow and the processing of modern plants at public costs, the dominant social, environmental and economic impacts, such as river, lake, ocean, soil contamination, In order to avoid processing service, Finally, designers need to estimate the interactions between the relevant water system and the design of further building systems in making decisions.

2.4.3 Energy Efficiency and Renewable Energy

Several writers suggested that energy savings must be the first planning approach of sustainable building design. Wilson and Malin (1995) noted that designing buildings with low energy usage is a top priority as it considers that ongoing energy usage is probably the biggest impact on the environment of the building I said. When choosing an alternative strategy it is always more important. The importance of an element depends on the case. For example, energy use in clinics may not be the first approach, and the importance as an element will depend on existing choices of options. Energy consumption of commercial buildings indicates to the operational stage. The materialized energy of the material mentioned in Section 2.4.4 discusses the preservation of materials and sources. In the US commercial buildings, it accounts for 3.6% of the planet's energy (US Department of Energy, 2011). The final consumption of US commercial buildings in 2010 is 37% in building heating and cooling, 14% in lighting, ventilation, office equipment, refrigeration, cooking, hot water supply and other uses. Figure 2.11 presents the final use of energy in US buildings for commercial buildings by the US Department of Energy (2011).

The energy source of a commercial building is basically electric power for all purposes and natural gas for heating (US Energy Information

Administration,2003). Because most of the power generation in the United States comes from coal with high carbon dioxide emissions per kWh, commercial buildings in the United States greatly increase global warming. Figure 2.12 shows US power generation (US energy information management, 2009).

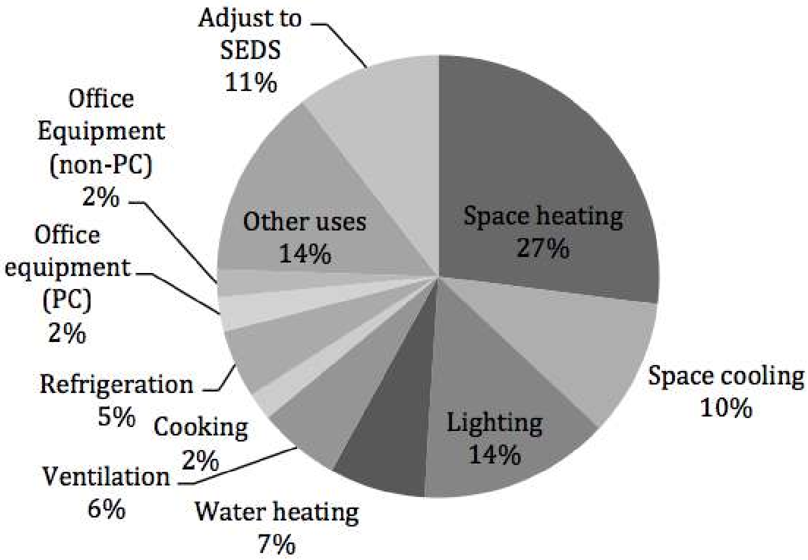


Figure 2.11 Absolute energy consumption by end use of US commercial buildings (US Department of Energy, 2011)

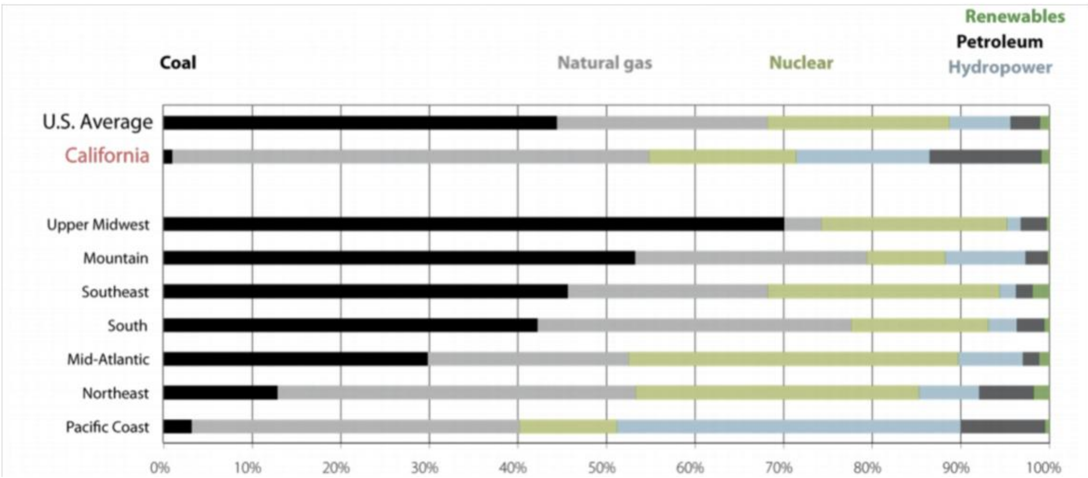


Figure 2.12 US electric power generation (US Energy Information Administration, 2009)

Energy sources do not have the same CO 2 releasesper kWh. For instance, Table 2.3 presents the CO_2releases per KWh generated by the main energy generation system measured in grams of CO_2 (BlueSkyModel.org, 2009).

Also, in order to consume the 1 kWh power existing in the building, it is necessary to generate approximately 3.15 kWh from the transmission power mainly due to loss of transmitted power. Consequently, the use of on-site renewable energy (such as solar and wind power) affords the potential for energy efficiency and decreases CO_2 releases per KWh.

In sustainable architectural design, designers need to consider the building's objectives (lighting, air conditioning and heating needs, etc.) and the energy necessities according to the climate and the energy resources used within the building. In addition, designers need to assimilate building systems (such as structural systems and mechanical systems).

Table 2.3 Initial energy needed (BlueSkyModel.org, 2009)

Source	Coal	Natural Gas	Oil and Diesel	Nuclear	Hydro-electric	Geo-thermal	Solar/ PV	Wind Power	Wood-biomass
Average CO_2 (g/KWh)	909	465	821	6	4	-	105	13	1500

2.4.4 Preservation of Materials and Resources

The waste that produced by buildings throughout their life cycle is great, from construction to building procedure to destruction. In sustainable buildings, the designers need to take into consideration the embodied energy of materials, as well as the choosing of materials to decrease waste at the same time as the demolition stage. The choosing of materials should also take into account their influence on inhabitants of buildings and the long-term public, environmental and economic impacts of materials used in design and construction of the building.

Preservation of sources is a design of resilience, and therefore buildings can be re-used at the final phase of their life cycle rather than demolished. The designers should also set flexible buildings.

2.4.5 Best Interior Environmental Quality

Design of sustainable buildings must attempt to develop the quality of the Indoor Environment Quality (IEQ). According to the US Environmental Protection Agency (2009) Americans waste 90% of their time indoors. Thus, the internal environment impacts publics' health, wellbeing and productivity. IEQ involves:

1. Internal air quality
2. Acoustical quality
3. Thermal comfort

2.4.6 User and Stakeholder Comfort

In the design of sustainable buildings, various distinct viewpoints must be taken into account relying on the benefits of the stakeholders.

• End users can care about usability, maintenance, durability, aesthetics, safety, IEQ, and operating and maintenance expenses.

• Designers can take into consideration various materials and systems, how they are assembled, how they are viewed, and how much they cost.

• Holders may be worried about market value, cost of life cycle, and particular levels of environmental performance.

Despite objections against sustainable architectural design, we realize and translate customer value and realize mutual goals in common (Phelps, 2012). In the design procedure, the purpose and ambition of the project is frequently detected. In order to realize sustainable design, cooperation between stakeholders is necessary. Many questions are raised concerning decision making methods for sustainable decision making.

2.5 Rating Systems

2.5.1 LEED

2.5.1.1 LEED 2009

The current version of the U.S. Green Building Council (USGBC) [U.S. Green Building Council, 2013b] Leadership in Energy and Environmental Design (LEED) [U.S Green Building Council, 2013a] for New Construction and Major Renovations (LEED 2009) includes LCA as a 1-point "pilot credit," meaning that the credit is designed for projects wanting to participate in testing new LEED language and provide feedback. The current language of the pilot credit adopts the same language as the draft LEED v4 (see description under LEED v4 below).

The original wording of the pilot credit differed from the current version and served as a starting point for introducing LCA into LEED. Originally, a "LEED Credit Calculator" was developed that took the results from Athena Eco-Calculator and weighted the results using weighting factors developed by the BEES LCA tool to calculate a final impact score. The LEED Credit Calculator then assigned LEED points depending on the LCA impact score relative to the average impact score from all participating projects. This concept of comparing LCA results between projects participating in LEED was dropped by LEED v4 in favor of using a reference building to which environmental performance can be compared.

2.5.1.2 LEED V4

In LEED v4, set to be released in 2013, LCA is a 3-point option for the building life cycle impact reduction credit within the Materials and Resources category of the Building Design and Construction rating systems. The other options within the credit are for historic building reuse, renovation of abandoned or blighted building, and building and material reuse. If none of these options apply to the project, LCA is the only option for obtaining points within the credit category. For projects where multiple options apply, only the virgin materials are intended to be included in the whole building LCA.

LEED v4 states that LCA results should be conducted of the "project's structure and enclosure that demonstrates a minimum of 10% reduction, compared with a reference building, in at least three of the six impact measures listed below, one of which must be global warming potential." The acceptable impact categories are: fossil fuel consumption, global warming potential, acidification potential, eutrophication potential, ozone depletion potential, and smog potential. Additionally, no impact category can increase by more than 5% when compared to the reference building. All criteria must be met by the design building in order to receive the full three points. If one or more criteria are not met, no points are awarded.

LEED v4 specifies that the reference building used must be of "comparable size, function, orientation, and operating energy performance as defined in EA Prerequisite Minimum Energy Performance" to the building design being considered. This is to ensure that both the design building and reference building achieve the same energy performance. The service life of both buildings is required to be at least 60 years and must be the same for both the design building and reference building.

No specific LCA tool is specified for use; however, the same tool must be used to assess both the design building and the reference building. Additionally, LEED requires that data sets are compliant with ISO 14044. LEED states that the LCA system boundary should include the pre-use, maintenance, and end-of-life phases of a building and exclude the use phase, as the operational energy is evaluated in a separate credit under the Energy and Atmosphere category. The current requirement in LEED v4 does not use the LEED Credit Calculator previously used in the original wording of the pilot credit and it appears as though LEED will continue utilizing the reference building requirement in future versions of the rating system.

2.5.2 International Green Construction Code

The International Code Council (ICC) [International Code Council, 2013a] International Green Construction Code (IGCC) [International Code Council, 2013b] incorporates an elective LCA, but does not require one. LCA can be used in place of the material selection section of the code. The IGCC states that "the assessment shall demonstrate that the building project achieves not less than a 20-percent improvement in environmental performance for global warming potential and at least two of the following impact measures," where the other impact categories are the same additional categories used in LEED: primary energy consumption (includes both renewable and non-renewable energy consumption), acidification potential, eutrophication potential, ozone depletion potential, and smog potential. There is no limit to an increase in any impact category.

To meet the elective requirement, the same LCA tool must be used for the project building and reference building and the LCA tool must be approved by a code official. The full life cycle of the building should be used and the use phase and operating energy of the building must be included in the assessment. However, IGCC excludes mechanical, electrical, and specialty (such as fire protection) equipment from LCA. Building envelope, structure, and interior and exterior finishes must be included in the assessment. IGCC specifies a minimum design life of 60 years for the building.

2.5.3 Green Globes

Athena Eco-Calculator was originally developed for use in Green Globes [Green Building Initiative, 2013], the first green building rating system in North America to incorporate LCA as a credit. Green Globes does not provide credit for achieving a certain improvement over a baseline, but instead awards credit for the educational experience of LCA. Under the Resources section of Green Globes, 55 of the 100 points available are assessed using LCA. LCA is intended to be used as a decision making tool in the schematic design phase to aid in selecting materials with a low total life cycle environmental impact. Green Globes plans to further integrate LCA into the rating system in the future.

2.5.4 CAL Green

In the California Green Building Standards Code (CAL Green) [State of California, 2013], LCA is voluntary. As with the green building rating systems, a comparative analysis of the project building to a reference building is required. The two buildings should be of similar size, function, complexity, and should also have similar operating energy. The service life of the building must be at least 60 years, unless otherwise approved. CAL Green considers ozone depletion potential, eutrophication potential, global warming potential, smog potential, acidification potential, and fossil fuel consumption as the impact categories. The project building must show at least 10% improvement in global warming potential and at least two other impact categories over the reference building. Structure, enclosure, interior ceilings, walls, floors, and exterior finishes are to be included in the assessment. Interior finishes, plumbing, mechanical, fire protection, and electrical equipment all do not need to be included. CAL Green offers that if whole building assessment is not elected, a minimum of 50% of materials or assemblies should be chosen using LCA. If a whole building assessment is conducted, the LCA can be substituted for prescriptive Material Conservation and Resource Efficiency requirements.

2.5.5 ASHRAE 189.1

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) [American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2013a] Standard 189.1: Standard for the Design of High-Performance, Green Buildings [American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2013b] includes LCA as a performance option within Materials and Resources for selecting materials instead of relying on the prescriptive requirements for recycled, regional, and bio-based materials. ASHRAE does still require the prescriptive material options to be considered when choosing the performance-based option of LCA. The LCA must be performed on a minimum of two building options, both adhering to project requirements, with one being a reference building. The chosen building design must have a 5% improvement over the reference building in at least two of the following impact categories: land use, resource use, human health effects, eco toxicity, global warming potential, smog potential, ozone depletion potential, acidification potential, and eutrophication potential. The elements considered in the LCA should be any materials permanently installed in the project.

ASHRAE does not require the use of a specific LCA tool but does outline the system boundaries that should be used for LCI, which are: pre-use, manufacturing, maintenance, and end-of-life. The use phase should not be included. The design life specified by ASHRAE depends on the building category: temporary, medium life, or long life. Commercial buildings fall under the long life category and ASHRAE specifies that long life buildings be considered to have a design life of at least 75 years.

2.5.6 Other

There are several other green building codes and rating systems developed and used in other countries that incorporate LCA, including the Building Research Establishment's Environmental Assessment Method (BREEAM) (BREEAM, 2013) in the United Kingdom and the German Sustainable Building Council (DGNB) (DGNB, 2013) in Germany. Additionally, there are several green building programs that do not specify use of LCA tools but outline requirements for reduction of embodied impacts and therefore benefit from the use of LCA. The Living Building Challenge (International Living Future Challenge, 2013) is one such rating system that requires projects to account for total footprint of embodied carbon. Architecture 2030 (Architecture 2030, 2013)is a challenge issued to reduce the greenhouse gas emissions produced by the building industry. The Architecture 2030 Challenge for Products is a subset of Architecture 2030 and aims to reduce embodied carbon impacts by 50% by 2030.

Architecture 2030 and other green building initiatives are encouraging the use of Environmental Product Declarations (EPD) to choose materials. EPD is a report or label that discloses the life cycle impact results from LCA of a product. EPDs are certified claims that are quality-assured and comparable. ASTM International (ASTM International, 2013) and other organizations are developing product category rule (PCR) standards that define what information should be included in the EPD for a given product category. PCRs also specify the scope (including functional unit and system boundary) of the LCA used to determine the EPD. There are currently PCRs for concrete and wood.

LCA requirements are likely to go through several iterations as more projects adopt the requirements and more data is generated on the applicability of the requirements with the intention of eventually making LCA mandatory. However, the general concept of comparing a design building to a reference building appears to have widespread support. ASTM International currently has a work item, WK28938, dedicated to developing criteria for whole building LCA reference buildings. The standard intends to align with reference building requirements already included in the draft language of LEED v4, including requiring the reference building to be of the same orientation, size, and function of the design building. The standard also intends to require building enclosure and structural elements to be included in LCA, and excludes electrical, mechanical, plumbing, and fire protection equipment and elements. The standard is set to be finalized within the coming year and will likely be adopted by green building rating systems utilizing a reference building in LCA credit requirements.

CHAPTER 3

METHODOLOGY

3.1 Overview

The main environmental harms in the world are global warming and depletion of the ozone layer. Energy effectiveness has been at the head of policy discussions due to weather alteration worries and high-energy costs (Kneifel, 2010). There are several chances to mitigate unwelcome environmental troubles rising from our society. Commercial buildings have a significant role in energy use and can put great strain on the country's power grids during peak periods.

The design of buildings has important effects on energy consumption in the life cycle of buildings. Energy-efficient design has been particularly enhanced in advanced countries as a tradition in which overall energy effectiveness can be attained through the life cycle of buildings. In this research a comparative study of two commercial buildings has been conducted whichever is more energy efficient. Two ideal buildings were studied to signify the mass of commercial buildings built in Gaziantep, Turkey. Particular architectural, functional and operational records for the buildings were taken from executive drawings, utility bills taken from administration office of both of buildings (Sanko Park and Forum). In the case of Turkey, there is presently no existent database for materials that are used in buildings. Given the different manufacturing procedures and variances in the economic arrangement of each country, the use of ICE data to determine the energy efficiency of the materials used in Turkey can lead to inaccuracies.

3.2 Descriptions and simplifications

Sanko Park shopping mall is one of the largest enclosed malls in the region, construction of US$160 million project located in Gaziantep, Turkey. Sanko Park began in 2007 and the center opened in the spring of 2009(Figure3.1 and Figure 3.2). The building consists of 7 blocks as shown in Figure 3.3.

Figure 3.1 Sanko Park mall exterior photo

Figure 3.2 Sanko Park mall interior photo

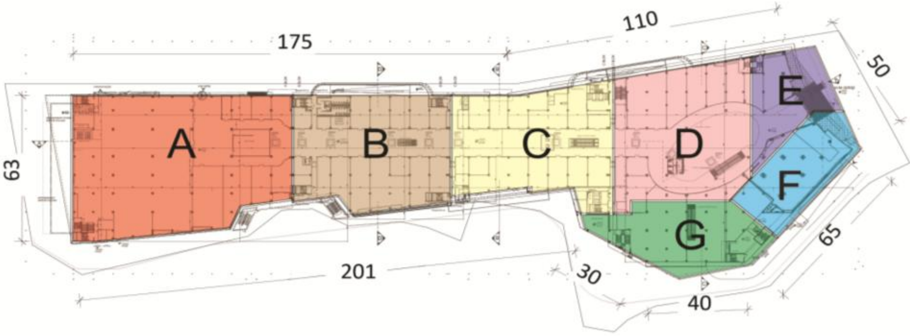


Figure 3.3 Sanko Park floor plan reprinted from the original documents

The second building is Forum shopping mall located in Gaziantep, Turkey, construction of 120 million euros investment value. Forum opened in October 2013 (Figure 3.4 andFigure3.5). The building consists of 4 blocks as shown in Figure 3.6.

Figure 3.4 Forum mall exterior photo

Figure 3.5 Forum mall interior photo

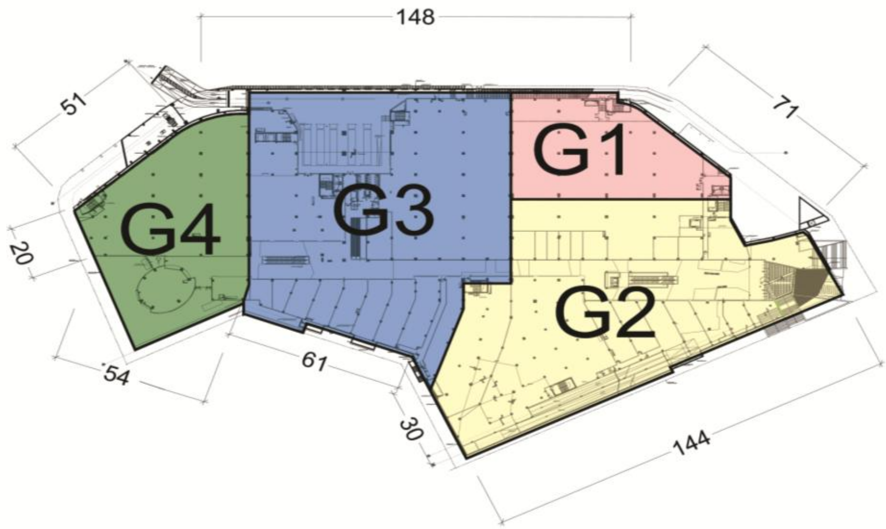


Figure 3.6 Forum mall floor plan reprinted from the original documents

There are statistically important variances in the number of stories, the number of Stores, construction areas, net areas, gross areas and elevation of buildings. B1 (Sanko Park) has a total retail floor area 55,000 square meters, four stories and 216 stores. B2 (Forum) has 44,000 square meters, three stories and 120 stores.

3.3 Assumptions and uncertainties

The building's LCA includes various overviews and presumptions associated with the building's energy needs during the construction, operation and dismantling stages, the expected lifetime of the building, and the specific energy related with the material used in the future. There are significant uncertainties related to energy use and releases at the demolition stage. The fuel efficiency of the new cars (measured in liters of fuel consumed per kilometer) has decreased considerably in the 1990s due to fuel efficiency standards. An integrated policy package that integrates fuel efficiency standards may reduce total fuel consumption and greenhouse gas emissions of light vehicles from 32% to 50% over the past 30 years (United States Environmental Protection Agency (EPA), 2004)

The locality of the building, the construction materials and methods used, the material manufacturing procedure, etc. affect the overall energy requirement, and the difference of these factors may change the results of this study. The following assumptions were made during calculation:

- The life cycle of the buildings were considered to be 50 years.
- Standard building construction methods and materials were assumed to be the same over the next 50 years.
- The design and materials of the building are mainly gained from the original project documents.
- The service life of the structural elementswereconsidered to be identical to the service life of the building.
- All final products were manufactured in Gaziantep city and considered that most resources are located within 40 km radius.
- Energy needed to provide thermal comfort was quantified on an annual basis for each heating and cooling season and assumed to be constant over the building's 50 year lifetime.
- It is considered that the building will be destroyed 50 years later. Dismantling of the building depends on heavy machinery such as excavators, loaders, trucks, etc. The disassembled energy of the final use is regarded as diesel.

- EE related to dismantling and removal of building materials was deemed unimportant and excluded from the study.
- Environmental characteristics such as indoor air quality are not included, but the environmental impact is assumed to be constant with the lapse of time.

3.4 LCA Methodology

The basic idea of LCA is to determine the environmental effects of the product at several phases of the life cycle.

The LCA assesses the total resources inputs; involving energy, water and materials, and green loading, involving CO_2 emissions and building waste, at several stages of the life cycle. They can be denoted accurately by equation (3.1):

$$I = I_{extraction} + I_{manufacture} + I_{onsite} + I_{operation} + I_{demolition} + I_{rescycling} + I_{disposal} \quad (3.1)$$

Where I denotes the life cycle environmental impact, and I_j denotes the environmental impacts of j^{th} building stage. LCEA pays attention on energy data to a system and $LCCO_2A$ pays attention on the CO_2 corresponding emissions emitted from a system (Table 3.1).

3.5 LCEA and LCCO2A Methodologies

LCEA is a method that represents all energy inputs of building in its life cycle. The limits of the system involve the use of energy in manufacturing (embodied energy), the use of (operating power), and stages of destruction. The manufacturing phase includes the manufacture and transportation of building materials and repair of buildings.

The operating phase includes all activities (heating, cooling, lighting, household appliances, cooking and hot water) related to the use of buildings, over their lifetime. The final stage is the demolition phase, which involves the destruction of a building and the transfer of dismantled materials to landfill sites or recycling plants. An analysis of Asia can be performed using either primary or secondary energy.

Main energy is the rough oil used to generate heat and electric power, such as natural gas, coal, or fuel oil. Minor energy is an energy product that is generated from rough fuel, such as electric power obtained from the grid or heat obtained from a steam system in the region. Shortly, main energy is the energy extracted from nature (coal

And natural gas) while minor energy is the real energy used (e.g. electricity)(Asif et al. 2007).

LCEA should be given mathematically by substituting the terms I's in Eq. (3.1) by E's to get Eq. (3.2) as shown in the next:

$$E = E_{extraction} + E_{manufacture} + E_{onsite} + E_{operation} + E_{demolition} + E_{recycling} + E_{disposal} \quad (3.2)$$

Where E indicates the entire energy used during the whole life cycle of a building, and Ej indicates to the energy used during j^{th} building stage.

While $LCCO_2A$ takes into consideration all the carbon corresponding emission output from a building over different phases of its life cycle.The value of life cycle carbon emissions can be calculated by substituting the expressions I's in Eq. (3.1) with "CO_2" and accurately it can be calculated from the next equation (3.3):

$$CO2 = CO2_{extraction} + CO2_{manufacture} + CO2_{onsite} + CO2_{operation} + CO2_{demolition} + CO2_{recycling} + CO2_{disposal} \quad (3.3)$$

Where CO_2 indicates to the CO_2 release of the entire life cycle of a building, and CO_{2j} denotes to the CO_2 release throughout the j^{th} building stage.

Table 3.1 Basic models of LCEA and $LCCO_2A$

Energy Input

Construction • Materials extraction and processing (Forest and plastic products, aluminum, limestone, sand, stone, copper, iron, zinc, natural gas, transportation) • Constructionmaterial manufacturing (Cellulose products, fiberboard, vinyl siding, aluminum frames, pipes, drywall, paints, transportation) • Construction of building (Foundation and site works, structural framing, siding and roofing, electrical and mechanical works, painting, transportation)
Operating Home use (Space heating and cooling, water heating, lighting, maintenance materials, home appliances)
End of Life Demolition and recycle (knock down, site cleaning, disposal,

CO_2 Output

3.5.1 Construction stage evaluation

There are three ways used in life cycle evaluation: process evaluation, Input-Output (I-O) evaluation1, and mixed analysis. Due to the difficulty of the upstream necessities for commodities and facilities, process evaluation that is commonly used has some disadvantages. The second way, I-O evaluation, uses the national average data for each division of the economy and is taken into consideration by several academics to be more complete than the process evaluation. Furthermore, the analysis of I-O is generally used as a black box, with slight awareness of the numbers being considered for each procedure (Crawford, 2008).To eliminate downstream and downstream deductions, I-O mixed evaluation integrates process data and I-O data into process-based mixed evaluation. Explicit raw data of a particular product under study are computed using process evaluation. The application of process records raises the accuracy of the evaluation, but it is not easy to gain the necessary records. Every method has its specific intensity and limits, but mixed analysis is commonly deemed the favorite method for embodied energy analysis (EE) due to its organized unity and the use of credible records. Table 3.2 (Atmaca&Atmaca, 2015) shows some advantages and disadvantages of process-based and I-O evaluation.

The evaluation of the construction stage contains evaluation of EE and CO_2 releases. EE is determined as the entire main energy (MJ) needed by building ingredients during the industrial stage (Blengini, 2009). Energy content of all materials used in buildings and mechanical systems, energy acquired at the time of new construction and restoration of the building. Embodied energy can be separated into two principal parts:

- Primary embodied energy: the energy embodied in a building's primary construction.
- Frequent embodied energy: The energy required to design and replace building materials over the useful life of a building.

Table 3.2 Advantages and disadvantages of process-based and I–O analysis

	Process-based LCA	I-O based LCA
Advantages	Accurate results, specified process Permits comparisons of specific products Classifies parts of practical improvements, weak point analysis Affords next product improvement estimating	The results are economy-wide, and full evaluations System-level evaluations are allowed Uses widely obtainable results, can be reproduced Offers upcoming produce improvement assessments Offers information on each product in the economy
Disadvantage	Setting the limits of the system is particular Tend to be time-intense and expensive Hard to use to new plan of the procedure Using private records It cannot be repeated if private records are used suspicion in records	Product ratings include total records Evaluations are complicated Financial costs must be connected with physical divisions Importations that are considered as commodities formed within economic limitations Available records for full environmental impacts Complicated to apply exposed economy (with large importations are not comparable) Doubt in data

The carbon and energy inventory (ICE) version 2.0 (Bastos et al.,2014) is used to calculate initial energy necessities and greenhouse gas releases. ICE contains embodied energy, carbon, greenhouse gases (calculated in grams of carbon dioxide corresponding and CO_2e) for a huge amount of materials. $LCCO_2$ deems all releases of carbon equivalent emissions from a building at different stages of its life cycle. The embodied greenhouse gas releases (EGHG) consist GHG releases from the withdrawal of rough materials to the construction site. ICE, the expression "embodied carbon" is used for carbon and GHG releases. Table 3.3 gives a list of all materials used in both of buildings gives both the primary energy and global warming potential per unit of mass.

The frequent embodied energy of building can be found by multiplying the amounts of materials through their number of alternatives over the lifetime of the building and energy intensity values.

We can define the replacement factor as the proportion of the lifetime of the building to the average lifetime of building materials. Replacement factor can be critical in defining the quantity of frequent embodied energy (C.K.Chau et al., 2007). Table 3.4 gives the replacement factors for several of the building materials as specified by many studies (M.K.Dixit et al., 2013). In most prior studies the frequent embodied energy symbolized about 23% of the life cycle embodied energy (R.H.Crawford 2008). It is observed that, the embodied energy is almost equally divided between the primary and frequent requirements (G.J.Treloar et al., 2000;R.H.Crawford et al., 2003;G.J.Treloar, 2007;G.Majeau-Bettez et al., 2011).

Table 3.3 Embodied energy and CO_2 amount varieties for some kinds of construction materials.

Material	Embodied Energy EE (MJ/kg)	Embodied CO_2 ($KGCO_2$/kg)
Blocks	1.5-6.9	0.2-0.6
Ceramic	10-20.5	1.4
Concrete	1-11	0.05-5.15
Glass	15-19	0.85
Granite	3.58	0.64
Marble	2	0.1
Plaster	1.4-1.8	0.12-0.16
Polyurethane	70	4.2
Rockwool	16.8	1.1
Steel	6-24	1.9
Timber	12-15	0.87
XPS	100	4

Table 3.4 Replacement factors suggested by literature.

Building component	Treloar et al., 1999	Chen et al., 2001	Scheuer et al., 2003	Chau et al., 2007	This research
Ext./Int. Walls	1.1	1	1	1	1.1
Doors	-	1.3	1.5	-	2
Windows	-	1.3	1.9	-	2
Wall/roof tiles	-	1.3	3.75	2.5	2
Paints and coat	8	5	15	5	5
Ceiling finishes	4	2	3.75	2.5	3
Floor finishes	2	3	4.16	2.5	3

3.5.2 Operating stage evaluation

Operational power is the energy necessary to maintain continuous well-being conditions in the building, energy for heating, ventilation, air conditioning, local hot water, lighting, and operation of the equipment. Operating stage is considered as the major part of energy consumption of the life cycle of commercial buildings.

There are three methods have been used to evaluate the use of the building's operational energy:

- Use actual power consumption registers taken from water and electricity bills.
- Reference to some energy use databases. For example, databases from the Energy Information Administration (EIA) in the USA.
- Using energy emulation methods.

In this research, actual power consumption registers taken from electricity bills. Table 3.5 presents an example of the monthly electricity bills records of each building. Both of the buildings use electricity for several functions

Table 3.5 Electricity consumption of each month in both of the buildings for year 2016

Electricity (KWH) 2016		
Months	Sanko Park	Forum
January	1433206	989031
February	1232602	885230
March	1256529	933101
April	1283178	958458
May	1406954	1039117
June	1540038	1144417
July	1762718	1277842
August	1806623	1304401
September	1469957	1095940
October	1337733	984985
November	1184794	889552
December	1347390	985007
Average	17061721	12487081

The primary energy necessity of the buildings is estimated by using the primary energy factor taken from the European Directive 2006/32/EC. The primary energy factor has been applied to convert electricity consuming into primary energy consuming. The primary energy transformation factor of electric power was 2.5 MJp/MJf, and the GHG quantity for generating electricity was 0.132 kgCO_2 eq. / MJ, established on the average of Turkish generation.

3.5.3 Destruction stage evaluation

Destruction energy is the energy needed at the end of the life of the building service to destruct it and to carry the materials to the landfill place or reprocessing plants (F.C. Luisa et al 2014). It is the total amount of energy consumed by the real destruction procedure and energy needed to carry the trash. It represents only a little amount of entire life cycle energy consumption. The stake of the destruction power was evaluated to be 0.2% of the entire life cycle consumption of the primary energy of the building (C.Scheuer et al., 2003 andM.Beccali et al., 2013). To detect the entire releases emitted during the destruction stage, the weights of trash obtained during the dismantling of buildings are transferred to those that will be transported by Lorries (B.Cheonghoon et al., 2013). The environmental weight of lorries transporting disposal to reprocessing plants or final disposal plants are estimated as follows (IEA International Energy Agency, 2009; European commission Annex 5):

$$\sum \mathrm{CO2} = \sum \left(\frac{WD}{LC}\right) \times DT \times FE \times EF \qquad (3.4)$$

Where WD is the weight of disposal (t), LC is the loading capacity (t), DT is the distance traveled (km), FE is the fuel economy (L/100Km) and EF is the CO_2 emissions factor.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Construction stage

In this research, procedure-based evaluation is used to acquire complete results. Life-cycle accounts of both types of buildings, involving the amount of every construction component in terms of mass, energy efficiency EE and CO_2 are shown in tables 4.1 and 4.2.

We can notice that Sanko Park has higher EE (532,809.314 GJ) and CO_2 (37,475.706 ton) releases. In comparison, Forum has lower EE (257,974.835 GJ) and CO_2 (18,015.233 ton) by 50% than Sanko Park in construction stage.

The life cycle EE and CO_2 quantities of both Concrete and steel that used in construction stage for Sanko Park and Forum are shown in Figs.4.1 and 4.2 respectively.

The life cycle EE and CO_2 quantities of the other raw materials used through construction stage are shown in figs.4.3 and 4.4.
Most of EE is granted from steel (37-38%), concrete (51-53%), blocks (7-8%) and the residual is the other raw materials. The larger quantity of EE for steel and concrete in comparison with other materials results from the higher quantity of steel and concrete used per square meter. Furthermore, it can be noticed from Tables 4.1 and 4.2 that the EE density of steel (21.6 MJ/kg) is very large in comparison with the other material.

Table 4.1 EE, CO_2 and construction material amounts of each section of Sanko Park

Sections	Materials	Amount (kg)	EE (MJ/kg)	CO_2 ($kgCO_2/kg$)	Total EE (MJ)	Total CO_2 ($kgCO_2$)
Foundations	concrete	20374908	2	0.113	40749816	2302364.604
	steel	1280150.77	21.6	1.9	27651256.8	2432286.478
Walls	Blocks	5898198.75	6.9	0.6	40697571.38	3538919.25
	plaster	1001514.14	1.8	0.1	1802725.466	100151.4148
	painting	100741.519	10.5	0.9	1057785.95	90667.3671
Floors	concrete	111167809	2	0.113	222335618	12561962.42
	steel	7363438.86	21.6	1.9	159050279.4	13990533.84
Flooring	marble	1085888.24	2	0.1	2171776.49	108588.8245
	polyurethane	42275.52	70	4.2	2959286.4	177557.184
Roof	concrete	3515588	2	0.113	7031176	397261.444
	steel	228600.786	21.6	1.9	4937776.978	434341.4934
Façade	insulation rockwool	613412.67	16.8	1.1	10305332.86	674753.937
	ceramic granite	784391.85	11	0.64	8628310.35	502010.784
	glass	180558	19	0.91	3430602	164307.78
	Total	**153637476**			**532,809,314**	**37475706.82**

It is realized from the analyses that steel releases CO_2 emissions by a percentage of (49-51%). The select of building materials can have observable consequences on energy consumption and CO_2 releases of the building.

The life cycle EE and CO_2 releases percentages of every sector of Sanko Park and Forum are shown in Figures.4.5-4.8, respectively. Around 76% of concrete and 80% of steel are used in floors construction. As a result, floors are responsible for (72-74%) of EE and (71-74%) of CO_2 releases, respectively.

Table 4.2 EE, CO_2 and construction material amounts of each section in Forum.

Sections	Materials	Amount (kg)	EE (MJ/kg)	CO_2 ($kgCO_2$/kg)	Total EE (MJ)	Total CO_2($KgCO_2$)
Foundations	concrete	12734317.5	2	0.113	25468635	1438977.878
	steel	800094.236	21.6	1.9	17282035.5	1520179.048
Walls	Blocks	1256893	6.9	0.6	8672561.7	754135.8
	plaster	601346.7	1.8	0.1	1082424.06	60134.67
	painting	42701.92	10.5	0.9	448370.16	38431.728
Floors	concrete	55641202.5	2	0.113	111282405	6287455.883
	steel	3743197.304	21.6	1.9	80853061.77	7112074.878
Flooring	ceramic	71744.9	10	0.7	717449	50221.43
	timber	3181.1376	12	0.87	38173.6512	2767.589712
Roof	concrete	2197242.5	2	0.113	4394485	248288.4025
	steel	142875.491	21.6	1.9	3086110.606	271463.4329
Façade	plaster	433551	1.8	0.1	780391.8	43355.1
	painting	34171	10.5	0.9	358795.5	30753.9
	insulation (XPS 4 cm)	14077.2	100	4	1407720	56308.8
	glass	110643	19	0.91	2102217	100685.13
	Total	**77827239.39**			**257974835.7**	**18015233.67**

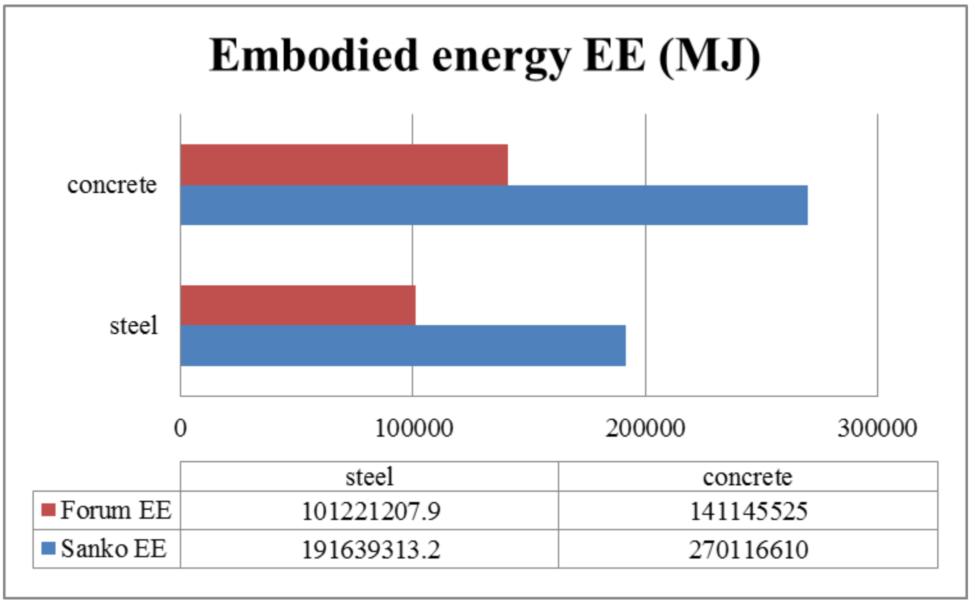


Figure 4.1 Life cycle EE quantities of steel and concrete used through construction stage for Sanko Park and Forum.

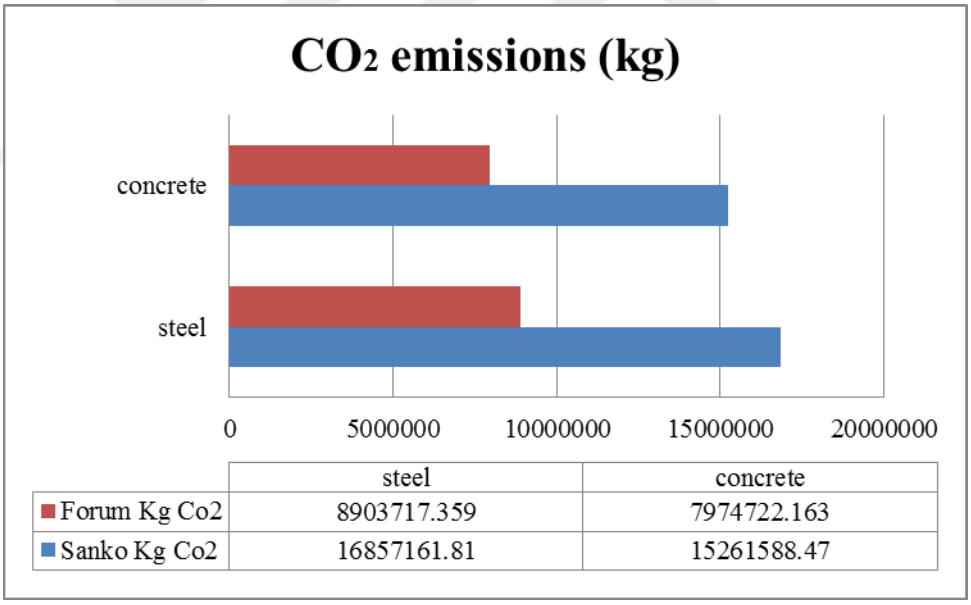
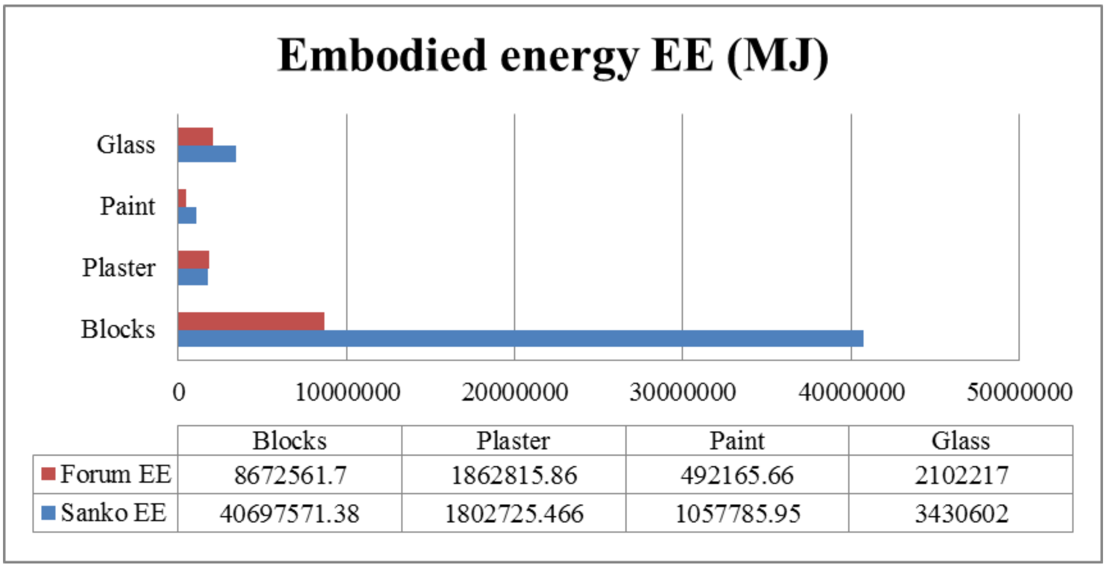
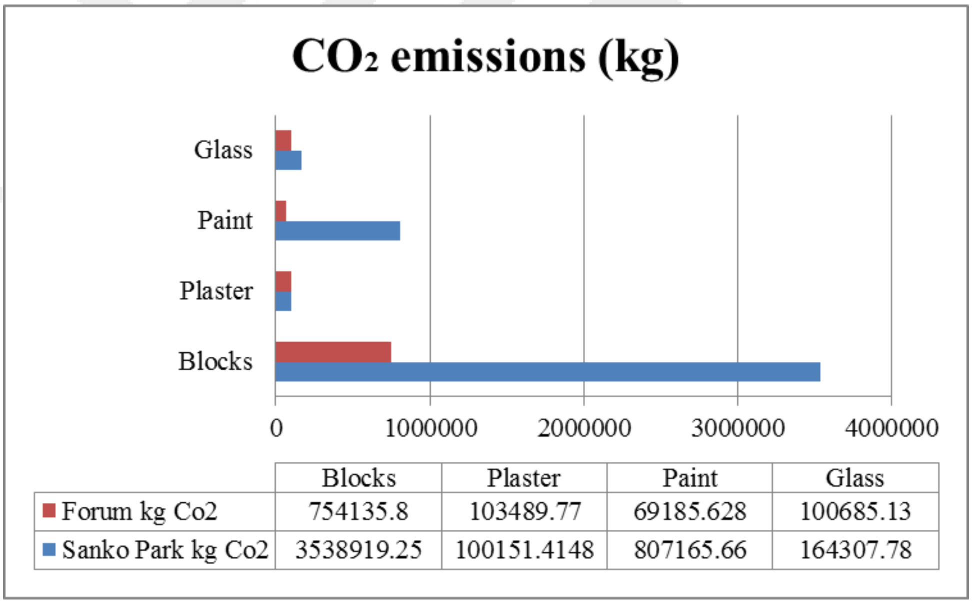


Figure 4.2 Life cycle CO_2 releases of steel and concrete used through construction stage for Sanko Park and Forum.



	Blocks	Plaster	Paint	Glass
Forum EE	8672561.7	1862815.86	492165.66	2102217
Sanko EE	40697571.38	1802725.466	1057785.95	3430602

Figure 4.3 Life cycle EE quantities of raw materials used through construction stage for Sanko Park and Forum.



	Blocks	Plaster	Paint	Glass
Forum kg Co2	754135.8	103489.77	69185.628	100685.13
Sanko Park kg Co2	3538919.25	100151.4148	807165.66	164307.78

Figure 4.4 Life cycle CO_2 releases of raw materials used through construction stage for Sanko Park and Forum.

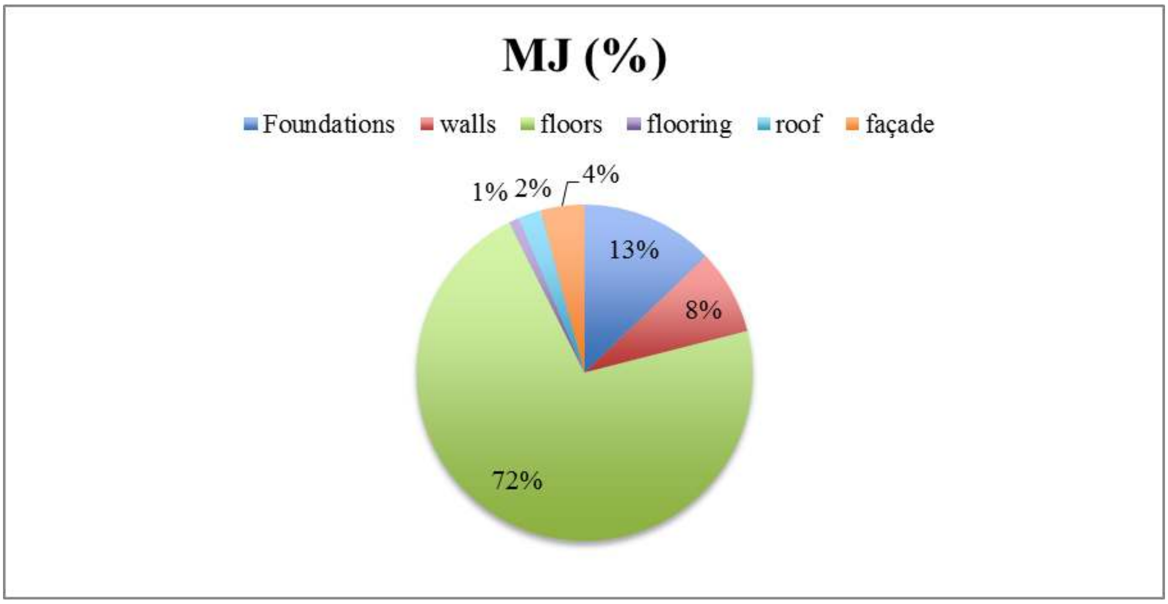


Figure 4.5 Life cycle percentages of every sector of Sanko Park.

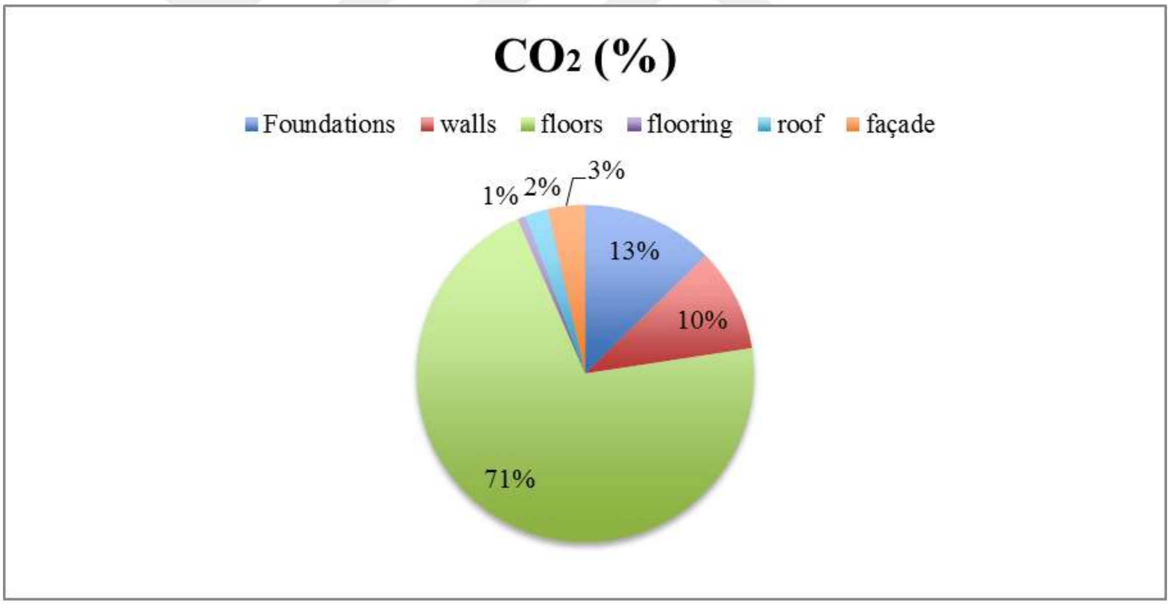


Figure 4.6 Life cycle CO2 releases percentages of every sector of Sanko Park.

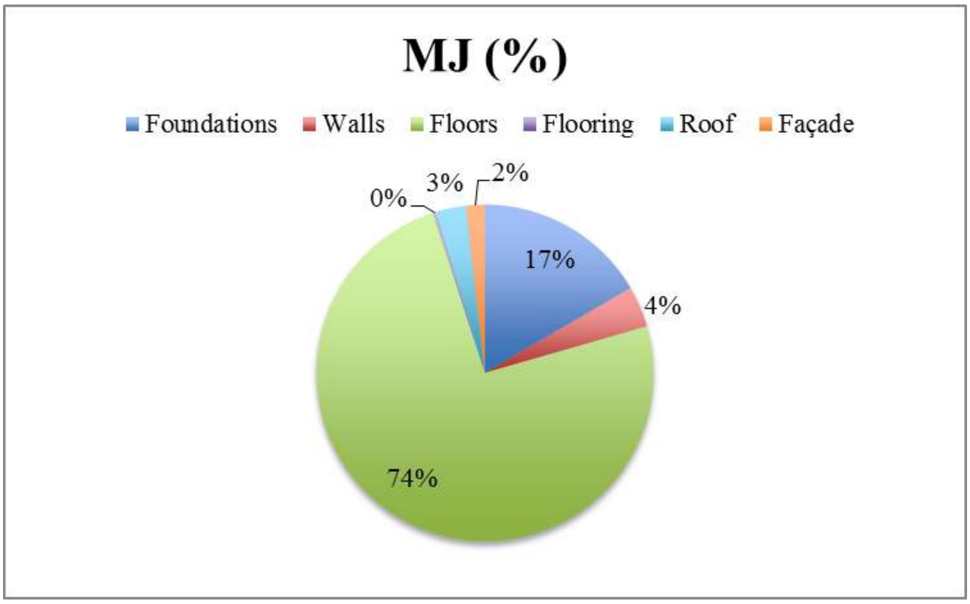


Figure 4.7 Life cycle EE percentages of every sector of Forum.

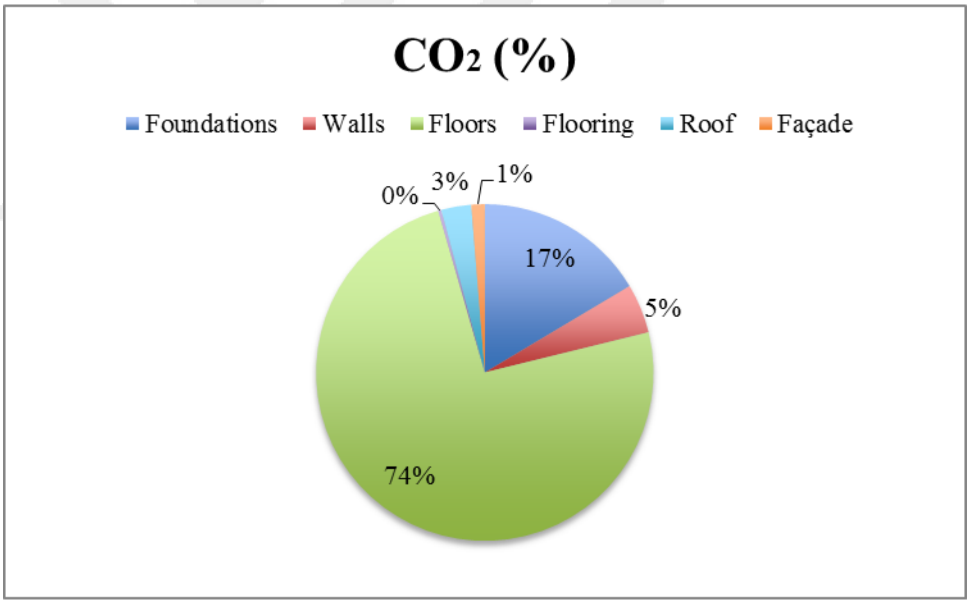


Figure 4.8 Life cycle CO_2 releases percentages of every sector of Forum

4.2 Operating stage

Operating energy in both Sanko Park and Forum is predominant and differs from 85% to 90%, respectively. Forum devours energy a little more than Sanko Park in operating stage: 44522.5 MJ/m^2 compared to 43872.99 MJ/m^2 for Sanko Park. Based on calculations, Sanko Park has lower CO_2 releases by percentage of 11%. In our case, both of buildings use electric power for heating. The primary energy requirements and CO_2 emissions of electrical power for Sanko Park and Forum are shown in table 4.3.

Table 4.3 The gross energy requirement and CO_2 releases of both buildings in operating stage

Operating energy	Sanko Park	Forum
Electrical energy consumption (MJ/m^2)	43872.99	44522.5
Emissions from electrical energy (kgCO_2/m^2)	5791.23	5876.91

4.3 Destruction stage

To evaluate the gross energy wasted during destruction stage we consider 0.2% of whole life cycle primary energy consuming of the buildings. To calculate the gross releases produced during the destruction stage, Eq.3.4 is used in calculations for both buildings. Table 4.4 presents the entire primary energy requirement and CO_2 releases of each building in destruction stage. The destruction of large commercial structures like shopping centers, which involve huge amounts of concrete and steel, needs higher energy than residential buildings.

Table 4.4the gross energy requirement and CO_2 releases of each building in destruction stage

Gross energy and CO_2 releases	Sanko Park	Forum
Gross energy consumption (MJ)	102.96	99.26
Gross releases produced (kg CO_2)	1152.28	583.7

4.4 Results and discussions

Figure 4.9 and 4.10 show the primary energy requirements and CO_2 releases for each building on a per square meter base.

The primary energy requirements and CO_2 releases of Sanko Park and Forum calculations are shown in table 4.5 and table 4.6 respectively. The construction stage expends energy by a percentage about 15% for Sanko Park and 10% for Forum and CO_2 releases by a percentage of 7% for Sanko Park and 5% for Forum.

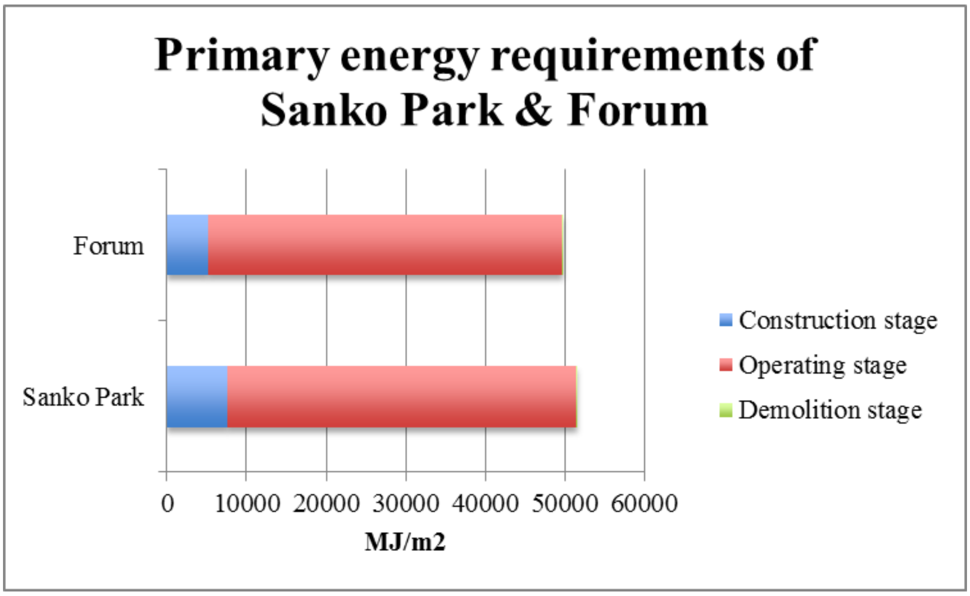


Figure 4.9 Primary energy requirements of Sanko Park and Forum

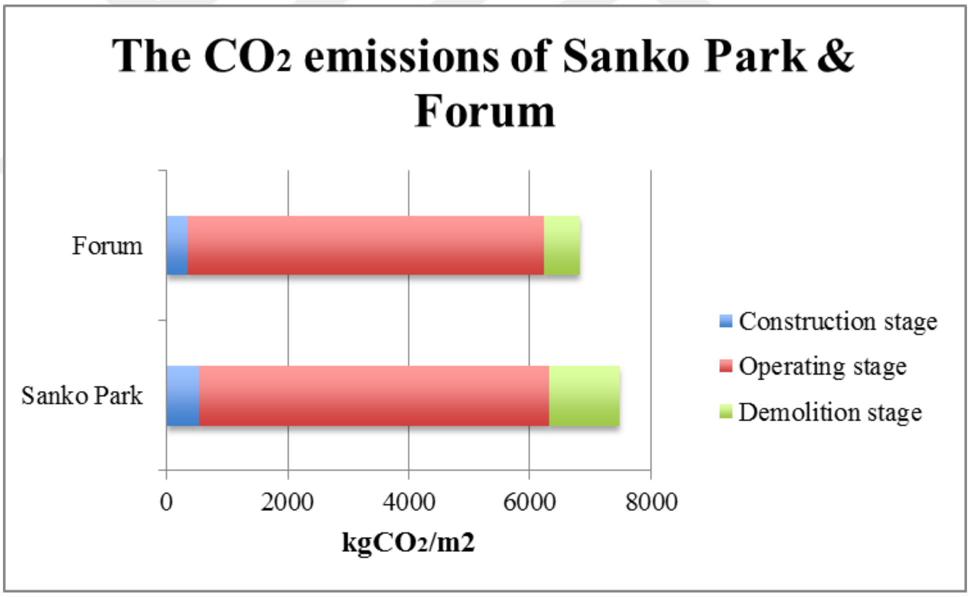


Figure 4.10 The CO_2 releases of Sanko Park and Forum

Table 4.5 The primary energy requirements and CO_2 releases of Sanko Park

Life cycle stages	Primary energy (MJ/m^2)	CO_2 releases (kgCO_2/m^2)
Construction stage	7611.56	535.36
Operating stage	43872.99	5791.23
Destruction stage	102.96	1152.28
Total	51587.51	7478.87

The EE of construction stage of Sanko Park as we notice in table 4.5 is 7611.56 MJ/m^2, while this number in Forum is 5110.03 MJ/m^2. It is clear that variance was a result from volume of structure. Large structures need more construction materials amounts.

The operating stage has the main role in primary energy demand and CO_2 releases for both buildings, which represent 85-90% of energy and 78-86% of releases for Sanko Park and Forum, respectively. It is noticeable that energy needs of destruction stage is negligible, on the other hand it consumes 15% for Sanko Park and 9% for Forum of CO_2 releases.

Table 4.6 The primary energy and CO_2 releases of Forum

Life cycle stages	Primary energy (MJ/m^2)	CO_2 releases (kgCO_2/m^2)
Construction stage	5110.03	356.85
Operating stage	44522.51	5876.97
Destruction stage	99.26	583.70
Total	49731.8	6817.52

In this study two commercial buildings of the same of geometric properties and similar materials built in Gaziantep City have been considered. The primary energy demand and releases of the buildings vary from 49632.54 MJ/m^2 for Forum to 51484.55 MJ/m^2 for Sanko and 6233.82 KgCO_2/m^2 to 6506.59 KgCO_2/m^2 per year, respectively. The outcomes of the LCA analyzes are influenced particularly by the volume and distinction of each building. The electric power plays a significant role in energy consuming in operating stage. In comparison with residential buildings, LCE and GHG releases outcomes of our study are greater. The reason is that commercial buildings are larger than normal buildings and the utilization of this type of buildings is continuous without stop in certain time per a day. In order to decrease energy consumption in operating system, we can provide the buildings with photovoltaics method that use solar cells to convert energy from the sun into a flow of electrons by the photovoltaic effect. Solar cells produce direct current electricity from sunlight. We can install 100KW commercial solar PV system, which has around 380 to 410 panels. Each panel measures around 1.6m × 1m, so it needs at least 656 m^2 of roof space. On average, a 100KW solar system generates 430 to 480 units per day. The study is reiterated after installing solar panels. The results are shown in figure 4.11 and figure 4.12.

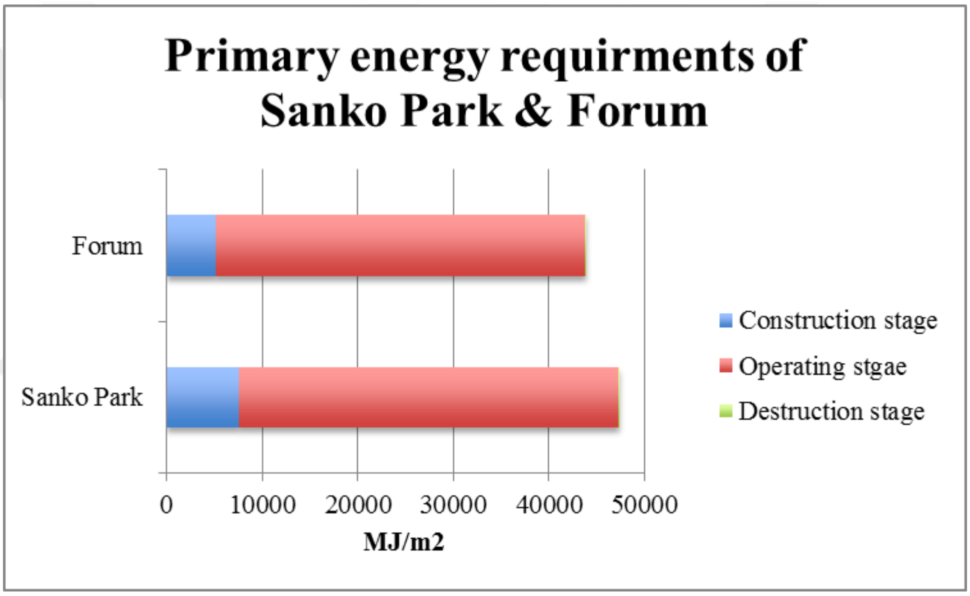


Figure 4.11 Primary energy demand of Sanko Park and Forum after adding PV solar system

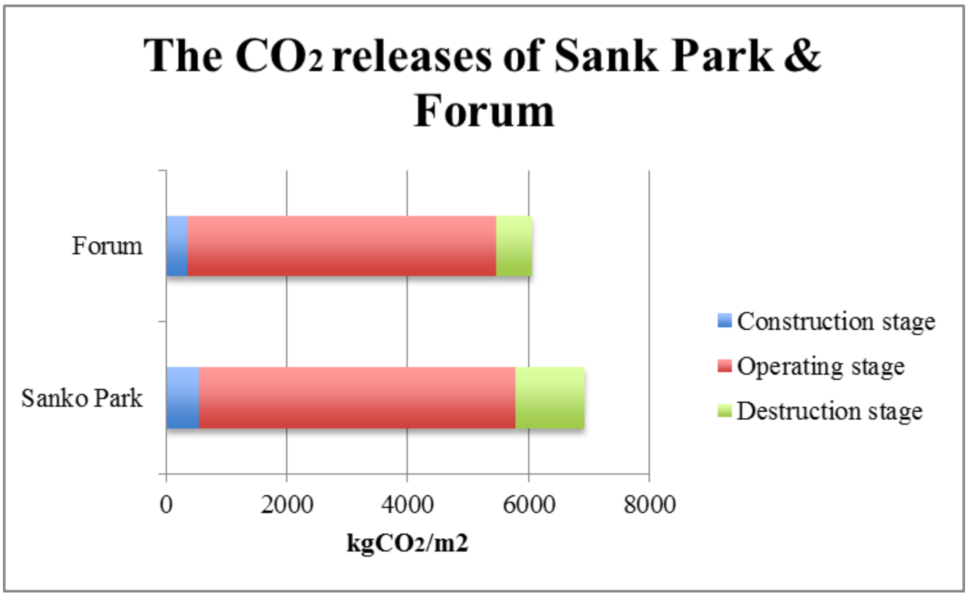


Figure 4.12 The CO_2 releases of Sanko Park and Forum after adding PV solar system

The results show that the solar system can save electricity consuming by a value of 4165.71 MJ/m^2 for Sanko Park and 5776.08 MJ/m^2 for Forum. In addition, it is noticeable that solar system decrease CO_2 releases by a value of 549.87 $KgCO_2/m^2$ for Sanko Park and 762.44 $KgCO_2/m^2$ for Forum. In Gaziantep case only 6 months of the year are considered because of cold climate of Turkey.

CHAPTER 5

CONCLUSION

Two public commercial buildings constructed in Gaziantep, Turkey were considered. LCEA and $LCCO_2$ were analyzed. Building construction, operating and destruction stages were analyzed.

The energy demand and CO_2 releases of construction and operating stages account for 14%, 86% and 7%, 77% for Sanko Park; and 10%, 90% and 5%, 86% for Forum respectively. According to calculations for 50-year lifespan, the operating stage plays a main role in energy consumption, by percentages of 86-90% of the gross energy demand and 77-86% of CO_2 releases, respectively. In construction stage, the floors occupy the greatest part of EE demand and CO_2 releases. Decreasing of life cycle energy requirement and CO_2 releases of building is very important by minimizing its operating energy by using advanced technologies. The life cycle analysis procedure suffers a lack of all energy requirements through construction stage. In sum, decreasing the needs of operating energy and using construction materials with low EE intensity sound to be the most significant perspectives the efficient design of buildings. Based on results, volume of building and number of stories affect on energy demand and CO_2 releases throughout entire life cycle.

The study presented the range of life cycle energy of Sanko Park and Forum is between 49731.81-51587.52 MJ/m^2 and CO_2 releases between 6817.52-7478.88 $KgCO_2/m^2$ that considered high.

In order to decrease consuming of energy designers must use alternatives:

- Increasing the thermal implementation of the building.
- Decreasing the internal weights to decrease materials quantities of construction.
- Use more windows to increase natural lightening and ventilation

- Optimizing solar systems.
- Decrease land use.

Additional researches and studies are needed to concentrate on the use of alternative construction materials and climatic and economic aspects especially in Turkey.

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