A STUDY ON ELEMENTARY SCHOOL BUILDINGS IN TERMS OF SUSTAINABLE DESIGN PRINCIPLES WITH THE OBJECT OF DEVELOPING INTERVENTION OPPORTUNITIES

by

Ece Demir

Submitted to the Institute of Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science
in
Architecture

Yeditepe University

2010

A STUDY ON ELEMENTARY SCHOOL BUILDINGS IN TERMS OF
SUSTAINABLE DESIGN PRINCIPLES
WITH THE OBJECT OF DEVELOPING INTERVENTION OPPORTUNITIES

APPROVED BY:

Asst. Prof. Dr. Murat Şahin ....
(Advisor)

Assoc. Prof. Dr. Seda Tönük ....
(Co-Advisor)

Assoc. Prof. Dr. Füsun Sezen ....

Asst. Prof. Dr. Kerem Ercoşkun ....

Prof. Dr. Yavuz Koşaner ....

DATE OF APPROVAL: 24/12/2010

ACKNOWLEDGEMENTS

I would like to express my gratitude and special thanks to my supervisor Assist. Prof. Dr. Murat Şahin for his enthusiastic guidance, criticism, encouragements, supporting suggestions and valuable insight throughout the study. It has been a great pleasure and honor to work with him.

I would again like to express sincere appreciation and special thanks to Assoc. Prof. Dr. Seda Tönük, my co-advisor, for her encouragement, guidance, contributions and also for her endless tolerance and understanding on last and most busy four months of my thesis.

I owe special thanks to Assist. Prof. Dr. Kerem Ercoşkun for his never-ending encouragement, support and help from the beginning of this thesis.

I would also like to thank the examining committee members, Prof. Dr. Yavuz Koşaner and Assoc. Prof. Dr. Füsun Sezen for their valuable suggestions and comments.

Finally, my special thanks and love go to my parents Sevil and Sami Demir for the education they provided me and their generous support and encouragement throughout my life and to complete this study. This thesis is dedicated to them.

ABSTRACT

A STUDY ON ELEMENTARY SCHOOL BUILDINGS IN TERMS OF SUSTAINABLE DESIGN PRINCIPLES WITH THE OBJECT OF DEVELOPING INTERVENTION OPPORTUNITIES

Over the last ten years, many school buildings in many countries have been designed on the basis of sustainability principles. Such buildings entail a complete design process in which passive design methods are used as well as energy efficient equipment. The aim is to create better educational environments in sustainable schools with high-performance building system, where academic performances of both students and teachers increase. However, public schools in Turkey have been built as typified projects by the Ministry of National Education, without consideration for different regional climatic conditions. As a result, this thesis researched potential redevelopment of existing school buildings, which have economic value, instead of developing a new sustainable school schema.

The main purpose of this thesis is to research sustainable intervention opportunities to typified existing school buildings in terms of some key elements of sustainable school design principles, such as sustainable site, water efficiency, energy and atmosphere, material and resources, indoor air quality.

In this regard, firstly, a comprehensive literature review was conducted on the concepts of “sustainable design”, “ecological design” and “energy efficient design”. After exploring sustainable school buildings applied and their design principles accepted broadly worldwide, school buildings in Turkey were examined. Then, sustainable intervention opportunities were proposed for “10025R-480 type” elementary school building by using daylight shadow values those were generated by the “Autodesk Ecotect Analysis” energy performance simulation software.

After establishing the design interventions, pre-intervention and post-intervention values for the building envelope were compared using “DesignBuilder” building energy performance software and the effect of intervention on the heating energy gain was examined. Assessment of the case study was finally presented as a proposal including progressive interventions for all typified elementary school buildings.

ÖZET

İLKÖĞRETİM OKULLARINDA SÜRDÜRÜLEBİLİR TASARIM PRENSİPLERİ DOĞRULTUSUNDA MÜDAHALE OLANAKLARI GELİŞTİRMEYE YÖNELİK BİR ÇALIŞMA

Pek çok okul yapısı çeşitli ülkelerde özellikle son on yıldır sürdürülebilirlik prensipleri doğrultusunda tasarlanarak uygulanmaktadır. Bu yapılar, pasif tasarım yöntemlerinin benimsenerek aynı zamanda enerji etkin ekipmanların kullanıldığı, bütünleşik bir tasarım sürecini içermektedir. Yüksek performanslı yapı sistemine sahip sürdürülebilir okullarda öğrencilerin ve öğretmenlerin akademik performanslarının yükseldiği daha iyi öğrenme ortamları yaratmak hedeflenmektedir. Türkiye'de ise kamuya ait okul yapıları Milli Eğitim Bakanlığı tarafından farklı iklim bölgelerinde bölgesel koşullar göz önünde bulundurulmayarak tip projeler olarak uygulanmaktadır. Bunun sonucu olarak bu tezde, yeni bir sürdürülebilir şema geliştirmek yerine, ekonomik bir değere sahip mevcut okul yapılarının sürdürülebilir adaptasyonu araştırılmıştır.

Bu tezde, ana amaç tip projeye sahip mevcut okul yapılarına uygulanabilecek sürdürülebilir müdahale olanaklarını, sürdürülebilir okul tasarım prensiplerinden sürdürülebilir arazi, su etkinliği, enerji ve atmosfer, malzeme ve kaynaklar, iç mekan hava kalitesi gibi ana başlıklar doğrultusunda değerlendirerek araştırmaktır.

Çalışma amacı doğrultusunda öncelikle, konuyla ilişkili sürdürülebilir tasarım, enerji etkin tasarım ve ekolojik tasarım kavramları ile ilgili olarak kapsamlı bir kaynak taraması yapılmıştır. Dünyada uygulanan sürdürülebilir okul yapıları ve tasarım prensipleri irdelendikten sonra Türkiye'de uygulanan okul yapıları incelenmiştir. Daha sonra 10025R-480 tip projesine sahip örnek bir ilköğretim okul yapısına uygulanabilecek sürdürülebilir müdahale olanakları, "Autodesk Ecotect Analysis" bina enerji performans yazılımının sağladığı gün ışığı gölge değerleri doğrultusunda sorgulanmıştır.

Müdahale olanakları belirlendikten sonra, örnek okul yapısı için yapı kabuğu müdahalesi öncesi ve sonrası değerleri "DesignBuilder" bina enerji performans yazılımı aracılığıyla analiz edilerek bu müdahalenin ısı enerjisi kazancına etkisi değerlendirilmiştir. Son olarak, vaka çalışması sonucunda, tip projeye sahip tüm ilköğretim okul yapıları için sürdürülebilir müdahale aşamalarını içeren bir öneri sunulmuştur.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

LCA	Life Cycle Assessment
EIA	Energy Information Administration
COBA	Cost Benefit Analysis
WCED	World Commission on Environment and Development
IECC	International Energy Efficiency Code
IPCC	International Panel on Climate Change
TURKSTAT	Turkish Statistical Institute
CHPS	Collaborative for High Performance Schools
LEED	Leadership in Energy and Environmental Design
AIA	American Institute of Architects
IAQ	Indoor Air Quality
GHG	Greenhouse Gases
HVAC	Heating Ventilating Air Conditioning
ASHRAE	The American Society of Heating, Refrigerating and Air-Conditioning Engineers

1. INTRODUCTION

This chapter introduces the subject area and presents the objectives of the study, together with a clear explanation of the potential users of the results and methodology followed. It also presents constrains and limitations within the thesis and explains the study structure.

1.1. INTRODUCTION TO SUBJECT AREA

Increasing global population is leading to the depletion of non-renewable resources rapidly and negative impacts resulting from the uncontrolled use of these resources are evident in environmental problems. The need for appropriate management of environment and resources has gradually resulted in the emergence of the concept of sustainability with ecological consciousness, and solutions to environmental problems have been developed in the context of this concept.

The concept of "sustainability", assessed in terms of economical, social and ecological aspects, highlights the importance of the built environment and examines the design, construction and management stages by including the relationship between buildings, their environments and users. In addition, nowadays, many buildings consume a great amount of energy and pose environmental threats. This case results in both short and long term environmental and economical threats in regional and global scales. One fifth of global energy is consumed by buildings comprising both residential and commercial consumers [1]. However, sustainable and green buildings aim to reduce energy consumption through passive design methods and by using renewable sources and energy efficient equipments. In the USA and many European countries, many applications could be seen which serve as examples of sustainable architecture and conform to specific national standards. There are currently few examples of such buildings in Turkey but, recently, the concept of sustainability has gained greater prominence and is now frequently mentioned.

There is a need to create awareness of sustainability throughout society and certain courses within the educational curriculum aim to promote the adoption of such behaviour among children. However, in addition to the curriculum, designing educational buildings as a “learning environment that teaches sustainability” will undoubtedly become a more effective tool for creating such consciousness. In America and Europe, many studies about “sustainable schools” that have been designed in this direction as a whole have shown the positive impacts on the building users’ conception of sustainability.

Design interventions to existing buildings as well as the construction of new, sustainable educational buildings will both contribute to the creation of sustainable learning environments and to reduce energy consumption. When existing educational buildings are examined, it is seen that the highest proportion are elementary school buildings, which therefore have the greatest negative impacts on the environment. Furthermore, such buildings are regarded as “typified projects” and generally lack sustainable design principles.

Sustainable refurbishment of educational buildings that have typified projects could be in different ways of interventions. As the skin of architecture, building envelope systems become the fundamental interpretation between the interior and the site condition that modulate thermal, solar, acoustic and other forces [2]. Energy consumption is highly reduced with the sustainable refurbishment of existing building envelopes [3]. Accordingly, sustainable interventions to existing elementary school building’s envelope are also significant. However, as most school buildings are constructed as typified projects, there is potential opportunity to apply sustainable design interventions to many such schools.

For this reason, there is a need to re-evaluate existing elementary school buildings that have typified projects, from the viewpoint of sustainability; in order to raise sustainability awareness among children at early ages and to seek opportunity to reduce energy consumption of these buildings.

1.2. OBJECTIVES

Especially in the developing countries, educational buildings are designed as typified projects in order to meet the demand of these buildings rapidly. Therefore, it could be mentioned that sustainable design principles are of secondary importance. Investigating the typified elementary school buildings, the objectives of this study are:

- To emphasize the proliferation of sustainable designs intended to reduce the negative impacts of the buildings on the environment and to examine the approach of sustainable design principles in educational buildings,
- To emphasize the importance of sustainable design of the education buildings,
- To re-evaluate existing typified elementary school buildings in the direction of sustainable design principles and to research the appropriate intervention opportunities for progressive sustainable design through a case study,
- To use building energy performance simulation software as a tool to assess the effects of the interventions on building envelope.

1.3. POTENTIAL USERS OF THE STUDY

Sustainable intervention opportunities are adapted for typified elementary school buildings. So, first of all, occupants of these school buildings are the potential users of the study. According to previous works it can be said that these interventions create better learning environments which are thermally, physically comfortable. Also, by means of these implementations, schools might be used as a tool that teaches sustainability and generates awareness.

The intervention to building envelope reduces heating energy consumption, so the funds which local governments pay for the schools for the bill expenses of schools can decrease. Because of the high ratio of elementary school buildings through existing building stock, a measurable impact on energy and resource consumption for society as a whole will be provided with the help of the sustainable interventions. Therefore, government's dependency on foreign countries might decrease.

1.4. THE APPROACH TO SUBJECT MATTER (METHODOLOGY)

This study focused on researching the sustainable intervention opportunities to elementary school buildings located in the Anatolian side of İstanbul, in terms of sustainable design principles. At the first stage of the study, a general survey was conducted to examine the changing usage of the terms sustainable, ecological and energy efficient design in the historical period.

At the second stage, the sustainable school concept and design principles were examined. Necessary criteria for new and existing sustainable school designs were explained and toward these criteria, the examples of sustainable schools were presented.

The third stage provides a general overview of typified elementary school buildings in Turkey which represent the highest proportion of schools in Turkey. Architectural drawings of typified elementary school projects were obtained from the İstanbul Provincial Directorate of National Education, İstanbul Special Provincial Administration and İstanbul Provincial Directorate of Public Works and Settlement; these were compiled and assessed with on site observation and documentation method. In addition, administrative staff was also formally and informally interviewed to gather further information about the process of typified projects, from the site selection to its implementation, in the above-mentioned institutions.

At the fourth stage, 10025R-480 type Şehit Öğretmen Mehmet Fidan Elementary School was chosen for the case study through five commonly applied elementary school types. After determining the school in the Anatolian side of Istanbul, architectural and spatial features of the school building were re-defined. In addition, sustainability of the ŞÖMF elementary school was examined through a generated sustainability checklist. Then, this school lack of sustainable design principles was modeled in “Autodesk Ecotect Analysis” software and daylight shadow values were visualized.

In the final stage, these daylight shadow values were used to identify appropriate interventions for ŞÖMF elementary school, in line with the sustainable design principles. These interventions were schematized for the school by taking the illumination level of facades and spaces into account. To obtain a tangible result from these energy efficient and sustainable interventions, ŞÖMF elementary school building was modeled and simulated in “DesignBuilder”, building energy performance simulation tool. After intervention to building envelope, heating energy expenses were assessed and compared before this intervention with the help of this software, and heating energy savings with this energy efficient renovation were presented. Then the practicability of implementing sustainable design interventions in all types of elementary schools was discussed and a general progressive intervention proposal opportunity was researched for all typified schools.

Also, the methodology adapted by the author is presented in the following.

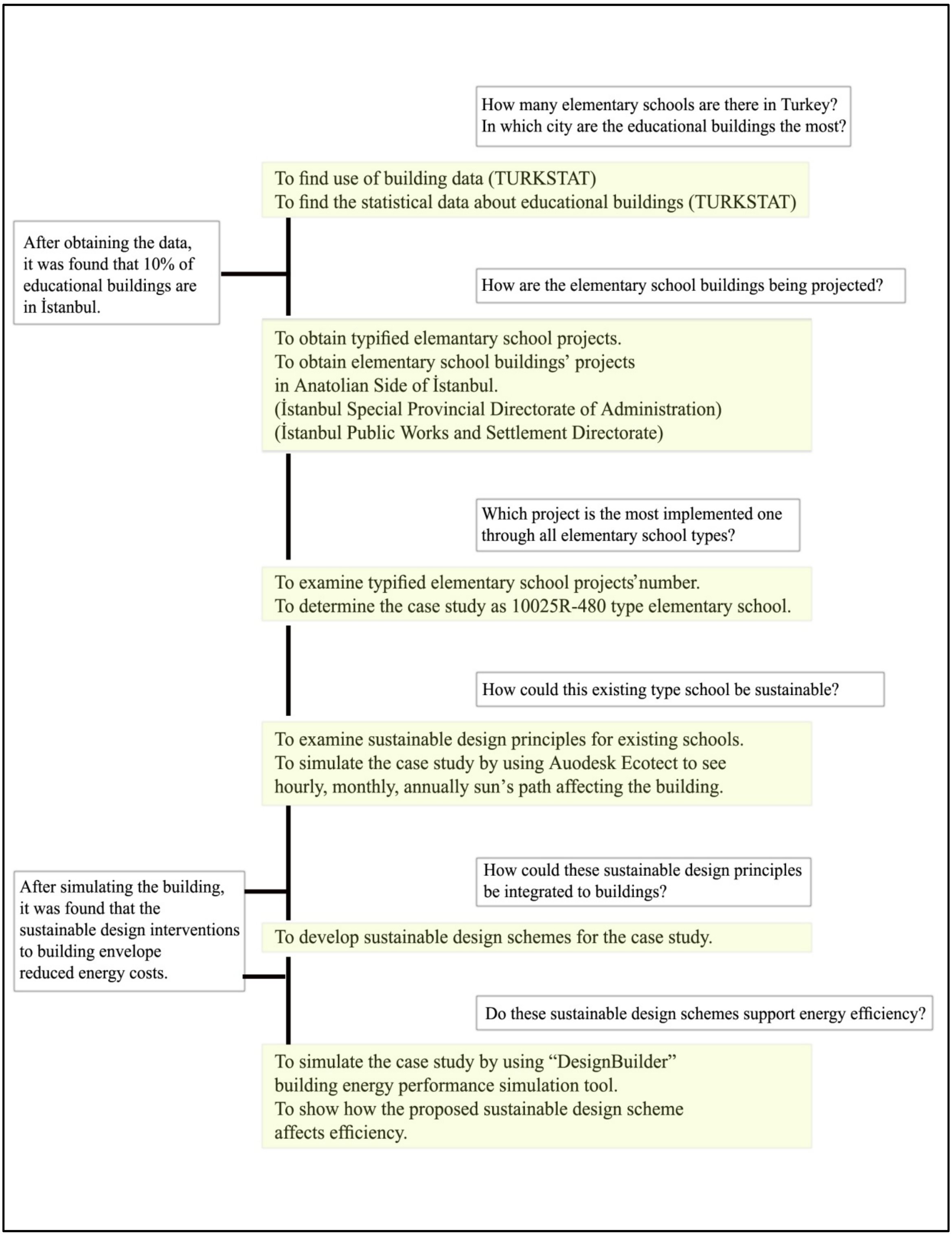


Figure 1.1. The methodology adapted by the author.

1.5. CONSTRAINTS AND LIMITATIONS

Information obtained by sustainability research can be of enormous value to propose and study the sustainable interventions for the school buildings. However, there are a number of reasons why, in this thesis, all of these potential interventions may not be studied with the subtitles they include.

As time constraints, because of all of the intervention steps, such as “materials and resources”, “energy and atmosphere”, “indoor environmental quality”, “water efficiency”, “sustainable site”, are major study areas, it requires focus on each of these specific titles. So, all of these titles researched with a general framework except the performance analysis under the title of “Energy and Atmosphere”.

There are two limitations that need to be acknowledged and addressed regarding the present study. The first limitation concerns the contradiction between the elementary schools’ type projects and school buildings’ construction projects; and limited information that were obtained from İstanbul Special Provincial Administration, İstanbul Provincial Directorate of Public Works and Settlement and İstanbul Provincial Directorate of National Education. So the research findings are limited by a case study of 10025R-480 type ŞÖMF elementary school which is the most implemented type and about which the most information was obtained. The study on sustainable intervention opportunities would be much more likely to produce findings generalizable to the other types of elementary school buildings and climate regions.

The second limitation is about to use the building energy simulation tools in a limited way while analyzing the energy performance within the author’s knowledge. According to the U.S. Department of Energy, Building Energy Software Tools Directory, more than 350 building energy software tools are available for sustainable and energy efficient design process. Of these software tools, TRANSYS, Autodesk Ecotect Analysis, and Energy Plus based DesignBuilder are used most commonly. So, “Autodesk Ecotect Analysis” and “DesignBuilder” were chosen for the building simulations. DesignBuilder was preferred due to its interface that reduces potentially incorrect inputs and the convenience it provided in the modeling process. Also Autodesk Ecotect Analysis was used as it is applicable for visualizing sun's path diagrams of the buildings on an hourly, monthly and annual basis.

1.6. STUDY STRUCTURE

The study consists of five chapters. The first chapter is composed of the argument for, the objectives of, and a general outline of the procedure of the study. It concludes with the study structure of the thesis.

Chapter 2 consists of a review of the relevant literature which 50 published works and 6 websites are scanned, covering the topics of environment and environmental problems, ecology and ecological design, sustainability and sustainable design, energy and energy efficient design.

Chapter 3 presents definitions of a sustainable school, explanations of sustainable school design principles and the assessment of example projects in line with these principles.

Chapter 4, the evaluation of typified elementary school buildings in terms of sustainability, composes the main chapter of the study. First, it reviews the typified elementary school buildings in Turkey and describes the case study and the ŞÖMF elementary school building in the Anatolian side of İstanbul. Then it examines the sustainability of the case study through a sustainability checklist and researches sustainable intervention opportunities to ŞÖMF elementary school building. Also, this chapter defines the evaluation of the new energy performance after the intervention to building envelope, by calculating heating energy demand and by comparing the results with the first case before the intervention by the help of "DesignBuilder" building energy performance simulation tool.

Chapter 5 then sets out the specific results obtained from the analyses described in the preceding chapter and concludes the study by summarizing its findings and offering pertinent recommendations.

2. LITERATURE REVIEW

2.1. INTRODUCTION AND DEFINITION OF TERMS AND CONCEPTS

This chapter defines the concepts used within this thesis and the scope of related terms. The emergence of these concepts and their broadening definitions with the increasing significance of environmental problems was examined; the process of integrating these concepts within the architecture discipline was explained. It is very difficult to determine the limits of these concepts. However, as a result of the literature review, contemporary definitions were explained and the sub elements that remained within the interface of architecture were defined.

2.1.1. Environment and Environmental Problems

All fields of natural science as they bear on the physical and biological environment around us are involved by environmental science. "The physical and chemical conditions where living organisms are placed and the other living organisms around this place create the environment of these organisms [4]". Global environment can be analyzed through three system traits: openness (whether a system is isolated from other systems), integration (strength of the interactions among the parts of the system) and complexity (refers to many kinds of parts a system has) [5].

The interdependence of man and environment is in part a problem of different studies. Workings of society, including the growth of cities by using resources of land and capital are the study areas of economics and sociology, but then, building as a response to social demand is the study area of engineers, architects and surveyors. Environment is in a relationship between physical and social interactions of man [6].

Different fields define the environment in their own examination area. As in the Figure 2.1., in the discipline of architecture, environment systems are separated in two groups as physical environment and social environment [7].

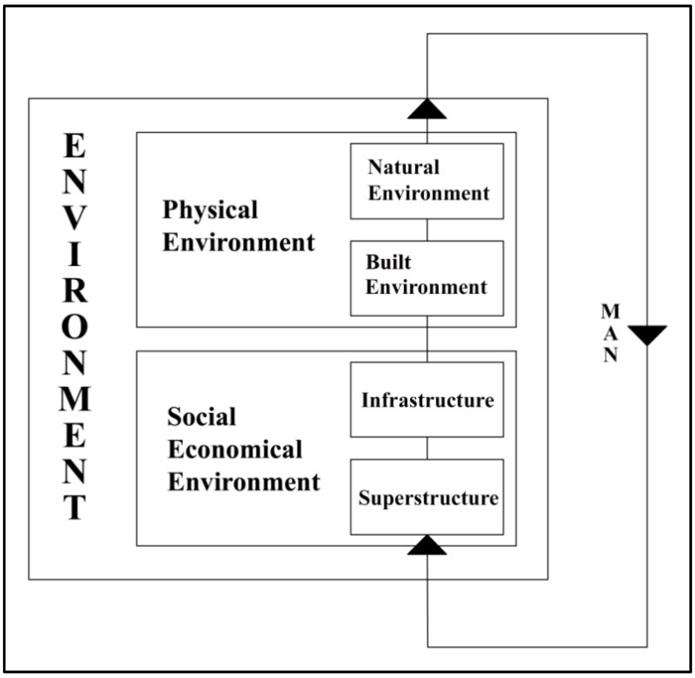


Figure 2.1. Different fields that define the environment [7]

According to Cain, Bowman, et al., "The physical environment is the ultimate determinant of where organisms can live, the resources that are available to them, and the rate at which their populations can grow [8]." The most fundamental characteristic of the physical environment is climate, and the physical environment also includes radiation from the sun which drives the climate system as well as biological energy production [8].

Physical environment factors are separated into natural and built factors. Natural environment factors that could be taken into consideration while designing a building include climate, temperature, sun, prevailing wind, humidity, topography, hydrological and geological site conditions, water sources and flora around the site. These factors should be studied during the design process. A built environment is generally defined as including all kinds of buildings, objects or spaces that are manmade; the social environment includes all social behaviors with the culture of the society.

Prior to the industrial revolution, in the period from the 18th to the nineteenth century, environmental resources were generally utilized in harmony and balance. The industrial revolution represented a major turning point in human history, caused major changes in agriculture, manufacturing, mining, transport, and technology. These effects of industrialization initially affected the socioeconomic and cultural conditions of the United Kingdom then, subsequently spread throughout the world. Population growth has taken on new dimensions in the last 50 years with global industrialization. Accordingly, depletion of resources increased. Non renewable resources are inclined by governments because of the low initial cost, which leads to increase CO2 emissions [9].

Despite the energy crisis of 1973, it was believed that technological innovation would continue to permit unrestricted energy consumption. However, the realities of finite resource levels and the carrying capacities of ecosystems come to terms at short notice [10].

The disappearance of forest cover, air and water pollution, the loss of biodiversity and changes to atmospheric chemistry reflect the need for more effective environmental protection. Therefore, in different countries to figure out environmental problems, these subjects have been discussed and some reports related to environmental and sustainable development themes were presented.

After considering the 1987 Brundtland report, in which population growth and sustainability problems were discussed, in the 1992 "United Nations Conference on Environment and Development (UNCED)" global summit in Rio de Janeiro highlighted environmental and sustainable development themes.

The two most immediate global environmental threats are:

- Climatic change, caused by the artificial introduction of large amounts of greenhouse gases into the atmosphere;
- Abnormally high incidences of ultraviolet radiation on the Earth's surface, caused by the destruction of the ozone layer [11].

In order to place the issue of climate change at the top of the international political agenda, the Kyoto Protocol, an international agreement linked to the United Nations Framework Convention on Climate Change, was adopted in Kyoto, Japan, on 11

December 1997 and came into force on 16 February 2005. “The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European Community for reducing greenhouse gas (GHG) emissions. These amount to an average of five per cent against 1990 levels over the five-year period 2008-2012 [12]”. In addition, this convention also aims to encourage the use of solar energy, to enable heating with less energy, to supply mechanical services such as heating and cooling, and to promote the use of energy efficient technological systems within industry.

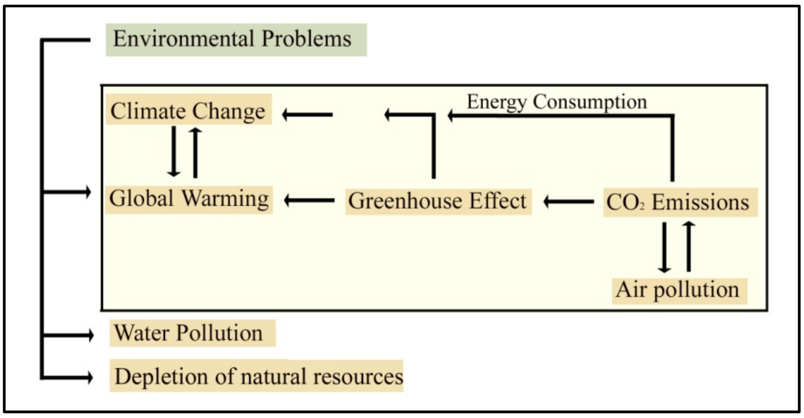


Figure 2.2. Environmental Problems

When factors cause environmental problems are examined, it is seen that a problem leads another problem and this case proceed as a chain reaction. As it is seen in the Figure 2.2., climate change, global warming, CO2 emissions, air pollution and greenhouse effect are related to each other. All of these problems are concerned with unconscious energy consumption.

As abovemetioned, CO2 emissions that cause climate change are derived from the use of non-renewable energy resources such as fossil fuels. “Buildings consume half of the energy that is used by human beings. The art of building and consumption patterns have changed dramatically during the last two centuries [10]”. Therefore, ecological, sustainable and energy efficient design concepts that make more efficient use of resources are examined in detail in the following sections.

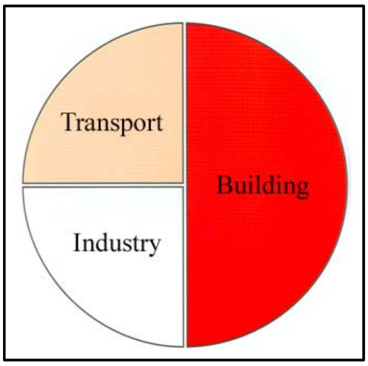


Figure 2.3. World energy consumption [10]

2.1.2. Ecology and Ecological Design

The term ecology was introduced by German biologist Ernst Heinrich Haeckel in 1866 [13]. "The word ecology is derived from the Greek *oikos,* meaning 'household', and *logos*, meaning 'study'. Thus, the study of the environmental house includes all the organisms within it and all the functional processes that make the house habitable [14]". As in the Figure 2.4., Odum illustrated the simple, essential relationships and connections between natural energies and renewable resources as an ecological model.

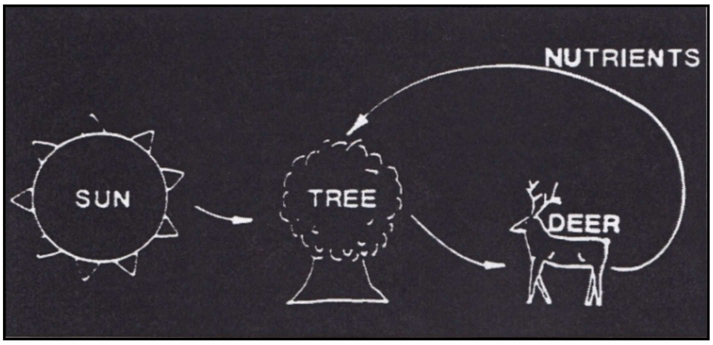


Figure 2.4. Odum's ecological model [14]

The term ecology has been defined in various ways, some of which are as follows:

- "Ecology is the study of how organisms interact with their environment. One of ecology's central goal is to understand the distribution and abundance of organisms [5]".

- Ecology studies relationships between organisms and environment over a large range of temporal and spatial scales using a wide variety of approaches [15].

- Ecology offers the science of the relations of organism and the environment, integrative of the sciences, humanities and the arts-a context for studies of man and the environment [16].

Since 1970, human and nature relations have been included within the scope of ecology, as defined during the second half of the nineteenth century, as the discipline examining the relationships between organisms and with the natural environment [4].

At first, ecology was defined as an unimportant branch of biology. Then humans entered the scope of ecology with the issue of climate change, which is the consequence of humans' destructive role in the environment, and with the increase in environmental problems such as flooding, drought etc. [4]. Over time, human ecology was examined in detail and this field of science, examining the relationships between plants, animals and their environments then started to examine the relationships between humans and their environment.

The ecological approach extends to the rituals and stories created by the Australian aborigines to protect the ecological maps of their territories and to the years when Yanomamö society, which possessed indigenous knowledge of the Amazon rain forests, produced hundred of plant species to increase biological diversity. These cultures retained this millennial knowledge to the present time [17].

Besides, early examples embody ecological approaches could be seen as; Socrates, who lived between 470-399 BC, designed a sun tempered house in accordance with the passive methods of prevention and awareness to benefit from the sun as in the Figure 2.5., Sokrates pointed out that winter sun could be easily taken in from the south facade but, in summer, sun passes through the rooftop and south facade is shaded mostly. According to Vitruvius, as in the Figure 2.5., Sokrates suggested that south facade could be high in level to benefit from winter sun while north facade is lower in height to be able to protect the building from cold winter winds [18].

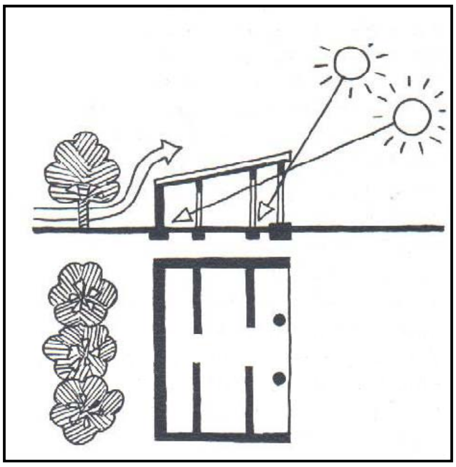


Figure 2.5. Socrates' sun-tempered house, MÖ 469-397 [18]

During the environmental movement of the late 1960s and '70s, the term "ecological" was accepted to refer to anything related to the "environment". Also, in the 1970s, some examples and studies examined sun, wind etc. as passive solar design principles that could be defined as ecological design in our days. Some examples of ecological design applications are as follows:

As a passive solar technique, indirect gain collects and stores energy in one part of the house and uses natural heat movement to warm the rest of the house. One of the more ingenious indirect gain designs employs the thermal storage wall, or Trombe wall inside an expanse of south facing glass. In 1964, original "Trombe" wall house in Odeillo, France, designed by Felix Trombe and Jacques Michel, by using a design for a thermal mass solar wall originally patented by Edward Morse, in 1881 as in Figure 2.6. Named after its French inventor, Felix Trombe, the wall is constructed of high density materials, masonry, stone, brick, adobe, or water-filled containers and is painted a deep color (like black, deep red, brown, purple or green) to more efficiently absorb the solar radiation. The working principle of trombe wall is as solar heat is trapped between the masonry and the glass. Trombe wall obstructs views to the outdoors, so it works well on a site where a southern view is not desirable. If there is a good southern view, opening and windows can be integrated into the Trombe wall [19].

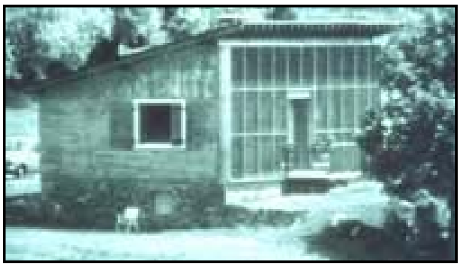


Figure 2.6. Original "Trombe" wall house in Odeillo, France, 1964 [19]

The New Alchemy Institute was a research centre founded in 1969, growing out of a critique of modern industrial agricultural processes, researching energy efficient, integrated systems of living that could operate in harmony with the planet. Many of the ideas developed at the New Alchemy Institute are now regarded as standard ecological design practice, such as the use of composting toilets, water purification using plants, solar collectors, or composting greenhouses. As seen in the Figure 2.7., in 1976, a building called “The Cape Cod Ark” was designed for the Institute based on criteria dependent on sun and wind [20].

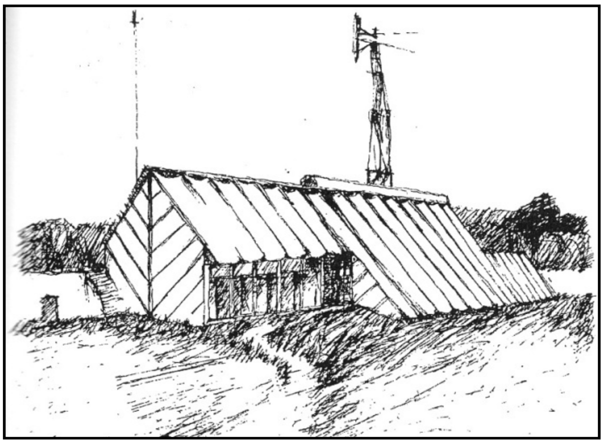


Figure 2.7. The Cape Code Ark as standard ecological design practice [20]

In 1978, Day Chahroudi defined buildings as organisms in one of his studies and proposed a new climatic envelope for reducing the energy use of existing building stock [21].

Also in 1978, Ekose'a Homes Inc. evolved from the San Francisco born architectural company Ekose'a, founded by architects Lee Porter Butler and William Randolph Pearson in San Francisco, California, and examined ways of designing natural energy conserving houses. The "double envelope" concept used in these houses allowed buildings to function well as an energy conserving structure in any climate without strict requirements in orientation or design style [22].

These examples adopt ecological design criteria and systems intended to reduce energy costs, which referred to as "soft technology". Soft technology is emphasized in various issues of the journal "CoEvolution Quarterly", which has an ecological framework.

The word "green" was the buzzword of 1980s. In the early 1980s, the lead nations such as Germany and Netherlands began research into environment and design. In the mid to late 80s, the concept green was increasingly mentioned in media and advertising with the increasing environmental consciousness in Europe. Identifying current environmental concerns with a specific colour provided green design a ready-made symbolism as green products, green packaging and numerous books on how to be green [23].

Some concepts related to the term "ecology", such as ecotechnology, ecological engineering, and ecological sustainability, were disseminated globally by the Ocean Arks International, which was founded in 1981 to create ecological solutions [20]. Also, John Button referred to approximately ninety sightings of the prefix "eco" in 1988, including ecological architecture, but neither of the terms were "ecodesign". Within the academic literature, the term Ecological Design Association (EDA) was used within the journal "Ecodesign", formed by 1989. Ecodesign terminology has developed by borrowing ideas from the fields of scientific "ecology" and political "environmentalism" [23]. Following this period in which environmental concepts came to the fore and when the components required for green design were determined, the need to methodologically analyze the ecological design in more detail arose.

In the early 1990s, various conferences and seminars were held on ecological design. In the UK, some studies focused on individual product or product systems related to ecodesign practice. Industrial ecology was a new framework for conceptualizing environmental and technical issues in this new interdisciplinary subject. LCA (Life Cycle Assessment), EIA (Environmental Impact Assessment) and COBA (Cost Benefit Analysis) focused on ecological systems for minimizing pollution. Ecological systems are driven by an ecological model based on the flow of energy and materials. An ecological model is powered by sustainable energy sources such as the sun, gravity, or natural cycles. Thus, ecodesign is referred to as a mechanistic view of the world which ignores the unpredictability of chaos and complexity [23].

By the late 90s, the original term “green design” was rarely used. At that time, rather than green design, the most widely used terms were ecological design and environmentally sensitive design. In turn, these terms gave way to “sustainable design” [23]. When the concepts related to the subject are examined, Figure 2.8. that shows widely used terms throughout history is schemed as below.

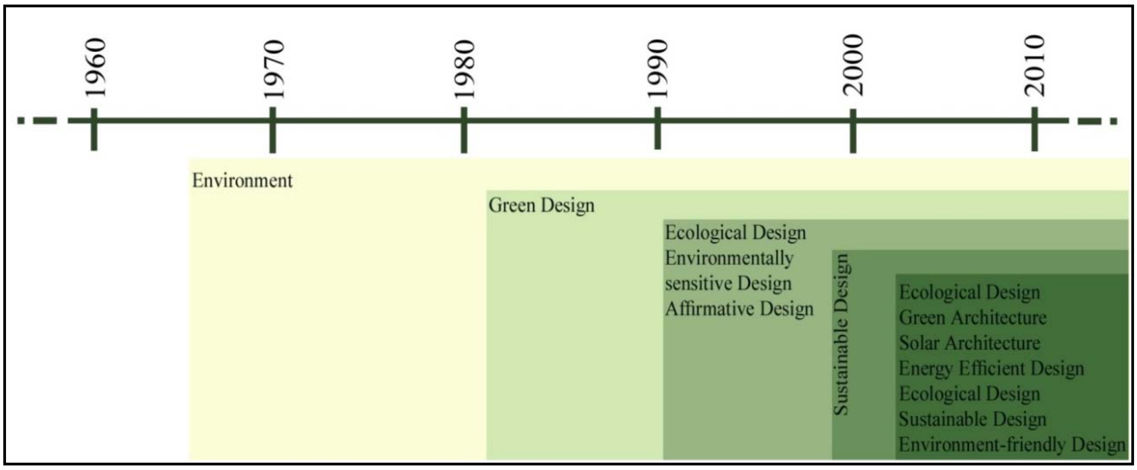


Figure 2.8. Widely used terms throughout history

Over time, the creation of new terms showed a regular development within the scope of theory and practice, and now proposed solutions in terms of the complexity of problems encountered in the field are being assessed.

Ecological design can be defined as “any form of design that minimizes environmentally destructive impacts by integrating itself with living processes [17]”. This integration of design implies respecting species diversity, minimizing resource depletion, preserving nutrient and water cycles, maintaining habitat quality and attending to all the other preconditions of human and ecosystem health. The perceived environmental crisis affected ecological design and its themes of investigation.

Everything that is built and made by humans, based on ecological awareness, can help reduce environmental impacts compared with non-ecological designs. Therefore, ecologically sound technologies, planning methods, and policies across scales and professional boundaries are required to be integrated into the design process. As in nature, function and form bridge many scales; a larger context of ecological approach should be adopted as nature’s own design strategies, flows, cycles and patterns.

Ecological design is simply the effective adaptation to and integration with nature’s processes and offers three critical strategies: Conservation, regeneration and stewardship. Small-scale experiments on methods of living lightly, such as many emerging technologies, alternative building materials, renewable energy, organic food, recycling, conservation etc. could be referred to as the first generation of ecological design. The insights of literally dozens of disciplines as genuine culture of sustainability are weaved at the second generation of ecological design. The second generation of ecological design could be described as the shift towards a genuine culture of sustainability, which combines insights from literally dozens of disciplines to derive solutions to technologically, socially and environmentally complex problems [17].

From Jack and Nancy Todds’ definition, the term ecological design is to design for human settlements that incorporate principles inherent in the natural world in order to sustain human populations over a long span of time [20].

With the development of an ecological design concept, the number of newly created terms increased, principles were developed to integrate ecology into the design and key elements required for ecological design were determined.

John and Nancy Todd provided nine key precepts for ecological design as below:

- The living world is the matrix for all design.
- Design follows, not oppose, the laws of life.
- Biological eguity determines design.
- Design reflects bioregionality.
- Projects are based on renewable energy sources.
- Design is sustainable through the integration of living systems.
- Design is coevolutionary with the natural world.
- Building and design help in healing the planet.
- Design follows a sacred ecology [20].

Accordingly, underlying principle of ecological design is the natural living world. Ecology as a discipline is interrelated with design concept. Some concepts used in ecological design and using principles of them are as follows:

- Energy source is whenever feasible, renewable: solar, wind, small-scale hydro, or biomass.
- Materials that are used should be as restorative materials cycles in which waste for one process becomes food for the next; materials also should be designed in reuse, they should be recyclable, flexible, ease of repair and durable.
- Pollution should be minimized; scale and wastes conform to the ability of ecosystems to absorb them.
- Toxic substances should be used extremely sparingly in very special circumstances.
- Ecological accounting should be sophisticated and cover a wide range of ecological impacts over the entire life-cycle of the project, from extraction of materials to final recycling of components.
- Ecology and economics should be perceived as compatible and long run view.
- Design criteria should focus on human and ecosystem health and ecological economics.

- Sensitivity to ecological context responds to bioregion; the design is integrated with local soils, vegetation, materials, culture, climate, topography; accordingly it can be said that the solutions grow from place.
- Sensitivity to cultural context respects and nurtures traditional knowledge of place, local materials and technologies.
- Biological, cultural and economic diversity should maintain biodiversity and locally adapted cultures and economies that support it.
- Knowledge base should integrate multiple design disciplines and wide range of sciences.
- Spatial scales should integrate design across multiple scales, reflecting the influence of larger scales on smaller scales and smaller on larger.
- Whole systems produce designs that provide the greatest possible degree of internal integrity and coherence.
- Role of nature is as being a partner of design phases; whenever possible, substitutes nature's own design intelligence for a heavy reliance on material and energy.
- Underlying metaphors are cell, organism and ecosystem.
- Level of participation is as a commitment to clear discussion and debate.
- Types of learning in ecological design is by making nature and technology visible, thus the design draws closer to the systems that ultimately sustain community.
- Response to sustainability crisis is provided by viewing culture and nature as potentially symbiotic [17].

All of these principles are accepted within the literature. Fundamentally, ecological design seeks to mimic and support nature and its behavior. Ecologic design aims to produce environmentally friendly buildings. However, such designs are not limited to the construction phase, but also seek to examine the relationship between building and environment by introducing a wide range of guiding principles.

2.1.3. Sustainability and Sustainable Design

Sustainability has become a key concept in the environmental policy and research arena. While much of the current literature describes the necessary conditions for sustainability, or ways of achieving sustainability, or what sustainability is not, few writers actually define the term. It has been nearly three decades since the term sustainability rose to prominence.

In accordance with UN - sponsored World Commission on Environment and Development (WCED) report called *Our Common Future* published in 1987, sustainable development defined that meets the needs of the present without compromising the ability of future generations to meet their own need. It contains within it two key concepts:

- The concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and,
- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs [24].

The terms “sustainability” and “sustainable” appeared in the *Oxford English Dictionary* during the second half of the 20th century for the first time as supporting and keeping up the needs. The etymology of the terms originates from the French verb *soutenir,* "to hold up or support" [25].

Button defined sustainability as an ecological term which means “the capacity of a system to maintain a continuous flow of whatever each part of that system needs for healthy existence [26]”.

Bachman defined sustainability as a broad term for the healthy habitation of nature. Also, according to him, “The systems mode of sustainability addresses biological patterns as well as the physics of building energy use [2]”.

Groups such as the International Union for the Conservation of Nature and Natural Resources, the Global Tomorrow Coalition, and the World Resources Institute established sustainability as a desired goal of environmental management, development, and international cooperation.

The terms related to sustainability concept are defined as sustainable biological resource use, sustainable agriculture, carrying capacity, sustainable energy, sustainable society, sustainable economy and sustainable development. Also, there are three alternative perspectives in which the term is used such as social, ecological and economic sustainability as in the Figure 2.9. According to Brown, Hanson, et al., a social definition of sustainability might include the continued satisfaction of basic human needs -food, water, shelter- as well as social and cultural necessities such as security, freedom, education, employment, and recreation. However, the ecological definition of sustainability focuses on natural biological processes and the continued productivity and functioning of ecosystems. Long-term ecological sustainability requires the protection of genetic resources and the conservation of biological diversity. An economic definition of sustainability is more elusive. Economists tend to assume the inevitability of economic growth and do not, for the most part, address the issue of sustainability [27].

Much like the Vitrivius' principles –firmness, commodity and delight- the three elements of sustainability have spatial relationships. Sustainable design is said to form part of the sphere within which these relations are resolved spatially.

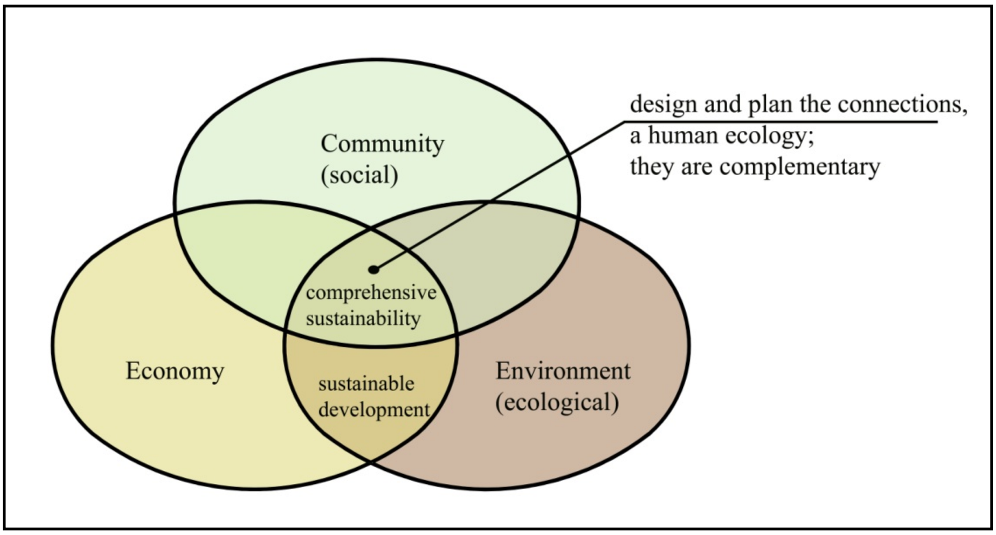


Figure 2.9. The three rings of sustainability illustrate interdependence of the elements [13], [28]

Sustainability word became a mantra for the 1990s which was offering the possibility of balance and permanence in a world where the opposite is experienced. Sustainability movement offers a response to the environmental crisis that makes needed connections between nature, technology, power relations, culture and values. In the late 80s and 90s, a huge literature on sustainability developed. Sustainability is not a single movement that is as varied as the communities and interest. Educator David W. Orr defined it as two approaches called ecological sustainability and technological sustainability. Technological sustainability is based on technological answers and market solutions to every problem. Ecological technology, in case, is based on finding new alternatives as rethinking agriculture, energy use, urban design, transportation, economics, resource use [17].

Throughout human history, raw materials and its impact on the environment have been a constant issue. The roots of the concept of sustainability can be traced back to ancient times. Environmental problems such as deforestation and soil salinization and loss of fertility, which are referred to as sustainability problems today, occurred as early as the ancient Egyptian, Mesopotamian, Greek and Roman civilizations. However, population growth, increased consumption after the Industrial Revolution and the danger of unsustainable depletion of crucial resources such as wood, coal and oil boosted awareness of the need to use resources sustainably.

By the late 1960s and early 1970s, different ideas about sustainability, progress and development started pointing in a new direction that of sustainable development. The term sustainable development appeared to have been used in the 1972 book “Limits to Growth”. Increasing population, food production, industrialization, pollution and consumption of nonrenewable resources were pointed out [29]. Two World wars, scientific and technological advances in progress caused terrible damage to the natural environment. During the period of industrial and commercial expansion, population growth, pollution and resource depletion posed to the environment have been taken into consideration. The idea of ecological crisis has been popularized. Because of the fear that economic growth might endanger the survival of the planet, environmental concern became more radical as in the illustrated Figure 2.10. This alarmist mood was as an alternative to unlimited economic growth, stimulated a new mode of thinking about development as of sustainable development. In the 1990s, three major problem areas, the population explosion, pollution and the depletion of non-renewable resources have been identified. Especially in the developing countries, overcrowding, uncontrolled urbanization, housing shortages, slum conditions and inability of governments to supply proper municipal medical and educational services were the most important problems to handle with populations [30].

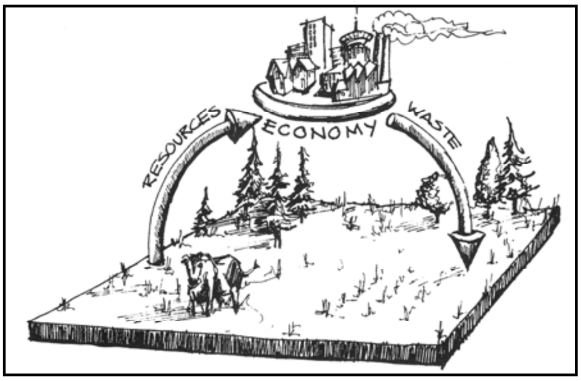


Figure 2.10. Thinking of economy as "industrial metabolism" that eats resources wastes leave this organism [31]

Despite so called green revolution, it was difficult to feed the population. Also, in accordance with the Brundtland Commission (WCED) report entitled Our Common Future, social equity, economic growth and environmental maintenance were three fundamental components of sustainable development. Briefly it can be said that sustainable development was a solution to growth problems.

After all of these concepts including sustainable development, the term ecological footprint related with them, has been occurred. According to Wackernagel "The ecological footprint is a measure of the load imposed by a given population on nature. It represents the land area necessary to sustain current levels of resource consumption and waste discharge by that population [32]".

2.1.3.1. Sustainable Design Principles

The term sustainable design has begun to be used or so to refer to a longer term and broader vision of ecodesign in the last years [23].

Dorsey and L'Esperance stated that "A 'Sustainable Design Charatte' is a process advocated by the American Institute of Architects (AIA) in which a multi-disciplinary team works together to envision alternative design solutions for a building program with an emphasis upon long-term economic, social and environmental sustainability [33]".

Sustainable design creates solutions that solve the economic, social and environmental challenges of the project simultaneously and these solutions are powered by sustainable energies. To design sustainably,

- What exists seasonally at the region and site scale (temperature, humidity, air movement, winds, soils etc.) should be learned and measured.
- What is needed by the users (comfort, water, renewable energies, and resources) and what exists on the site should be overlay and compared. Seasonal design approaches and opportunities should be listed to unplug.
- Effectiveness should be measured and assessed [13].

As one of the largest integrated design firms in California, LPA Inc., developed *10 Sustainable Principles* to guide and inform clients about the green planning, design, and construction process. These principles are as below:

- Inter + Acting: Communication, collaboration and cooperation are the essential components of the green planning and design process.
- Doing less: Conserving natural resources, reducing energy and water consumption, generating less pollution and greenhouse gas emissions generally designing and building with less.
- Challenging convention: Keeping an open mind and exploring with never assuming, settling and accepting the status quo.
- Zooming out: Each project is part of a much larger whole -the surrounding neighborhood, the entire community and its businesses, and the environment. The project team should integrate each project's planning, design, construction, and uses into that larger whole.
- Zooming in: Each planning and design component is part of a much larger whole. Analysis of the basic functional needs to create a balanced, holistic design solution should be undertaken. Greening the details would green the project.

- Creating value: A sustainable design creates value, because it will not cost more than a conventional design and it will have lower operating costs than a conventional design.
- Proving: Providing the hard numbers that all stakeholders need about the true costs and benefits of sustainable designs.
- Stepping up: Although too many people are ignoring sustainable designs or taking a "wait and see" attitude, rather than stepping up and greening their schools; today benefits of sustainable schools is proven [34].

Researchers of the National Park Service in America have emphasized that sustainable design balances human needs with the carrying capacity of the natural and cultural environments and also it minimizes environmental impacts, importation of goods and energy as well as the generation of waste. According to the same source sustainable building design must aspire to:

- Use the building (or nonbuilding) as an educational tool to demonstrate the importance of the environment in sustaining human life,
- Reconnect humans with their environment for the spiritual, emotional, and therapeutic benefits that nature provides,
- Promote new human values and lifestyles to achieve a more harmonious relationship with local, regional, and global resources and environments,
- Increase public awareness about appropriate technologies and the cradle-to-grave energy and waste implications of various building and consumer materials,
- Nurture living cultures to perpetuate indigenous responsiveness to, and harmony with, local environmental factors,
- Relay cultural and historical understandings of the site with local, regional, and global relationships [35].

Also sustainable projects should meet criteria of:

- Being developed within existing urban boundaries and within walking distance to transit options. Cleaned up brownfield areas should be preferred for the new projects,
- Using green energy and being unplugged from nonrenewables,

- Being fully useful for intended function in a natural disaster or a drought,
- Being made of materials that have a long and useful life-longer than its growth cycle- and being anchored for deconstruction, (Every design should be a storehouse of materials for another project.)
- Using no more water than what falls on the site,
- Connecting impacts and wastes of the building to useful cycles on the site and in the environment around it,
- Being compelling, rewarding and desirable [13].

According to Ryn and Cowan, design is a hinge that inevitably connects culture and nature through exchanges of materials, flows of energy, and choices of land use. In consequence of whole these sustainable connections to design process; integrated design practice occurred for designing sustainable buildings [17]. In integrated design practice, the range of stakeholders includes the owner, the various designers and engineers (structural, civil, heating, ventilation, air conditioning and refrigeration [HVAC-R], plumbing, electrical and energy engineers), the builder and contractor, specialty consultants (daylighting, energy, sustainable design, and commissioning consultants) building users and operators [28]. In standard designs, architectures, engineers, consultants, society and users participate in the process when necessary and within a limited relation; in this integrated design process, they work face to face and each member has a say in every stages of the process. Also, mostly used tool of the integrated design process for energy is software that assesses building energy performance. Fundamental sustainability goals should be established early in design to set meaningful targets by the help of these softwares [28].

Bachman stated that “Integration is about bringing all of the building components together in a sympathetic way and emphasizing the synergy of the parts without compromising the integrity of the pieces. Terms that apply to integration are: inclusive, assimilative, whole, complement, fit, appropriate, multipurpose, adaptable, flexible, comprehensive, and so on [2]”.

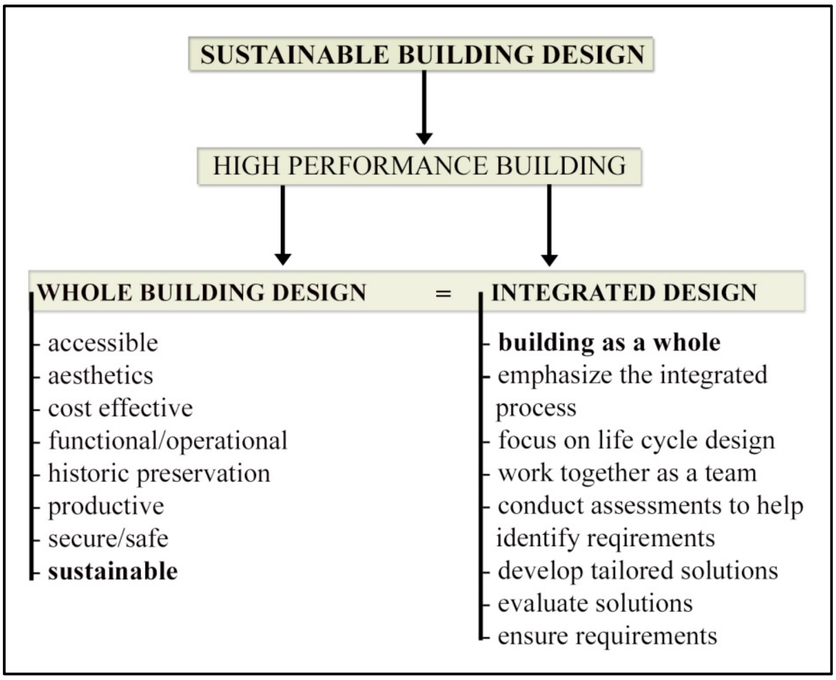


Figure 2.11. Integrated Design Team [2], [36]

The National Institute of Building Science evaluates the design process as a whole and defines this process as “whole building design”. It is suggested that the design purposes should be in harmony with each other in order to bring success to this whole design. Accordingly, as shown in Figure 2.11., the whole design of the building is carried out by the integrated design team.

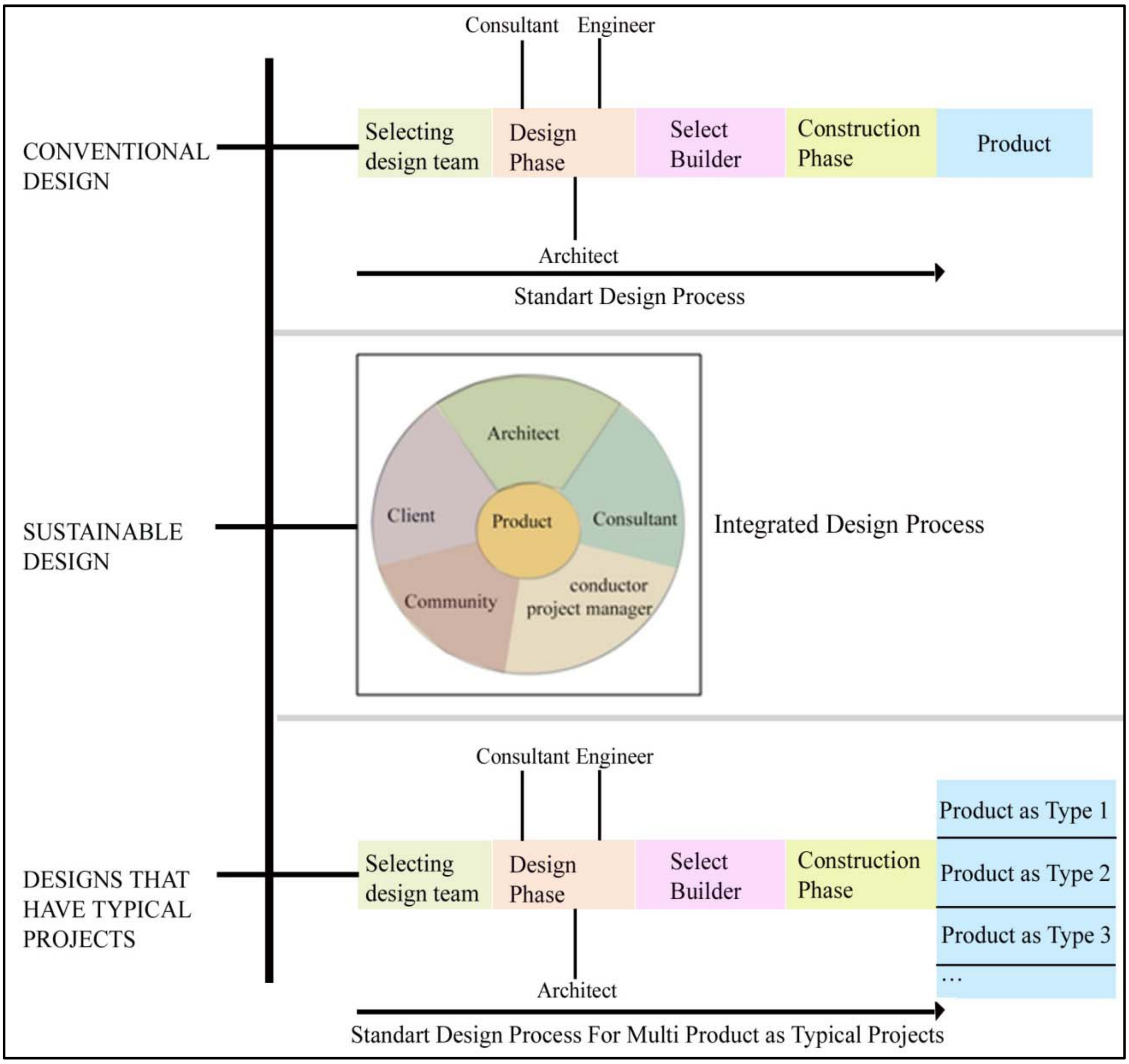


Figure 2.12.Three design process approaches

As it is mentioned above, conventional project delivery is a linear process that design team, consultant, engineers do not step in all phases of the design, while constructing the building. In the same way, projects that are designed as "type", this standart design process is adopted. As for in sustainable project design process, the product is in center that in all phases, architect, engineers, consultants, clients etc. take part in the design. Therefore, these design process approaches could be classified as constructing the conventional design, sustainable design and the design that has typified project as in the Figure 2.12.

2.1.3.2. Sustainability of Existing Buildings

There is a science to working with existing forms and structures that is comprised of a peculiar mixture of theory, research, and practicality a science of "found objects". The form is worked to transform what exists to something useful or relevant. According to Todd, the principles while working with existing structures are as below:

- Insulating to reduce reliance on fuel consumption for heating and cooling is the usual way to begin renovation of an existing structure.
- Adding passive solar elements, consisting of the addition of a skylight and a window greenhouse to the south side of the building.
- Trombe wall; a transparent wall added adjacent to the original wall which acts as a heat absorber and retains solar heat.
- Addition of a passive solar greenhouse placed on the most southerly oriented side of the building.
- Active solar applications [20].

All of the built structures in the world need considerable design renovation work to make them approach sustainability or energy efficient. The following sustainable design principles are introduced in each existing structure:

- Introducing natural daylighting and ventilation
- Eliminating consumption of nonrenewables.
- Providing a healtier, more participatory environment for users.
- Redesigning so existing structure can function unplugged [13].

Besides, Tönük stated that while going further for reusing of existing buildings, it has a great importance that the economical life of the building has not been ended up yet. By the actuality of causing economic burden of standing by the old buildings by not using them; it is not profitable to invest a building that has ended up its economical life and reuse of this building. As seen in the Figure 2.13., building life – economical use diagram of Walter Meyer-Bohe clarifies this case [37].

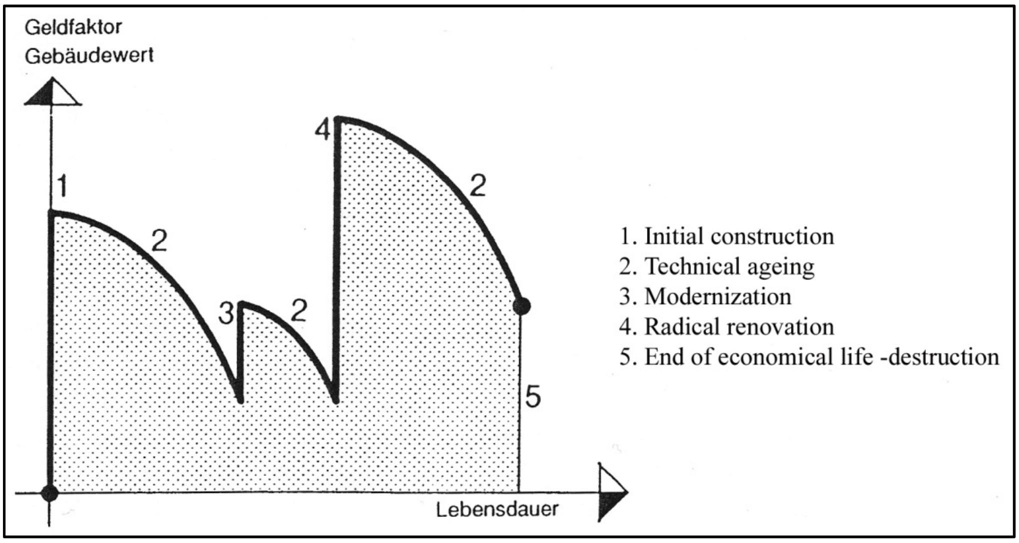


Figure 2.13. Meyer – Bohe's Building Life – Economical Use Diagram [37]

In the sustainability of existing buildings context, adapting a property as opposed to construct a new building, not only helps to reduce energy consumption, but also pollution and waste. Adapting buildings is not just about making them suitable for today's uses and conditions. It is also concerned with making them suitable for occupancy requirements and weather conditions in later years. Achieving a loose fit in a building will facilitate its adaptive reuse if necessary in future. For sustainable adaptation of buildings, requirements are determined as below:

- Profitability
- Flexibility
- Energy efficiency actions
- Environmental performance indicators
- Eco-friendly materials [38].

Considering existing building stock, and high energy consumption of these buildings, they could be interfered in an efficient way. So, it could be mentioned that reuse of existing buildings, renovation of these structures by increasing efficiency and sustainable adaptation are essential for increasing the performance of these buildings.

2.1.4. Energy and Energy Efficient Design

Gevorkian stated that energy is transformation from one form to another, but it is never created or destroyed. “This principle, the *law of conservation of energy,* was first postulated in the early nineteenth century and applies to any isolated system. The total energy of a system does not change over time, but its value may depend on the frame of reference [39]”.

According to Freeman, “Energy can be defined as the capacity to do work or to supply heat. This capacity exists in one of two ways as stored potential or as an active motion [5]”.

Energy Information Administration, (EIA) defined energy as the vital force powering business, manufacturing, and the transportation of goods and services to serve the world economies in the *International Energy Outlook Report* [1]. U.S. Department of Energy classify the energy sources as, bioenergy, coal, electric power, fossil fuels, fusion, geothermal, hydrogen, hydropower, natural gas, nuclear, oil, renewables, solar and wind.

Natural resources are usually defined in terms of their effects on environment as in two groups, renewable and non-renewable resources. As in the Figure 2.14., the cycle of solar energies on Earth can be divided into solar energy that has been stored underground for years and the energy comes from sun daily [10].

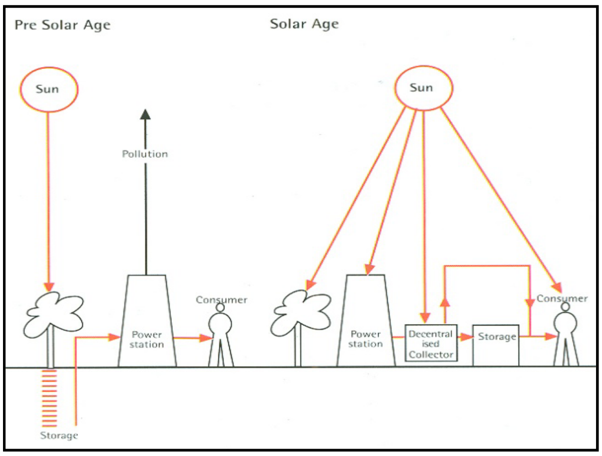


Figure 2.14. The cycle of solar energies on Earth [10]

Non renewable energy resources are fossil fuels, oil, natural gas, coal, nuclear energy which have been stored underground for thousands of years -old solar energy-. Energy is neither produced nor consumed only transferred. All energy sources are a form of solar energy, stored as biomass in trees; as fossil fuels in oil, gas and coal. These sources are discovered and utilized by enabling technological innovations. Before the Industrial Revolution, local microclimate, typically oriented to take maximum advantage of solar activity had been taken into consideration at the design of towns. Energy sources used were primarily renewable. Industrial Revolution could be defined as fuel based revolution. Renewable energy remained largely underdeveloped after 1945 because of the economic forms of fossil fuels and nuclear power that could be capable of meeting future. But today, it is appreciable that non renewable resources are breaking up. For this reason, energy production is from non-renewable to renewable sources, so called hard technologies to softer technologies those which are ecologically balanced [10].

Renewable energy resources are solar and associated with solar energy such as wind and biomass; also geothermal, hydrogen, water power and hydroelectric energy which reduce carbon emissions. The growth of clean renewable energy is an important part of addressing climate change [10]. “Renewable energy is energy obtained from sources at a rate that is less than or equal to the rate at which the source is replenish [9]”. Meanwhile entering a new solar age, sun has the most significant role while forming new conditions of cities and buildings. In order to understand the potential of solar energy, the ultimate natural power source, the sun should be examined.

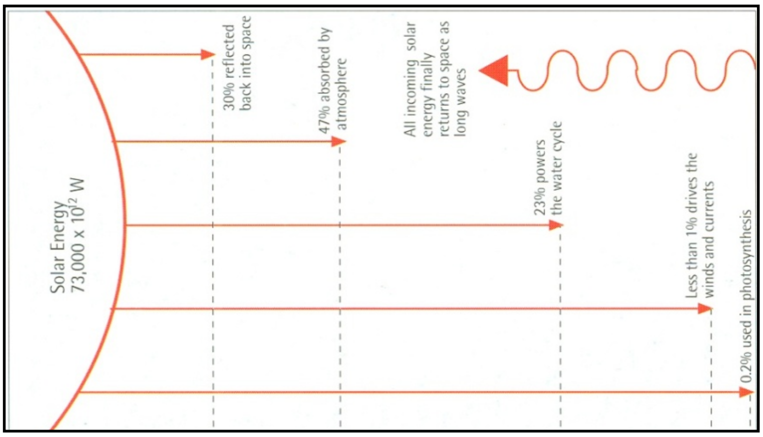


Figure 2.15. Different forms of energy on Earth occur by transformation of radiation [10]

There is no greater energy source like the sun which has the energy output of 2,000,000 million million times that of the largest nuclear reactor. The sun; Earth's only energy source, is 150 million km from the earth which has the temperature of fourteen million degrees Celcius at its core. Solar energy reaches the atmosphere in various forms such as wind, clouds, thunderstorms, rain and other weather conditions. Any form of solar energy can be converted into heat but heat can never be converted into other forms of energy. Also as shown in the Figure 2.15., different forms of energy on Earth occur by transformation of radiation coming from the sun [10]. The amount of solar radiation reaches the surface of the Earth depends on reflection, absorption, scattering and diffusion as shown in the Figure 2.16. [9].

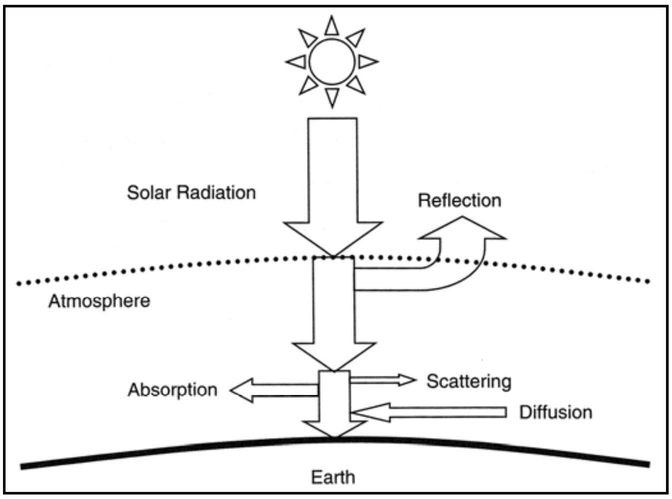


Figure 2.16. Solar radiation and the earth atmosphere system [9]

Solar energy is classified in three forms:

- Passive solar energy
- Active solar energy

Passive solar energy technology, in other words passive design techniques integrate building design with environmental factors that enable the capture or exclusion of solar energy. In passive solar energy applications, mechanical devices are not used. Simply, as it can be seen in the Figure 2.17., the roof overhang or thermal insulation are considered in passive design [9].

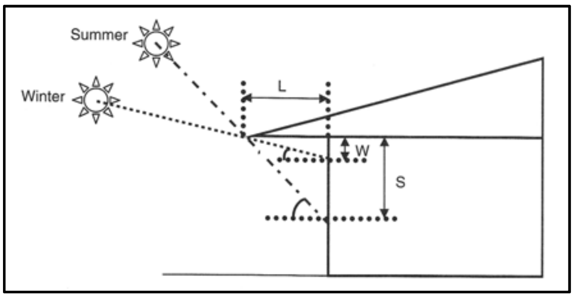


Figure 2.17. The roof overhang [9]

Passive solar architecture, as it was called in the 1960s and 1970s, referred to building system interaction with processes of climate, sun, wind, rain, and daylight. It featured a number of technologies for converting sunlight directly into winter heat gain. Most of its cooling strategies consisted of means of heat gain avoidance, but some work was done with earth sheltering, external mass, and night sky radiation cooling. As it was mentioned above, greenhouses, Trombe walls, and direct-gain heating strategies were most popular. Taking cues from indigenous and vernacular architecture, the components of passive environmental servicing were integrated directly into the envelope and structure of the building. This integration is part of what distinguishes passive architecture from active solar systems. Active systems are independent mechanical devices for converting sunshine, wind or other diffuse natural energies into usable concentrations of energy like heat or electricity. They include solar water heating, photovoltaic electric cells, and wind turbines. Active systems can power any building regardless of whether they are integrated into its construction, added on the roof, or in a remote location. Passive systems have a more powerful impact on building design than add-on active systems, precisely because the architecture itself is the passive system. This first phase of ecological architecture was very much about harnessing benign and renewable sources of energy that coexisted with the building on the site [2].

The other forms of energy as wind energy occurs with the rotation of the planet and the poles designate the Earth's wind patterns. Hydroelectric energy; Ancient civilizations used water wheels to relieve humans of some forms of manual labor. For example, The Greeks used hydropower around 4000 BC to turn water wheels for grinding wheat into flour. With invention of the water turbine in the early 1800s, hydroelectric power technology soon was advanced to produce electricity. The main advantage of hydroelectric power is that it is renewable and generates no atmospheric pollution during operation. It also has relatively low operational and maintenance costs [39].

The Hydrogen Energy Center classified the benefits of hydrogen under three basic tittles. According to these titles, the use of hydrogen greatly reduces pollution. When hydrogen is combined with oxygen in a fuel cell, energy in the form of electricity is produced. This electricity can be used to power vehicles, as a heat source and for many other uses. The advantage of using hydrogen as an energy carrier is that when it combines with oxygen the only byproducts are water and heat. No greenhouse gasses or other particulates are produced by the use of hydrogen fuel cells. Hydrogen can be produced locally from numerous sources. Hydrogen can be produced either centrally, and then distributed, or onsite where it will be used. Hydrogen gas can be produced from methane, gasoline, biomass, coal or water. Each of these sources brings with it different amounts of pollution, technical challenges, and energy requirements. If hydrogen is produced from water, a sustainable production system could be provided that is independent of petroleum products and is nonpolluting [40].

The term *geothermal* is a composition of two Greek words: *geo*, meaning “earth,” and *therm*, meaning “heat.” Combined geothermal means “heat generated from the earth.” Geothermal resources are manifested in a wide variety of forms, some of which include hot-water reservoirs, which are exothermally heated underground water reservoirs, and natural steam reservoirs, which manifest as ground steam. Geothermal energy as a technology involves the production of electrical energy by using the hot-water reservoirs [39].

In the *International Energy Outlook Report* the term "biomass" means “any organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural crop wastes and residues, wood wastes and residues, and aquatic plants as well as animal, municipal, and other wastes. The energy derived from biomass is known as bioenergy [1]”.

Tidal movement occurs as a result of the twice-daily variations in sea level caused primarily by the moon and the sun. Tidal power has been in use in milling grain since the eleventh century in Britain and France. The generation of electricity from tides is similar to hydroelectric generation, with the exception that water flows in and out of the turbines in both directions. Tidal power is a technology that makes use of captured energy contained in moving water mass owing to tides for conversion into electricity. Types of tidal energies extracted are kinetic energy, which results from currents arising between ebbing and surging tides, and potential energy, which results from the height or head differential between high and low tides [39].

By not using these renewable resources, the energy crisis of 1973 and 1979-81 illustrated to industrialized countries the dependency on high levels of energy consumption required to support their life styles [10]. Before the energy crisis of the 1970s, architects went about their work without possessing any vocabulary for the environmental impacts intrinsic to buildings [17].

Energy efficient designs first emerged with the energy crisis during the 1970s [41]. The first steps were taken in this field with the arrangements in energy codes, design standards and the certification systems. These improvements state incentives for energy efficient technological investments. Energy efficient building standards were developed by some groups such as ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers), in the private sector. Energy efficient design principles include measures taken in the building envelope, lighting, heating and cooling, technologies used in energy production and water and waste management.

The use of energy efficient design principles and renewable energy resources in buildings were adopted rapidly, due to the carbon emissions and the impact of green house gas effect that occurred with the use of non-renewable energy resources. The emphasis of ecodesign therefore shifted to designing buildings that meet their own energy needs and even produce surplus energy. As well as starting with the pre-design stage, energy efficient building design is also ensured through the design interventions and systems integrated to the buildings to reduce the energy consumption of the existing building stock. In this section, the necessary criteria for the energy efficient design of a building are examined.

The process of designing a building in way in which it consumes minimum energy during the whole life cycle, starts with the pre-design stage. Decisions made prior to the start of design, site selection and building size can be major determinants of energy use and environmental impact; For example, site selection shapes transportation energy. As well as sustainable design, energy efficient design should be thought as a whole. If the building is energy efficient, but the occupants of the building use a lot of energy, such as by arriving at the building by automobile; the energy use would mean that the overall sustainability goal could not be reached.

Energy goals in design can be classified as below:

- Climate responsive design incorporates passive techniques to reduce the energy use associated with space heating, cooling and water heating.
- Building envelope design should create a good thermal boundary between exterior and interior through air sealing, insulation, elimination of thermal bridging, selection of exterior finish materials and location and use of appropriate high performance windows and glass.
- Provision of controlled ventilation.
- Energy efficient equipment should be selected and properly sized equipment for heating and cooling should be used.
- Renewable energy to meet the remaining demands for power should be used in maximum [28].

To design a building in a sustainable and energy efficient way, climate responsive design is significant. When climatic conditions are changed according to regions, the building envelope and components generally have importance, especially in existing structures. So, climate responsive design strategies and therefore building envelope as an effective use are mentioned below.

According to climate responsive design, identifying the regional climate type associated with a given site is the first step. For identifying, maps and zip code climate zone data are available online with the International Energy Efficiency Code (IECC) and ASHRAE 90.1. Passive design techniques that are climate, site conditions, solar geometry, building form and materials or reject the natural energies at a site affecting a building can provide comfort while lowering the need for heating and cooling. With passive solar heating thermally massive materials such as a concrete floor slab, brick wall, or containers of water are used so, these materials receive the sun and store the heat and in the evening they reradiate the heat, warming the interior of the house even as outside temperature fall [28].

Site factors as topography, landscape elements, adjacent buildings and microclimates affect passive design strategies. For the north hemisphere, on the south side of a hill, a site may have excellent opportunities to use solar energy for space heating, water heating and electricity generation. On the north site of a hill, a site may have limited access to sun in the season when it is most needed for space heating during the winter. The sun can be blocked by neighboring buildings with negative and positive results. Also, density of trees and other vegetation on and near a site offer opportunities and obstacles. A specific site will promote or limit opportunities for passive heating and cooling. As key to low energy building design, these site limitations strengthen the case for thoughtful orientation of the building form and window openings [41].

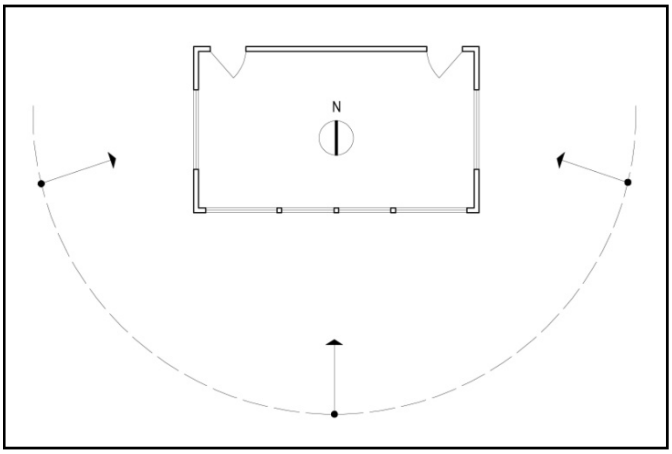


Figure 2.18. Suitable building envelope orientation in the Northern Hemisphere [28]

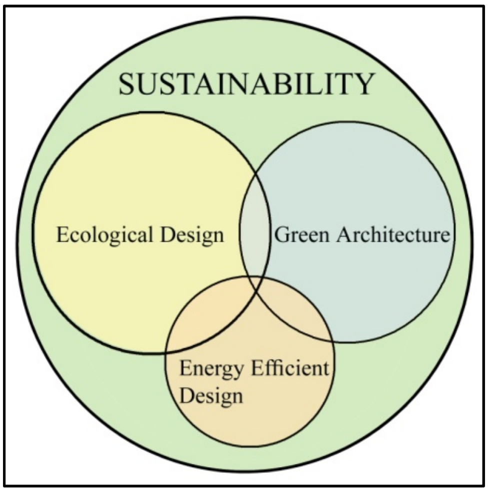
Firstly, building envelope design should response to the sun as shown in the Figure 2.18. for a building in the Northern Hemisphere. Rejection of solar heat and controlled admission shape building orientation, massing of forms, and the location of windows and skylights. With good orientation and envelope design, it is little to lose and much to gain by reducing the need for cooling according to economic, geopolitical, and environmental concerns suggestions. Illumination through admission of diffuse light from the north is created balanced interior by elongating the building along west axis. “Energy performance is critical but not sole factor in shaping architectural form. Views, functional needs, urban setting, and aesthetic considerations all influence how project design goals are established and balanced [28]”. In creating a tight building envelope an air barrier is an important component. As an air barrier, any material that is relatively air impermeable and long lasting can be used. Reducing air filtration would aid overlapping energy efficiency, design for durability and healthy indoor interiors. The transfer of heat across wall and ceiling assemblies is limited by insulation using different materials as batts, loose fill, low density foam or premanufactured as boards. As heat flows from hot to cold; across a building, heat will seek the path through elements that are more conductive than surrounding material [41]. So, details where thermal bridging is possible should be designed carefully. Windows and glass should be chosen to the climate region and also responding to the sun.

Consequently, the effectiveness of renewable energy in reducing the environmental impact of a building is increased by passive design techniques. Also in reducing the need for energy; good site orientation, air sealing, high performance windows, high levels of well-installed insulation and efficient appliances are cost effective. Benefitting from solar energy is the most important way to provide the efficiency by integrating solar thermal water heating and photovoltaics [28].

Humans have long understood the significance of utilizing solar energy, and many cultures have historically built shelters that maximized solar gain. Discussion of solar architecture has become increasingly prominent due to the emphasis on reducing energy consumption within buildings as a means of limiting carbon emissions. Thus, it would be beneficial to examine the integration of solar technologies with the architecture discipline.

2.2. CHAPTER RESULT

When the terms; energy efficient design, ecological design and sustainable design that become widespread with the green architecture movement, were compared related to the their definitions in different sources, it is appropriate to say that these concepts are usually used instead of each other and there is not an exact definition that separates them from each other. However, when these concepts were examined in the historical process, it is possible to see their range also with their emergence. Accordingly, it could be mentioned that in energy efficient design; it has not pointed out that the materials are natural or non-toxic, the exact emphasis was done through minimizing the energy expanses. With the concept of green architecture, not only energy efficient design principles were considered but also natural material using was pointed out. According to all of these principles in ecological design, the design process is discussed as an integrated design. On the other hand, sustainability concept could be evaluated under various subtitles such as; ecological, spatial, economical, technological and cultural sustainability.



Şekil 2.19. Conceptual relationships under “sustainability” tittle

According to the literature review, the relation of a variety of concepts in the working area is schemed as in the Figure 2.19. Here it is seen that the sustainability concept is considered as an expression that includes ecological design, green architecture and energy efficient design areas. Also, energy concept that is a significant area in terms of sustainability from economical and ecological perspective remains on the agenda with the depletion of non-renewable resources. When it is considered that buildings consume half of the world energy that is used by human beings; it is essential that adopting energy efficient and ecological design principles could be reached as a conclusion in order to provide sustainability.

3. SUSTAINABLE SCHOOL CONCEPT

As mentioned in the previous chapter, sustainable design is an approach that uses energy resources efficiently and systematically evaluates the effects of the building on the environment during the design process. In other words, efficient resource management and minimization of energy consumption constitute the basis of this approach.

Educational buildings are important parts of the building stock. Therefore, by considering the sustainable principles which reduce energy and resource consumption in high levels; "sustainable schools" are being constructed in countries such as Australia, England and America and the authorities aim to ensure that all schools will meet sustainability criteria by 2020. Other necessities of the sustainable design of school buildings other than energy efficiency and resource management, are discussed below.

Ecological literacy will become a vital part of all education, as the world transforms in its efforts to avert dangerous climate change. Future generations cannot be expected to value what they are being taught unless they experience these principles in operation within their learning environment. So they could come to think about sustainability when they are surrounded by sustainable educational built environments -schools- where children first learn what it is to be in the World in the society and a compelling moral and educational case exists for environmental stewardship.

According to Howard Kaplan, AIA LEED accredited professional, the future of education is linked to what is happening to the planet and is, in turn, linked to the design of schools [42].

School building design features and components affect student learning. Depending upon the conditions within the building such as thermal environment and noise level, the overall impact a school building has on students can be either positive or negative [43]. According to Taylor, "Livability of learning environments is the primary matter because children's bodies are still developing and outside agents can disrupt that growth and development, putting health and performance at risk. Children are especially vulnerable to environmental hazards such as poor air quality, lack of natural light, or noise [42]". Green school design aims to open buildings to daylight and views and responds to all these threats to the habitability of learning environments with the general goal of saving on energy costs and reducing energy loads for HVAC (Heating, Ventilating, Air Conditioning) systems. Therefore, green school design, in other words ecologically responsive (sustainable) school design, is an essential for healthy and effective learning environments.

Taylor describes the ideal educational environment as a carefully designed physical location composed of natural, built, and cultural parts (the context) that work together to accommodate active learning across body, mind and spirit. After explaining the ideal educational environment, she classified components of the physical learning environment across philosophies and related architecture with sustainability, as in Table 3.1. The context of educational environments is described as the whole setting for learning indoors and out, including school grounds and moving beyond school walls to community and the world; the entire built, natural, and cultural environment [42]. Therefore, as part of a simple framework for organizing design ideas of schools, the context of a learning environment should be investigated in detail in order to achieve sustainability.

Table 3.1. Components of the physical learning environment [42]

Image of the Process	**Ecoism (Ecosophy, Sustainabiliy)**
Architect	Architect as educator and orchestrator of environment
Architectural design process	Looks to field of deep ecology for ethical guidance, advocacy research, uses nature's patterns of sustainability
Architecture	Architecture that teaches and embodies the principles of sustainability and uses the language of ecology
Image of the physical learning environment	Promotes stewardship and sense of place through learning landscapes (people are a part of, not apart from, the environment)

Dudek determined requirements of school design as:

- Spatial configurations
- Acoustic design
- Sustainability
- Outdoor spaces [44].

So, according to this requirement list, it could be seen that sustainability is a key factor in overall design of a school.

Why to design the sustainable school is the question that the benefits of them could be the answer. Benefits of sustainable schools can be counted as;

- Higher student test scores (social sustainability),
- Lower operating costs (economic sustainability),
- Increased student attention (social sustainability),
- Enhanced teacher performance and satisfaction (social sustainability),
- Increased building life (economic sustainability),
- Lower environmental impact and changing attitudes (ecological sustainability). [45].

In Poudre Districts's Sustainable School Design Guidelines, the goals that could be achieved through sustainable schools are arranged that:

- Enhance student performance and attendance,
- Teach principles of sustainable design,
- Harmonize with the natural landscape,
- Provide higher quality lighting,
- Consume less energy,
- Conserve materials and natural resources,
- Enhance indoor environmental quality,
- Safeguard water [33].

Schools are the learning spaces where children spend most of their time. Designing these places based around sustainability has many positive impacts in terms of creating better learning environments in healthier spaces. As these impacts have proven to be important, the need for sustainable school design is often emphasized. Spatial approaches have changed from past to present and passive design methods were sometimes relied on to create healthy learning environments.

3.1. SUSTAINABLE FEATURES OF EDUCATION BUILDINGS THROUGHOUT THE HISTORY

The planning principles and organizational schemes for school buildings changed over time with the introduction to new approaches to meet the needs of educational buildings. Key historical movements and sustainability issues for mass education during this period are briefly mentioned below.

Whilst school systems existed in some shape or form throughout the world from the earliest part of enlightenment, the external style rather than the internal function had been emphasized. Later, according to English architect E. R. Robson, the form of the school was largely dictated by functions of size. Robson inadvertently adopted a model based around the form of the eighteenth century house, with individual (class)rooms, clearly articulated circulation routes and a large assembly hall at its heart. Also according to Robson, architectural and educational aspects of school design could be integrated and health concerns were also important. Two key criteria of Robson's schools were:

- The layout of classrooms (around a central hall),
- The number of pupils to be accommodated [44].

However, Robson's school environment was autonomous and closed to the outside world. In the 1900s, John Dewey promoted a more open approach of a classroom vista that was no longer restricted by high windowsills; instead, surrounding green spaces are used to encourage creativity [44]. Dewey's introduction of green landscaping visually to the students is an approach that is adopted today with the entrance of new environmental education to the curriculum in sustainable school buildings.

In later years, a hygienic environment was emphasized in the form of designs that combined the advantages of cross-ventilation and all round natural light within classrooms. According to the Report of the Consultative Committee on the Primary School, called the “Hadow Report” (1931), Duiker’s open air principles were influential. Southerly aspects and open green sites were offered. Modernism in mainstream school design appeared during the 1940s, with the free development of the plan. Design principles included three major environmental concerns, natural light, ventilation and acoustic isolation. Susan Isaacs produced furniture to the scale of children and focused on child-friendly details. Also, the environment was a vital element of the educational process [44]. In those years, where the concepts of green, sustainable, ecological design were not mentioned terminologically, it could be seen that the elements which are today known as sustainable design principles, such as natural ventilation, natural light, environment and building relations, were incorporated within contemporary school buildings.

After opening education places to environment, in 1967, a Report of the Central Advisory Council for Education called “Plawdon Report” (England) proposed three spaces: a generous outside covered space, a messy practical zone and a zone for reading, writing maintained the discipline of children interacting with each other. Generally, the key principle was enclosure [46].

Then, in addition to these conventional schools, open-air schools were provided with large folding classrooms. The parts of learning environment such as external areas, surrounding context and also social interaction rather than autonomous isolation became the educational strategy of 1980s with Herman Hertzberger. During the twentieth century, the major historical developments in school design were developed with standardized classes which envisaged social relations between the users through the organization [44].

In brief, within the history of school design during the nineteenth and the early part of the twentieth century, the essential dialectic was defined on the one hand as a resolute set of spaces to impose discipline and control; on the other the production of buildings which were not enclosing and confining in order to encourage individual creativity.

During the first half of the twentieth century, in order to impose discipline, the approach that challenged education within limiting walls notified that orientation towards the environment could increase the creativity of students. In today's sustainable schools, this approach could be interpreted as orientation towards green issues in order to facilitate environmental education. It draws attention in the school curriculums of the 1940s, in which natural ventilation and lighting were as the main design principles even they were not mentioned under the sustainability concept. In the 1960s, even the school places defined in the Plawdon Report emphasized that education should be carried out in more introverted places; in the 1980s, Hertzberger maintained that education should be carried out in schools with open plan schemes where the environmental and social relations were questioned. In this way, in the historical period, the main design principles that constitute the concept of sustainability were adopted in school buildings to use passive design methods and to question the relations between building and environment.

3.2. DESIGN PRINCIPLES OF SUSTAINABLE SCHOOLS

When sustainable school certification systems, such as LEED and CHPS are examined, it is seen that sustainable design principles are classified into two; designing new school buildings and renovation of existing school buildings in terms of sustainability. Accordingly, in this chapter, sustainable design principles for new school buildings and sustainable design principles for existing school buildings are examined and some examples of them are presented.

3.2.1. Sustainable Design Principles for New School Buildings

Dorsey and L'Esperance stated that “Every new structure that is constructed without sustainable principles is a lost opportunity for the lifetime of that building.” Schools are ideal application of sustainable design but if the building itself is not used to help teach students about sustainability and their role in a sustainable future, the full benefits are lost. So spaces as learning environments could be embedded with subject matter from native materials, to daylighting, to visually accessible building systems, to dynamic technologies. Superior learning environments and long term cost savings in building operations and maintenance are offered by sustainable design in schools [33].

In order to achieve sustainable schools, some design principles are used. The many planning, design, technology and other strategies to green a new or existing school are too numerous to list, and they are growing exponentially on a daily basis. The principles of sustainable school design used within different studies are as follows.

According to Ford, schools that are eco-friendly, rich in architectural character embody high performance design principles. According to these high performance design principles, tools utilized are as follows:

- Water is discussed as using rainwater harvesting, on site wastewater treatment, stormwater management, xeriscape landscaping, high efficiency irrigation systems, biofiltration, water saving plumbing fixtures,
- Energy is discussed as using photovoltaics, passive solar strategies, external sun shades, wind turbines, high performance building envelopes, ground source geothermal combined with heat pumps, thermal mass, high efficiency mechanical systems with web-based or computer controls, green roofs, “cool” roofs,
- Indoor air quality is discussed as using natural ventilation, solar chimneys, displacement ventilation, wind walls, use of low VOC materials,
- Recycled and green materials are discussed as construction site recycling, recycled content in building materials, certified green building materials,
- Transportation and multipurpose is discussed as accommodation of alternative transportation systems, adaptable school plants that can evolve with changing educational strategies, and schools that serve as community centers for after hours [47].

Gelfand determined the key elements of the main design strategies that must be taken into account in sustainable schools as follows:

- Daylighting,
- Building Structure and envelope,
- Heating, ventilating, cooling and plumbing,
- Landscaping and site design [45].

According to Taylor, while designing schools as sustainable living environments; site selection and design, solar orientation of school for maximum energy benefit, wind power, etc. could be investigated. And design potentials to provide sustainability in schools are determined as below:

- Providing systems for water harvesting and recycling,
- Designing transitional spaces for learning, extensions to classroom areas, or links to the outdoors such as porches, patios, courtyards, decks, attached greenhouses, animal pens, shade structures, weather stations, planters, and water or sand areas,
- Designing for agriculture and associated life skills,
- Creating habitats for students to observe and maintain, such as a wetlands area on the playground, or preserve existing habitats,
- Designing for student care and stewardship, not just janitor employment,
- Using local materials and vernacular building and landscaping techniques,
- Following LEED green design criteria to achieve certification [42].

The basic and cost-effective sustainable planning and design strategies that LPA Inc. has learned by applying its 'Sustainable Principles' to every kind of schools defined as the following subject matters:

- Landscape architecture,
- Water conservation and stormwater management,
- Materials and resources,
- Indoor environmental quality,
- Planning and design,
- Exterior design,
- Façade design,
- Thermal lag and diurnal differential,
- The roof [34].

As the sustainable school design principles are inter-disciplinary, the design process necessitates collaborative working. This team carries out physical, visual and performance appraisal according to an integrated design approach.

In addition to the design criteria, there are many elements that are included in the sustainable school design process. These elements are evaluated from the beginning to the end of the process. Figure 3.1. was illustrated in terms of the elements of sustainable school design are determined as: community-based planning, LEED and CHPS, integrated design, school as campus, environmental curriculum, flexibility for multiple uses, water efficiency, energy efficiency, resource efficiency, high performance learning spaces, daylighting, improved air quality, thermal comfort, improved acoustics and commissioning by Gelfand [45].

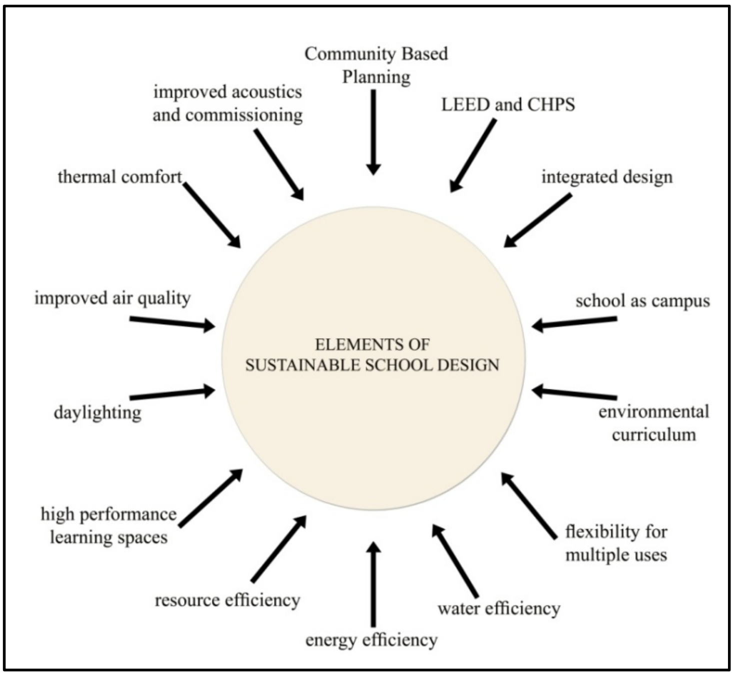


Figure 3.1. Elements of sustainable school design [45]

After examining sustainable design principles with main topics from different sources, main criteria those are defined by Ford, Taylor and Gelfand have taken into consideration. And also, by considering the sustainable, energy efficient and ecological design principles defined in Chapter 1, the Table 3.2. that includes sustainable school design principles is created as follows.

Table 3.2. Sustainable school design principles

SUSTAINABLE SCHOOL DESIGN PRINCIPLES			
Energy, resources and environment conservation **(ecological sustainability)** Enhancing academic performance, school as a teaching tool of sustainability **(social sustainability)** Lowering operating costs **(economic sustainability)**	**Energy**	**Design Elements**	Passive solar strategies
			Thermal mass
			High performance building envelope
		Equipment	PV panels
			External sun shades
			Solar tube
			Trombe wall
			Wind turbines
			Green roof, cool roof
			High efficiency mechanical systems (heating, ventilating, cooling and plumbing)
	Water	**Design Elements**	Rainwater harvesting
			Wastewater treatment
			Stormwater management
		Equipment	High efficiency irrigation systems
			Water saving plumbing fixtures
	Indoor Air Quality	**Design Elements**	Natural ventilation
			Displacement ventilation
		Equipment	Solar chimneys
			Wind walls
			Use of low VOC materials
	Materials	**Design Elements**	Construction site recycling
			Vernacular building techniques
		Features	Recycled content in building materials
			Certified green building materials
			Local materials
	Transportation and Multipurpose	**Design Elements**	Schools that serve as community centers for after hours
			Adaptable school plants that can evolve with changing educational strategies
			Schools that serve as community centers for after hours
		Features	Alternative transportation systems as carpooling, using bicycles
	Landscaping and site design	**Design Elements**	Reducing heat island effect
			Protecting or restoring habitat, planting the play environment
			Vernacular landscaping techniques
			Water efficient landscaping, integrating bioswales and retention areas
			Maximizing open spaces
		Equipment	Less heat absorbing material
			Light pavement

3.2.1.1. Site Selection

Selecting a site is the first job for the working group in the first case of a new school. According to Gelfand, “Location defines the impacts of development both to the site itself and to surrounding neighborhoods, transportation, habitat and hydrology. The site selected for a new school should not make it more difficult to walk to school [45]”. The sustainable school site should be:

- Central to the community it serves,
- Linked to walking and bike-friendly routes,
- Outside sensitive habitat,
- Coordinated with existing transportation, water, waste, and energy networks [45].

Close proximity of a school to the local community is important to reduce the students’ transportation costs. Transportation through walking or reduced travelling distance reduces the CO2 emissions of the vehicles. In addition, school buildings designed near the local community are used for evening classes and other community roles and thus the functionality of the building is ensured.

Additionally, in the site selection process for the school building, proximity to the transportation network, energy and resources should be taken into account. Energy and resource protection emphasized in the sustainable school design is important in terms of reducing the energy costs of the building.

3.2.1.2. Landscaping and Site Design

Elements to be used in sustainable school design are examined above. Besides these elements, other factors that constitute the environment of the building are also important. The LEED design manual for schools, examines the sustainability of the site in detail and emphasizes the following elements during the site selection and site design:

- Brownfield Redevelopment,
- Site Development: protecting or restoring habitat, maximizing open space,
- Stormwater Design,
- Heat Island Effect,

- Light Pollution Reduction,
- Site Master Plan [48].

Brownfield redevelopment includes rehabilitating damaged sites where development is complicated by environmental contamination and reducing pressure on undeveloped land.

Limiting disruption of natural hydrology by reducing impervious cover, increasing on-site infiltration, and managing stormwater runoff are essentials for stormwater and groundwater management.

In the US Environmental Agency Report, it is stated that “The term "heat island" describes built up areas that are hotter than nearby rural areas [49]”. An important spatial and temporal variation related to climate, topography, physical layout and short-term weather conditions characterize the phenomenon of the heat island [50]. In order to reduce heat island effect, limited or less heat absorbent pavements are used in the school sites.

For sustainable site master plan, all of the other subjects that are defined in LEED for Schools are considered. Besides all these, sustainable school campuses:

- Enrich the experience of everyone who uses them,
- Contribute to a less extreme hydrology,
- Support the soil biota without which no higher plants and animals can exist [45].

3.2.1.3. Orientation for Daylighting

Olgyay stated that “The total problem of orientation for buildings is composed of many factors such as local topography, the requirements of privacy, the pleasures of view, reduction of noise and the climatic factors of wind and solar radiation. But a large part of the architect’s task is to position of the building so as to take best advantage of the sun’s value for thermal effect, hygiene, and psychological effects [51]”.

When starting the sustainable school design, daylight design should be regarded by considering that the students are in the school at times when the sunlight is most intensive.

Successful daylighting requires integration of building shape, size, and orientation of openings, internal space planning, building envelope design, technicalities of glazing, shading, and detailing at windows and skylights [45]. Correct orientation of the classrooms provides a healthy and comfortable learning environment as well as minimizing artificial lighting and thus providing energy savings.

Fuchs and Zeumer stated that “Daylight is made up of direct and indirect components which differ considerably depending on the location. Daylight can be transmitted, absorbed, reflected, and refracted [41]”.

An appropriate orientation for a sustainable school is to locate the building with its long axis running east to west. This offers the longest potential window walls along the most easily controlled faces (north and south) [51]. Gelfand mentioned that “The advantage of the north and south faces is that the sun is highest at midday, and even the sunny side can be easily screened by overhangs that can be calibrated to shade windows in summer, when the sun is highest, while allowing the low winter sun to shine directly in, when its heat gain is welcome [45]”.

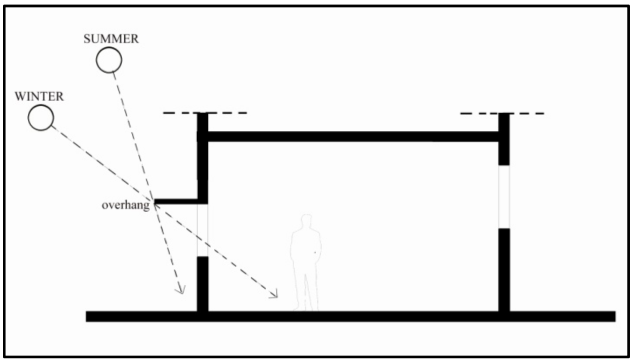


Figure 3.2. South side screening by overhangs [45]

In the composition of building facades, openings are also a major element. These apertures include windows, skylights, clerestory windows and borrowed light from other spaces as in the Figure 3.3.

Figure 3.3. The classrooms at Strawberry Vale Elementary school “borrow” light [52]

Also, some elements are parts of daylighting design, such as lightshelves used for reflecting direct sunlight onto the ceiling and protecting against direct sunlight directly adjacent to the façade; louvers, primarily as sunshades, used to redirect the incoming daylight, as shown in Figure 3.4.

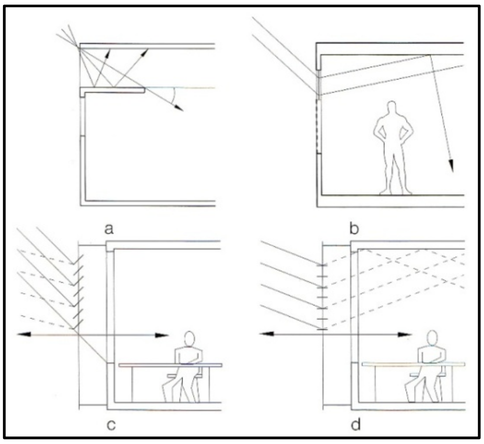


Figure 3.4. Using of lightshelves (a,b) and louvers(c,d) for daylighting [41]

There are most of the variations of school plan types such as single loaded bars (finger schools), double loaded bars (wing schools), courtyard schools, a variety of open plan or pod schools, radial panopticon schools, mall types, and multistory complex section school [45]. When the variations in the spatial configuration are taken into account, it could be seen that the principles of daylight use for all these plan types are also different.

As shown in the Figure 3.5., double loaded bars require different solutions on each side and a strategy for corridor lighting. Also, as seen in the Figure 3.6., courtyard schools need different daylighting solutions for all outer walls.

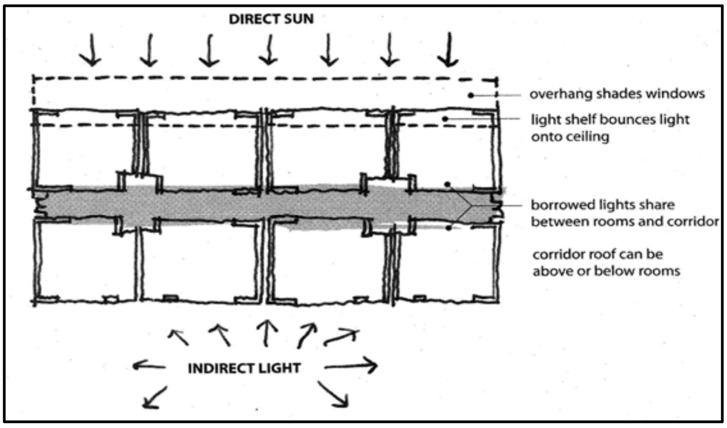


Figure 3.5. Double loaded bar plan type school's daylighting solution [45]

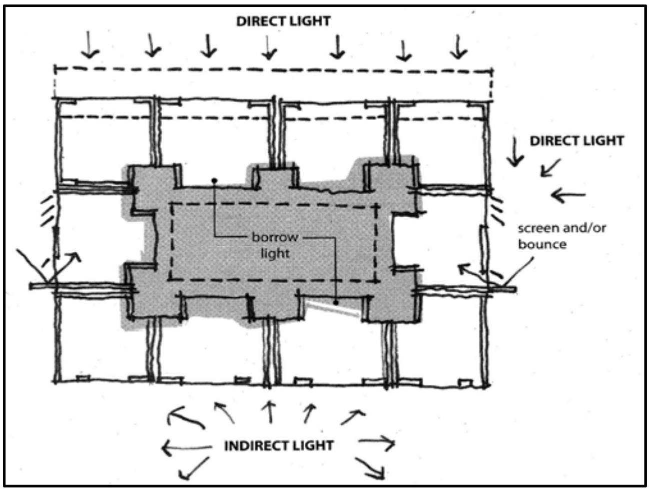


Figure 3.6. Courtyard school's daylighting solution [45]

Gelfand stated that "Solar building design and orientation principles help organize served and servant spaces to support functional efficiency but also to integrate a system of daylighting throughout a complex plan [45]".

3.2.1.4. Building Structure and Envelope

Concepts of flexibility and adaptability to changing external conditions have become part of building design. The sustainable building handles the tasks of insulating, excluding liquid water and managing water vapor in building skin; maintains a healthy mixture of gases, comfortable temperature and humidity by its mechanical and envelope systems that work together [45].

The building envelope systems, as fundamental component of a building, separate indoor and outdoor conditions. The envelope is also the most visible element of the building and responds to our appreciation of image, form, and orientation to the building. This interpretation sets in motion a large number of modulating functions of the envelope system - thermal, solar, acoustic, aerodynamic, and other forces- largely invisible to direct observation but highly significant to human occupation. Building envelope system is the major component of a building to control energy efficiency by various design applications [2].

As shown in the Figure 3.7., the energy subsystems of a building are the building envelope, the loadbearing structure and the technical services that have mutual effects on each other and can be linked in different ways [41].

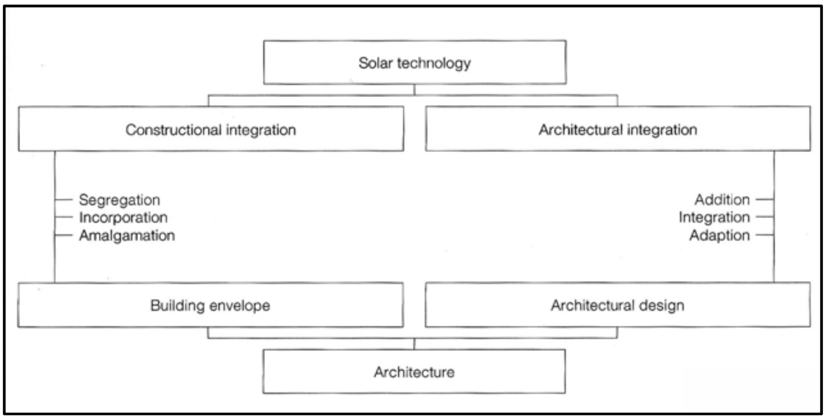


Figure 3.7. Building envelope and architectural design relationship [41]

For future developments in solar architecture, the architectural treatment of active solar components right up to the form of the building become especially important. In a new sustainable school design, it is necessary to integrate and adapt this active solar system to the building. Besides facilitating energy efficiency with active solar systems, the following sustainability criteria are important for the building envelope:

- Resource efficiency,
- Insulation,
- Weatherizing,
- Water and moisture control,
- Openings,
- Acoustics,
- Durability,
- Flexibility,
- Thermal comfort,
- Recyclability [45].

As the illustrated Figure 3.8., when the important concepts in the design of the building envelope of sustainable schools are examined as a whole, acoustics, resource efficiency and thermal comfort are ranked first. Other concepts and elements could be examined under these elements.

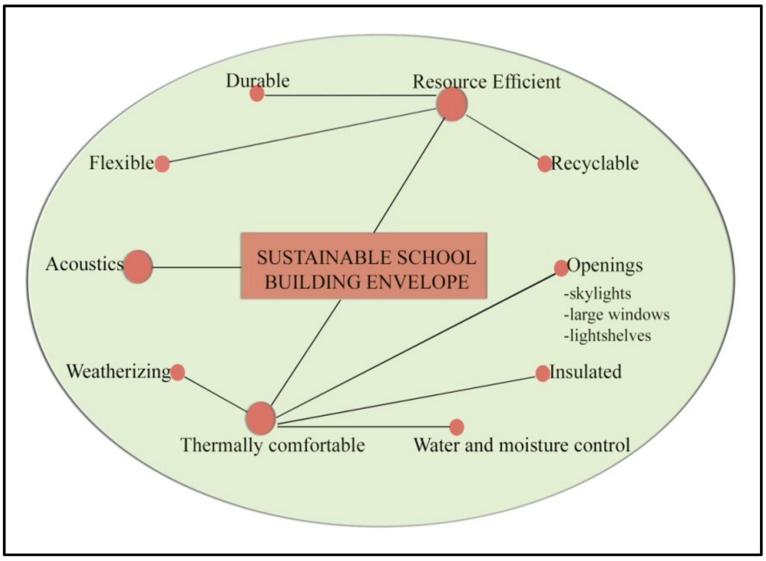


Figure 3.8. Sustainable building envelope design elements' relation diagram

3.2.1.5. Heating ,Ventilating, Cooling and Plumbing

In addition to keep occupants comfortable by using passive design strategies, important factors of designing a sustainable school building also include building services such as heating, ventilating, cooling and plumbing systems to provide comfortable learning environments. HVAC systems in educational buildings must meet performance criteria for thermal and acoustic comfort, indoor air quality and energy efficiency.

First, passive design methods should be used to deliver energy efficiency. One of these methods that reduce the use of HVAC equipment is providing natural ventilation. Natural ventilation necessitates the use of certain design methods and elements using the following natural ventilation types:

- Stack ventilation,
- Cross ventilation [34].

As shown in the Figure 3.9., stack ventilation functions according to the pressure difference that occurs as result of the rising hot air by absorbing the cold air coming from outside.

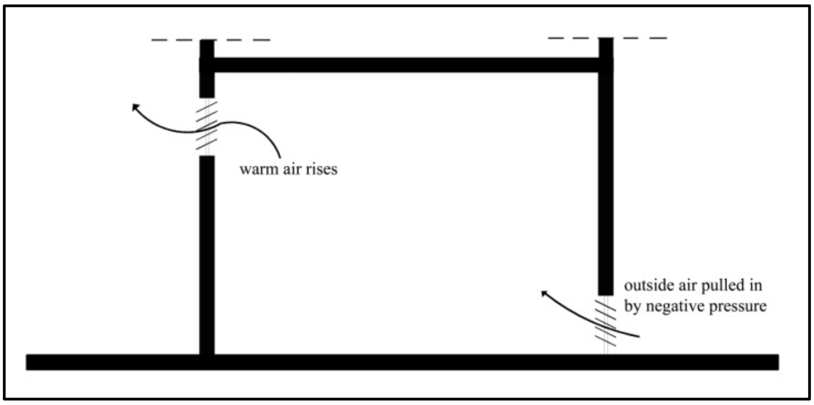


Figure 3.9. Working principle of stack ventilation [45]

As shown in the Figure 3.10., cross ventilation is based on the pressure difference created by the spaces on the cross surfaces.

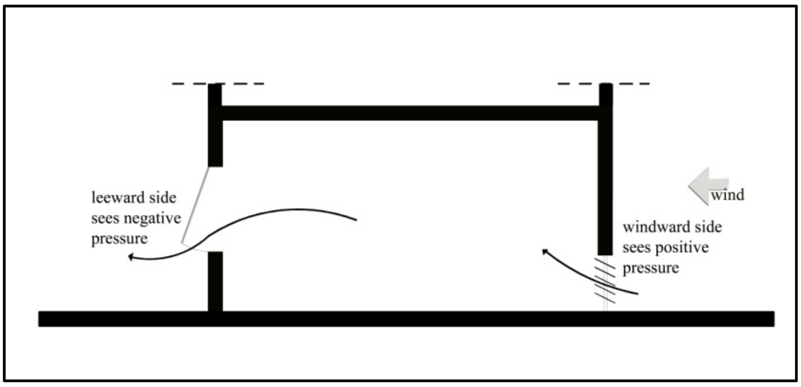


Figure 3.10. Working principle of cross ventilation [45]

As shown in the Figure 3.11., in addition to these natural ventilation principles, displacement ventilation based on pressure difference created via mechanical equipment is also another popular ventilation method.

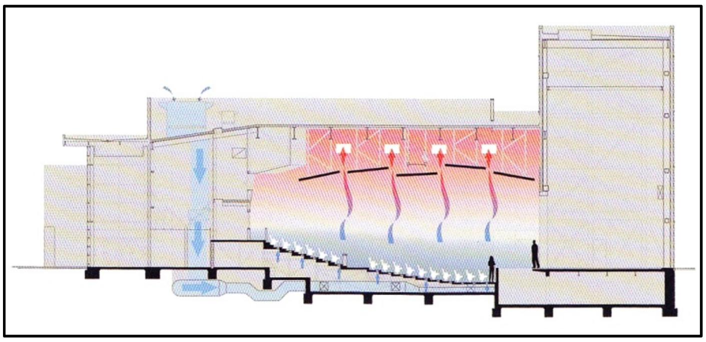


Figure 3.11. Ventilation principle used in Hector Godinez Fundamental High School [34]

Natural ventilation includes solar chimneys that provide a higher stack and a greater temperature difference. The chimney has glazing that faces the sun with a black or dark surface to increase heat. And there is a louver as in the Figure 3.12., on top of the stack lets the rising warm air out [45].

Figure 3.12. Solar chimneys in St. Leonardo's College, Sustainability Center [47]

HVAC equipment designed to provide energy efficiency in the sustainable building design should conform to certain criteria during the building life cycle. A proposed method for sustainable educational buildings emphasizes the necessity of meeting the following criteria:

- Handling issues related to the building design simultaneously,
- Making design decisions during the early stages,
- Design of an appropriate size HVAC system to enable the operation activity,
- Taking partial load performance into account during equipment selection,
- Reducing the electric loads produced at times of peak demand,
- Designing an HVAC system of appropriate size for the development,
- Establishing commissions for the inspection of HVAC systems,
- Development of operation and maintenance programs [53].

The use of certain high performance system equipment is needed to design mechanical systems that have all of these features. These high efficiency mechanical systems are based on complex calculations made during the sizing stages. By considering this issue, it is essential to emphasize the participation of the integrated design team to the design process.

3.2.1.6. Materials

McDonough and Braungart emphasized reducing, reusing, recycling, and regulating materials to help eco-effectiveness [54]. From this point of view, another important factor is the usage of building materials and resources that were rated highly in the sustainable building evaluation systems. Some of the specific materials and resources issues to be considered in the LEED for Schools Rating System are shown below:

- Building Reuse,
- Construction Waste Management,
- Materials Reuse,
- Recycled Content,
- Regional Materials,
- Renewable Materials [48].

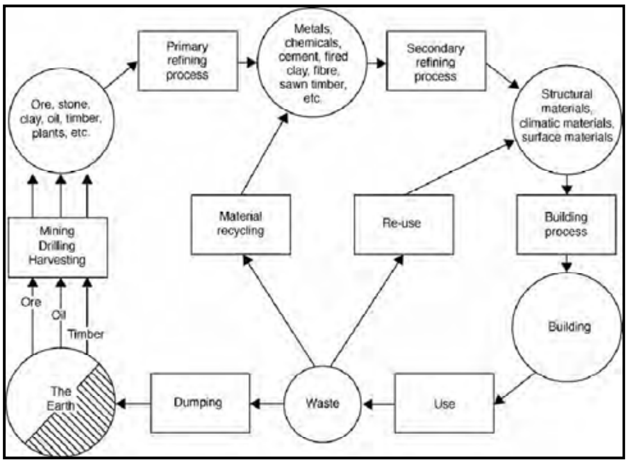


Figure 3.13. The cycle of materials [55]

There is three different phases while assessing the life cycle of building materials as pre construction phase, construction phase and post construction phase [56]. Berge stated "The embodied energy of a product includes the energy used to manufacture it all through the process of mining or harvesting the raw materials, refining, processing, and various stages of transport, to the finished product at the factory gate [55]". A major issue of sustainable building activities during the design and construction process is the usage of durable, long lasting materials with minimum impacts on the environment.

In the sustainable school design process, another issue that should be considered is the proximity of the material to the location where it is extracted and processed. Furthermore, the use of materials which threaten the users' health due to toxic gases is contrary to the sustainability criteria. In particular, material selection becomes much more important within educational buildings, whose users are young and spend much of their time within the building.

In sustainable schools, building material should be durable, renewable, reusable and non-toxic. Besides the use of building materials that do not threaten indoor air quality, finishing materials such as flooring, ceilings, wall coverings and paints should also meet all these criteria.

3.2.2. Examples of New Sustainable School Buildings

In this section, three examples of at which sustainable design principles are adopted, are examined with its plans, sections and elevations. Each of them has a special sustainability context. As the sustainable design principles are mentioned in the Section 3.2.1., the projects could be classified with the most significant feature of them as follows:

- Example 1. Primary school in Gando with passive design techniques
- Example 2. Benjamin Franklin Elementary School with its' site response
- Example 3. Nueva School Hillside Learning Complex with efficient technologies

Figure 3.14. Examples of New Sustainable School Buildings

3.2.2.1. Primary School in Gando, Boulgau

This Primary School is in Gando, with a population of 3,000, lies on the southern plains of a landlocked country Burkina Faso, in the West Africa as shown in the Figure 3.15. Architect Diébédo Francis Kéré from Burkino Faso, studied architecture in Berlin and made his first work for his village conceiving the idea of building a new village school to replace the decaying existing old one [57].

Figure 3.15. The map shows the region the school is located in

This project was the recipient of Aga Khan Award for Architecture in 2004. To achieve sustainability, the principles of designing for climatic comfort with low-cost construction, making the most of local materials and the potential of the local community, and adapting technology from the industrialized world in a simple way are the bases of the project. Basic tools such as floors that are beaten earth, natural ventilation, low tech construction and materials are used [47].

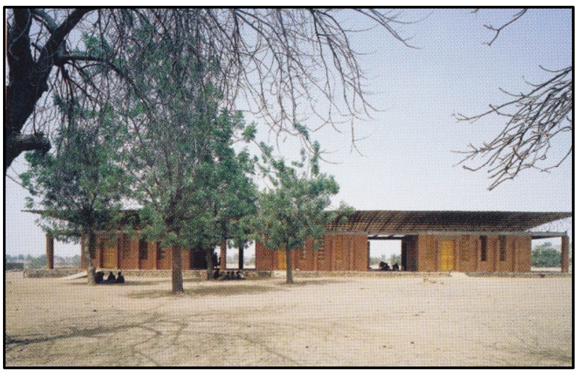


Figure 3.16. Overall view of the school [47]

Table 3.3. Fact sheet of Primary School in Gando

Sustainable School Example 2 – Gando Primary school		
Project	**Building Name**	Gando Primary school
	City	Gando, Boulgau, Burkino Faso
	Program	3 classrooms.
Team	**Architect**	Diébédo Francis Kéré
	Consultants	Issa Moné, technical officer, LOCOMAT, Burkina Faso, training in brick production
	Craftsmen	Sanfo Saidou ('Baba') and Oussmane Moné, master masons; Minoungou Saidou, welder. (All from Burkina Faso)
	Sponsors	Schulbausteine für Gando e.V. - Bricks for a School in Gando Association, Germany.
General	**Time -Line**	First school completed in July 2001. The second school completed in 2006
	Area	30,000 m² - built area: 500 m²
	Cost	First school- £16,500
	Plan	School building is designed to replace the old school that has fallen into disuse
Site	**Site description**	Gando, with a population of 3,000, lies on the southern plains of Burkina Faso, some 200 kilometres from Ouagadougou, the capital.
	Parking, cars	-
Structure	**Vertical Members**	The structure comprises traditional load-bearing walls made from stabilized and compressed earth blocks.
	Horizontal Spans	Concrete beams run across the width of the ceiling, and steel bars lying across these support a ceiling also of compressed earth blocks
Envelope	**Glass and glazing**	No glass. Steel window shutters made by local materials
	Cladding	Walls are from traditional earth blocks.
	Roof	Steel bars were used to create lightweight trusses, with corrugated metal sheeting laid on top to form the roof
HVAC	**Equipment**	-
	Special features	Principles of designing for climatic comfort are used. Natural ventilation. Cooling breezes circulate through the shutters and hot air drawn up through the ceiling.
Interior	**Finishes**	Local materials which are low-tech are used.
	Lighting	Without electricity, environmental control relies on traditional, passive techniques.

The building's form and materials were largely determined by climatic considerations. The building aligned from east to west in a linear fashion, three classrooms are arranged and separated by covered outdoor areas that can be used for teaching and play. The structure comprises traditional load-bearing walls made from stabilized and compressed clay blocks where concrete beams run across the width of the ceiling, and steel bars lying across [58].

This first Gando school was such a success that it became oversubscribed; so Kéré constructed a second building, which opened at the start of the year 2009, has 4 classrooms and a sandpit open area. And also he proposed a library near this new school as seen in the Figure 3.17. [57].

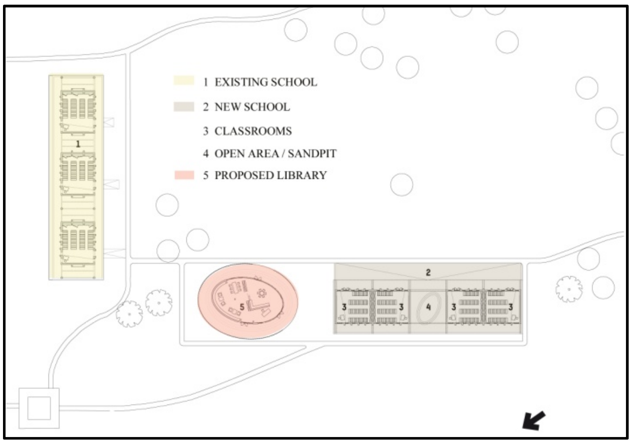


Figure 3.17. Site plan of Gando Primary School [57]

At each two schools, the new one and the other, the roof technique is the same. Overhanging roof ensures climatic comfort and shades the façades. It was not economical to transport large elements to the site from afar using lifting machinery such as cranes. Instead, native people of the village are taught to use a handsaw and a small welding machine to construct the roof where steel bars were used to create lightweight trusses, with corrugated metal sheeting laid on top form [58]. As it can be seen in the Figure 3.18., in the first built school, the roof cover sits on a terrace ceiling, in the second built school the roof cover sits on a vault ceiling.

Figure 3.18. Differences between the roof form. At the right second built school [57] at the left first built school [59]

Environmental control relies on traditional passive techniques without electricity. Thermal mass is provided by heavy walls. Cooling breezes circulate through the shutters and hot air is drawn up through the ceiling with stack effect at the second built school as in the figure 3.19.

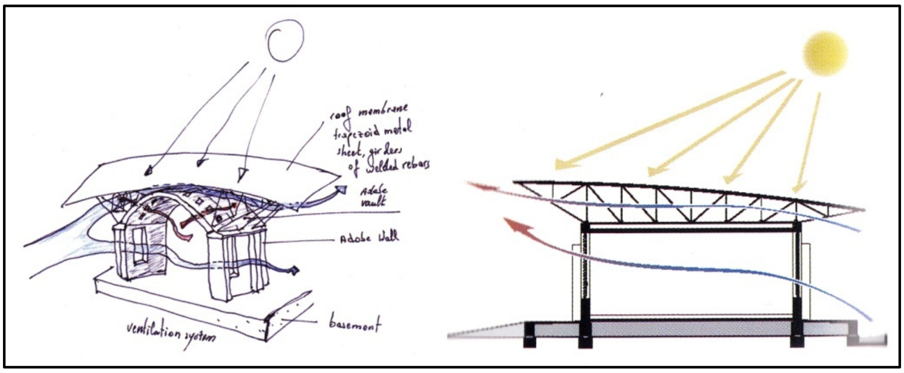


Figure 3.19. Principles of environmental control. First built school section at the right [47], second built school sketch at the left [57]

A school project did not raise such high expectations before. These school buildings are good examples of enabling sustainability only respecting regional climatic conditions with using passive design technologies. Neither solar panels or PV panels nor mechanical systems were used to provide energy efficiency.

Figure 3.20. New Gando school on the front [57]

3.2.2.2. Benjamin Franklin Elementary School, Washington

The new Benjamin Franklin Elementary School replaced an existing facility on a narrow 4 hectare site oriented north-south; was designed to connect students directly with the environment. The residential neighborhood surrounds with horse paddocks, equestrian trails and forested lands.

Figure 3.21. South courtyard with native plants and adjacent classroom cluster [47]

The school's two central courtyards are open to the natural environment. Direct connections to this native landscape, elements of the region's unique hydrologic process provide outdoor learning environments to students as shown in the Figure 3.22.

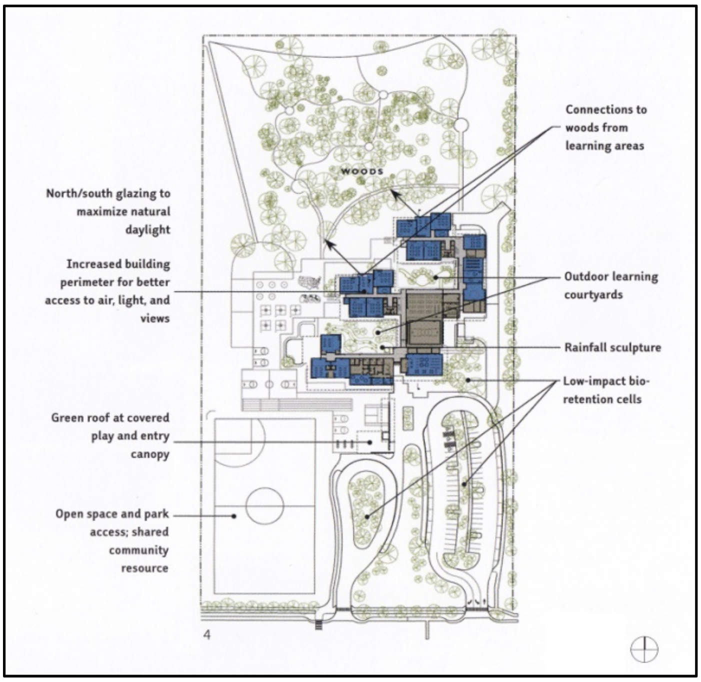


Figure 3.22. Site plan of Benjamin Franklin Elementary School [47]

Table 3.4. Fact sheet of Benjamin Franklin Elementary School [1]

Sustainable School Example 4 – Benjamin Franklin Elementary School		
Project	**Building Name**	Benjamin Franklin Elementary School
	Location	Kirkland, Washington, USA
	Program	Library, administration, kindergarten, early childhood, gymnasium, commons, classroom, activity area, food service, music, resource, technology, science,art
Team	**Architects**	Mahlum Architects
	Services	Mechanical: Stantec, Electrical:Coffman Engineers, Civil/Structural Engineer: Coughlin Porter Lundeen
	Contractors	SpeeWest Construction
General	**Time -Line**	Completed August 2005
	Area	5,280 m2
	Plan	The school's two-story classroom wings reach toward the site's large wooded area and visually connect students with nature
Site	**Site description**	There is a large wooded area near the site.
	Parking, cars	Open car parking area
Envelope	**Glass and glazing**	Operable windows, major glazing on the north and south
	Cladding	Cement board siding
	Roof	Prefabricated roof with steel trusses
HVAC	**Special features**	HVAC performance is 35% better than state energy code
Interior	**Finishes**	Durable, non-toxic, low impact finish materials including low VOC paint, rubber resilient flooring, wool tackable wall coverings,
	Lighting	Automatic dimming adjusts light levels in classrooms to maximize energy efficiency

Southern courtyard's functional ecosystem makes natural processes visible. This outdoor learning environment provides educators with a 3-dimensional, 'hands-in-the-dirt' laboratory fostering understanding through observation. A water feature fed by rain collected from the roof and integrated art installations enhance the experience.

Figure 3.23. Classroom cluster from outdoor play area [47]

450 students in grades K-6 are distributed within small learning communities formed by clusters of four naturally ventilated and daylight classrooms around a multipurpose activity area. Stacked within two-story wings that extend toward the woods, these communities are integrally linked with views and access to nature beyond. [47]

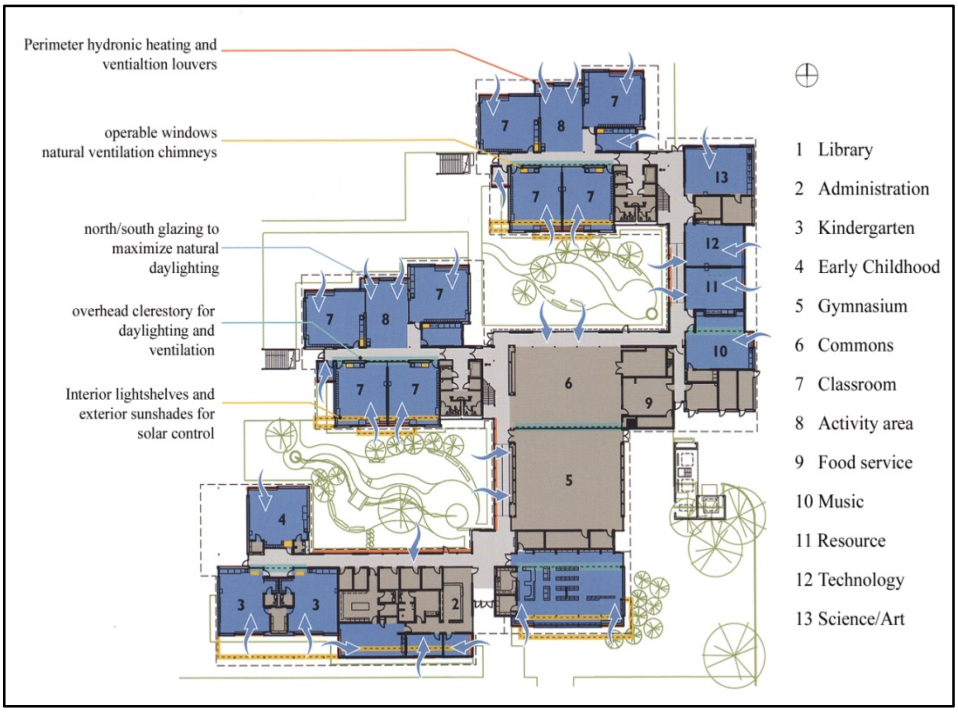


Figure 3.24. First floor plan [47]

Including indoor environmental quality, environmental connections, land use and site ecology, water and energy conservation, and appropriate material use; the new school expands learning by connecting the district's educational pedagogy with environmental sustainability at every level. Non-toxic, recycled and low-impact materials are used in the building.

Daylight and indoor air quality give the profound impact on student performance. In order to reach the goal of 100% natural ventilation and daylight in all teaching spaces, rigorous daylight and thermal modeling were used. Energy analysis of building envelope and HVAC systems confirms that the school design would perform 35% better than the state energy code.

Natural ventilation in classrooms utilizes “chimneys” for a natural stack effect. These chimneys draw fresh air through low-level perimeter windows and louvers and vent it at high level by the help of thermal buoyancy and pressure differentials. Whole-building natural-ventilation design techniques were employed to allow for passive cooling throughout the building during occupied seasons, affecting building orientation, windows, shading, construction materials, daylighting, and ventilation openings. In heating mode, before it is introduced into the classroom spaces, the air passes over fin-tube water heating elements located at the perimeter louvers. Windows are oriented to maximize daylight and shading devices control glare.

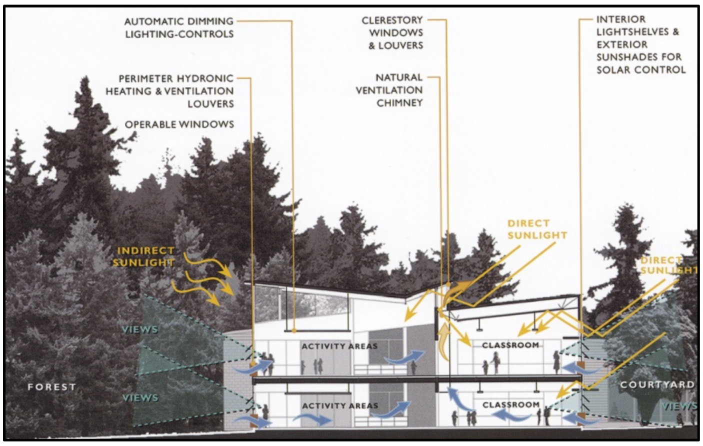


Figure 3.25. Typified Classroom cluster building section [47]

In the building, all spaces benefit from exposure to daylight and natural ventilation though the building's articulated footprint and roof form as seen in the Figure 3.25. Also the building skin provides a high-performance envelope with the insulation materials on walls and on roof.

Anticipating local, state and even national mandates for more sustainable buildings, Franklin Elementary School will be model for future development in the district. Also, the school district is committed to understand the effects of high performance buildings on student test results, staff retention, energy savings and true total cost of ownership. In the end, the school’s educational program not only celebrates current high performance building practices, but also focuses on inspiring and educating generations of students toward a sustainable approach to living [60].

3.2.2.3. Nueva School Hillside Learning Complex (Nueva School), Hillsborough

Nueva school is an additional building, designed in an existing campus that already includes a gymnasium, a middle school and a lower school in suburban Hillsborough, California. But the project had been seen more than just an addition which was as an opportunity to create a front door and a town square for the school that serves 400 high-achieving children from prekindergarten through eighth grade. The Hillside Learning Complex replaced a parking lot on Nueva's 33-acre campus with new structures designed to protect and enhance the native ecosystem.

Figure 3.26. General view of the Nueva School [61]

The concept design was the winner of an invited design competition in the region. A detailed analysis of the site microclimate and ecologies were undertaken by the design team to confirm the concept design organization. For the glazing selection, exterior shading, envelope construction, plug loads, lighting, domestic water heating, and mechanical systems with an eye for efficiency, economy, aesthetics, and long-term durability were the project modeled at every design stages.

To determine the key project milestones, the project team held focused design discussions involving students and faculty members. The spaces were designed to offer inviting, healthy, and flexible places to learn, fostering community and creative interaction at many scales [62].

Table 3.5. Fact sheet of Nueva School Hillside Learning Complex [62]

Sustainable School Example 5 – Nueva School Hillside Learning Complex (Nueva School)		
Project	**Building Name**	Nueva School Hillside Learning Complex (Nueva School)
	Location	Hillsborough, CA
	Program	Indoor Spaces: Classroom (53%), Cafeteria (12%), Structured parking (9%), Circulation (8%), Mechanical systems (7%), Restrooms (5%), Office (5%) Outdoor Spaces: Wildlife habitat (57%), Patio/hardscape (25%), Parking (7%), Garden—decorative (5%), Drives/roadway (4%)
Team	**Architects**	Leddy Maytum Stacy Architects
	Engineers	Forell/Elsesser Engineers (structural), Rumsey Engineers (mechanical and plumbing), Integrated Design Associates (electrical), BKF Engineers (civil), Charles M. Salter Associates (acoustical)
General	**Time -Line**	Completed September 2007
	Area	2,510 m²
	Plan	Suburban setting, 3 2-story buildings
	Cost	$16 Million, The project was funded by donations from the school community
Site	**Site description**	Site buildings so as to help occupants celebrate the natural beauty. The project team carefully preserved majestic native oak trees and nonnative cypress trees, and new landscaped open space covers 123% as much area as the building footprint.
	Parking, cars	Limit parking area
Envelope	**Glass and glazing**	Glazing with a low Solar Heat Gain Coefficient, large exterior windows and high ceilings to increase the benefit from daylight,
	Cladding	Concrete walls with wooden exterior shading devices.
	Roof	green roof
HVAC	**Special features**	Operable windows, fans and passive turbine ventilators allow 85% of the project to be naturally ventilated and cooled.
Interior	**Finishes**	Natural Linoleum Flooring, NSF 140-2007e Platinum-Certified Carpet Tiles, Recycled-Cotton Insulation, Structural Steel Framing, Zero-VOC and Low-VOC Interior Paints
	Lighting	A 30-kW photovoltaic array located on the classroom building roof provides about 24% of the project's site energy needs

By addressing many issues common to the region and beyond, including energy-efficiency, greenhouse gas reduction, water conservation, biodiversity preservation, and resource efficiency, the design connects to the regional community. The school provides a bus service that is used by approximately half of the students; with the nearest public transit stop more than two miles away. Carpooling is encouraged by the school, which is the primary transportation alternative to the school bus. Also 32 parking spaces were required, a 16% reduction from the original parking provided on the site. The urban heat-island effect is reduced through the use of green roofs, covered parking, and high-albedo paving with the contribution of the project.

Designing development to have pedestrian emphasis rather than automobile emphasis, providing vehicle access to support car and vanpooling, providing incentives for non-automobile commuting options, selecting already-developed sites for new development were considered as green strategies of the land use.

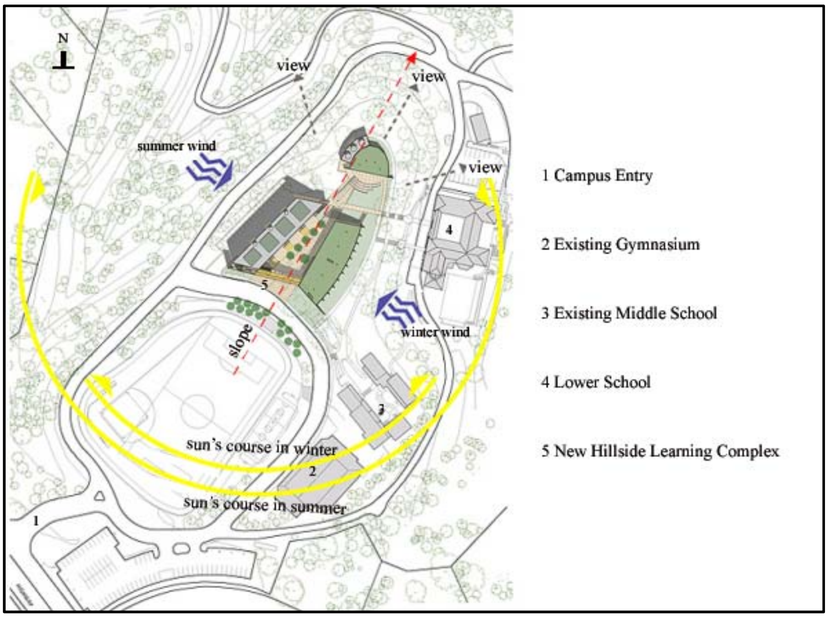


Figure 3.27. Site plan of the Nueva School [61]

Majestic native oak trees and nonnative cypress trees were carefully preserved in the area. Building materials and colors from the materials of the site were derived, reinforcing a visceral connection to the land. Site drainage is reduced by a stormwater management plan to a practical minimum.

The Hillside Learning Complex includes three buildings—a library and media center, a student center, and a classroom building with administrative offices, seven classrooms, and an R&D lab—which are organized around a central plaza as shown in the Figure 3.27. The classroom building serves only the fifth through eighth grades. The student center serves lunch to the same group. The library serves the entire school.

Figure 3.28. Aerial view of the Nueva School [63]

Figure 3.29. First floor plan of the Nueva School [61]

Peak storm flows are reduced by about 3048 m² of green roof area on the library and student center. As in the Figure 3.30., the library roof drains into a bioswale bordering the eastern edge of the library. Expressive of the semiarid climate, a constructed "arroyo" in the central plaza dramatically comes to life during rainstorms, directing stormwater from the classroom building roof to retention and dispersion areas below.

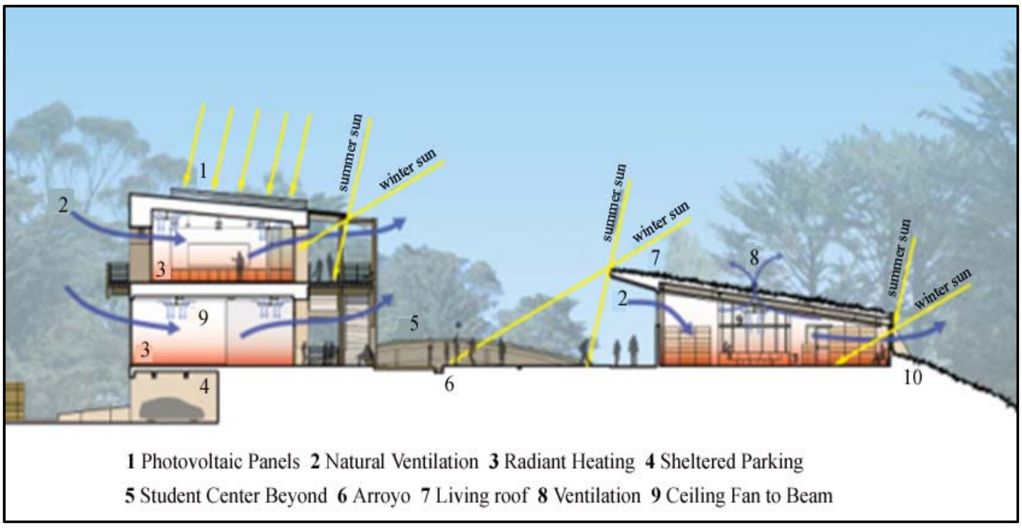


Figure 3.30. Section shows daylighting principles of the Nueva School [63]

The building orientation balances design responses to the mild climate, topography, and place-making, optimizing the benefits of outdoor living, daylighting, and natural ventilation. The buildings conform to the natural topography while also being oriented to the sun and the northwest breezes that dominate during the warmest months.

The one-story library and student center are designed to lay low in the land, maximizing solar access to the central plaza while reducing exposure to the southeast sun and winter winds. The two-story classroom building's roof form optimizes access to daylight, wind, and views as well as solar access for the rooftop photovoltaic array. This photovoltaic array located on the classroom building roof provides about 24% of the project's site energy needs.

Also the classroom building's exterior corridors provide sun control and protection from winter storms. As an enclosed "band shell", the south-facing student center completely opened to the outdoors in warm weather, eliminating the need for extensive exterior shading.

The building materials are selected for economy, durability, and resource efficiency. Nonnative cypress trees removed from the site to make room for construction were reused on the buildings as screens, benches, and decks [62].

Figure 3.31. Sections [62]

This school building uses 65% less energy and 50% less water than a typified new school facility in the U.S. The environmental features of the whole school building provided the opportunity to earn a LEED Gold rating from the U.S. Green Building Council.

Figure 3.32. Sunshades on different facades [64]

3.2.3. Sustainable Design Principles for Existing School Buildings

If the fact, that 50% of total global energy consumption is associated with buildings is taken into account, it is inevitable that sustainable design interventions for the efficient use of energy in the existing building stock will substantially reduce this consumption.

The relationship between existing buildings and the sustainability concept is addressed in Section 2.1.3.2. According to this, the main criteria for the sustainability of an existing building are determined as: providing more natural ventilation and lighting, reducing the use of non-renewable resources, providing a healthier and participatory environment, and sustainable refurbishment and adaptation of the buildings.

Sustainable design interventions to existing school buildings are appropriate both for improving academic performance and environmental awareness of future generations and for reducing energy costs, due to the high energy consumption within school buildings in the existing building stock.

Green modernization is even more sustainable than constructing new schools. The "reduce, reuse, recycle" mantra of the environmental movement is applied directly to the green modernization and expansion of existing schools [34]. The benefits of green modernization and expansion of existing schools are as follows:

- By modernizing existing buildings or expanding on an already developed property rather than using a greenfield site, a school district reduces its development footprint.
- Green modernization is also more cost-effective than new-build.
- Green modernization allows the school district to reuse existing school facilities and also some of the school's existing furnishings in new and sustainable ways.
- Expansion projects generate less waste than new construction, and demolition waste may be reused on site [34].

Sustainable modernization of existing buildings has advantages such reduced long-term costs and increased academic performance, exam grades and learning capabilities of the students.

To integrate sustainable design principles to existing schools, a cooperative planning, design and construction process is necessary, as for new-build projects. To provide this, an integrated design team should be constituted. This integrated design team handles the building and its surrounding area again under the following elements:

- Sustainable sites
- Water efficiency
- Energy & atmosphere
- Materials & resources
- Indoor environmental quality [48].

3.2.3.1. Sustainable Sites

First of all, interventions to the site are evaluated by examining the existing school campus and the education program. As mentioned in Section 3.2.1.1., outdoor spaces and firm soils are handled in line with the principles determined for new building design. Major criteria needed for this are:

- Reducing the heat island effect of the material used in the firm soil,
- Designing the site as a tool that teaches sustainability,
- Designing in accordance with the habitat.

Sustainable sites are evaluated under the subjects of:

- Building exterior and hardscape management plan,
- Integrated pest management, erosion control, and landscape management plan,
- Alternative commuting transportation,
- Stormwater quantity control [48].

In order to protect students, teachers, maintenance technicians, and other staff the integrated pest management, erosion control and landscape management is intended by reducing harmful chemical use, energy and water waste, air pollution, solid waste, and chemical run-off such as gasoline, oil and salt at the school sites. Alternative commuting transportation such as carpooling, use of public transportation, walking, bicycling, operating fuel efficient vehicles or implementing compressed work week schedules may be encouraged for sustainable sites. Stormwater quantity control is another part of sustainable sites. By improving stormwater management strategies, stormwater runoff decreases [48].

Replacing asphalt parking, roadway, and sidewalk surfaces with permeable paving supports both stormwater management and groundwater recharge. Bioswales in parking lots and around the buildings help to both cleanse and reduce stormwater runoff [34].

3.2.3.2. Water Efficiency

Improved water management in existing schools reduces the energy costs substantially. Besides landscaping interventions to the site, using more efficient plumbing systems within existing building also reduce these costs.

Dorsey and L'Esperance stated that in order to conserve both water and energy to the extent possible, the following steps are applied to the sustainable design process:

- Minimize the amount of water required to operate the school both indoors and outside.
- Evaluate the various water uses, distinguishing those that can be performed using raw (untreated) water, versus functions requiring treated water.
- Evaluate methods for providing the required raw water supply using on site resources [33].

Water conserving plumbing fixtures can save tens of thousands of gallons of potable water. Water consumption and costs are greatly reduced by replacing the existing landscaping with drought-tolerant mostly native plants. Also installing water conserving irrigation systems that uses gray water recycled from on site help lower water consumption and costs [34].

Potable water use for irrigation is reduced or eliminated and cut in the sustainable school buildings. By using gray water or roof water or waterless urinals, the huge quantities of potable water going down toilet and urinal drains can be reduced. Also, visible collection of rainwater and its ultimate use to water gardens can be the part of the sustainable curriculum [45].

3.2.3.3. Energy & Atmosphere

Improving energy efficiency within existing school buildings is the most important step in terms of sustainability. The following criteria should be examined in the design to provide energy efficiency.

Insulation is a simple and vital means of conserving energy. In schools, such as soybean based insulation or cotton insulation that do not have toxins leak into the indoor environment could be used. A green roof also reduces the rooftop heat island effect while reducing building's air conditioning requirements and lowering energy consumption [34].

If the HVAC system in the existing building is not energy efficient, then the system needs to be renewed. Moreover, a shift may be required from non-renewable energy resources to renewable.

The integration of photovoltaic systems is a common practice used in existing buildings, as it provides electrical energy production. In these systems, when the building is, in principle, planned without the use of solar technology; "addition" stands for a design attitude, as shown in the figure 3.33. "When adding any solar technology, the architectural and geometrical configuration of the building is ignored. The building is merely a supporting structure for the solar technology [41]."

Figure 3.33. PV panel integration on rooftop [65]

Lighting systems used in existing school buildings should be supported by movement or ambient light sensors, so that they can be used in an energy efficient way. Also, in spaces with insufficient natural lighting, interventions such as use of clerestories or the expansion of the openings, reduce lighting costs.

As for the building façade replacing inefficient glass with high-performance glazed windows lets in natural daylight while keeping out solar heat. Adding external sunshades prevents interior spaces against overheating [34]. To reduce the energy costs of the existing schools, the abovementioned interventions might be applied.

3.2.3.4. Materials & Resources

By using a wide variety of green building materials that promote a healthy indoor environment and have minimal negative impact on the world's natural resources, the project team can significantly enhance a school's sustainability [34]. Besides the replacement of building materials in existing school buildings with sustainable materials, recycling of existing materials is also important. While replacing materials, the materials' end life should be taken into consideration.

It is important to use healthier, natural, rapidly renewable and green building materials, particularly low and zero VOC paints, sealants, glues, finishes, and furnishings which will help improve indoor air quality.

3.2.3.5. Indoor Environmental Quality

Aside from lack of hygiene for ventilation systems, or insufficient ventilation in general, there are other factors responsible from indoor environmental quality as, high emission levels of health damaging and stench-intensive materials from the components [66].

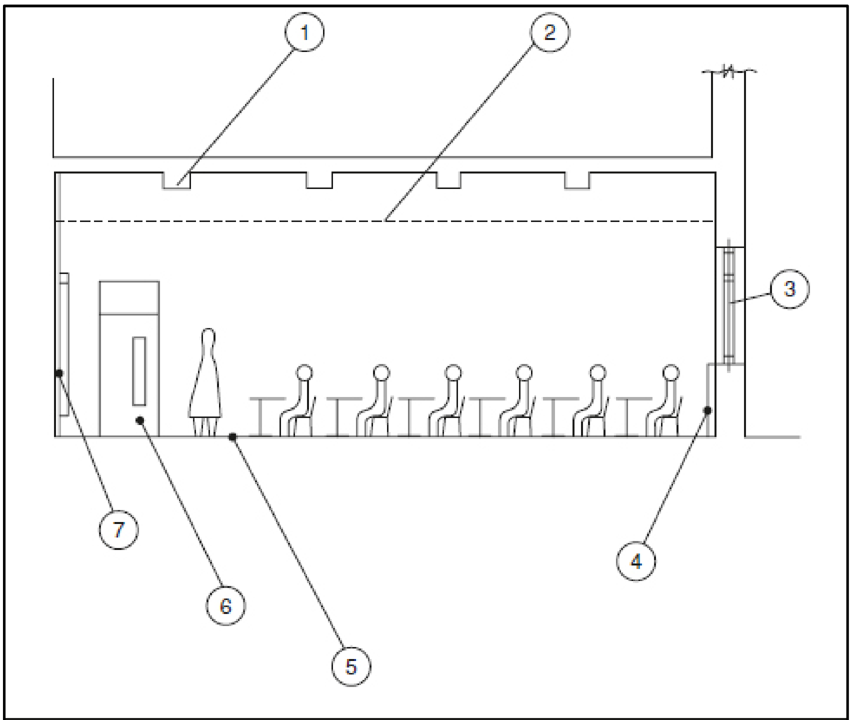
The subjects related with indoor environmental quality are:

- Indoor Air Quality,
- Emissions from Building Components and Furniture,
- Hygienic Requirement for Air Exchange [66]. Depending on this, Gelfand states that:

> "Indoor air quality is tied to the materials in the room, maintenance procedures, and ventilation. An integrated approach to specifying low vocatile organic and nontoxic compounds, no added formaldehyde and appropriate airing or flushing procedures before occupancy can turn over a building with good air quality from the beginning [45]".

Attention to the selection of building materials in existing buildings ensures high quality indoor air. Previous researches indicate that healthy environments increase the academic performance of students. To provide another high quality indoor air, an important factor is the usage of ventilation systems that regard hygiene conditions.

Also it is possible to say that heating, ventilating and air conditioning systems that are examined in the Section 3.2.1.5., are also notable for existing school buildings' indoor air quality.



Notes
1. Existing uneven ceiling surfaces can deflect sound, causing acoustic 'dead zones'.
2. New suspended ceiling can reflect sound more efficiently to avoid occurrence of 'dead zones'.
3. New double glazing for acoustic as well as thermal efficiency. Low-emissivity glass used.
4. New radiators for more efficient heating.
5. Cushioned sheet vinyl or short-piled carpeting for acoustic and anti-static qualities.
6. Self-closing entrance door with lower viewing panel glazed Georgian wired glass.
7. Acoustic panels on walls.

Figure 3.34. Refurbishment works to a typified school classroom [38]

When the sustainable design principles of existing school buildings are examined, integration of these principles to classes where students spend most of their time provides a typified classroom adaptation as in the Figure 3.34.

3.3.4. An Example of Sustainable Renovation of an Existing School Building

In this chapter, an example of sustainable renovation of an existing school building is examined. When the sustainable school examples were examined, it was seen that it is possible to find more information about new school buildings. But data on sustainable refurbishment of school buildings are limited and only for reduction of energy costs in general. So in this section, an example which has a sustainable adaptation including both sustainable practices and energy reduction is examined in detail.

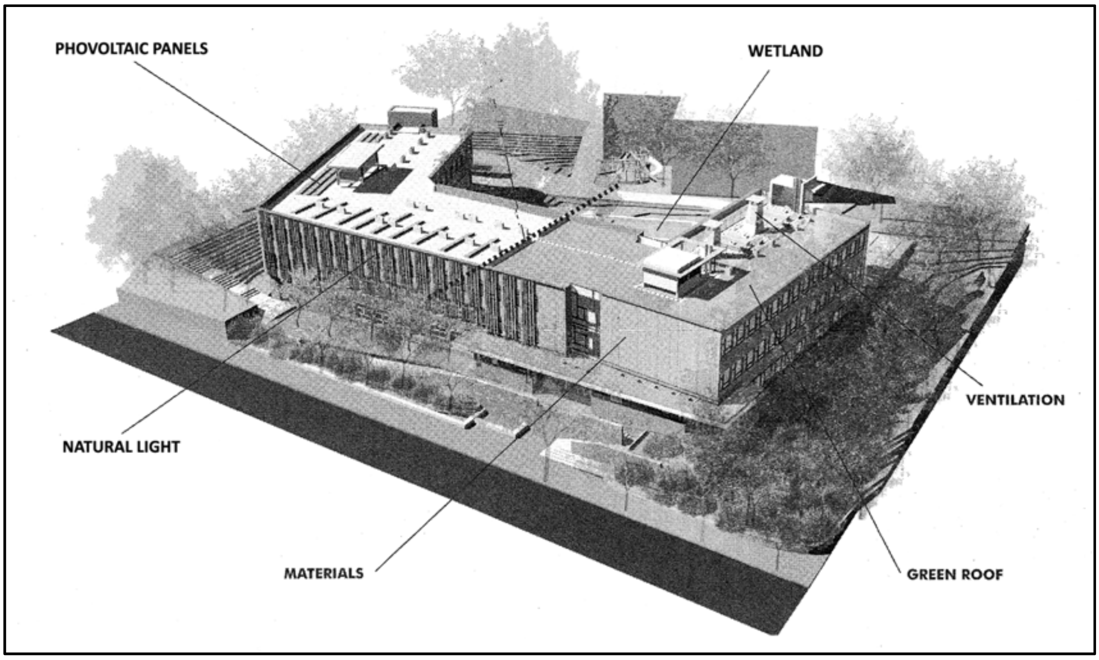


Figure 3.35. Sustainable adaptation of Sidwell Friends Middle School [45]

3.2.4.1. Sidwell Friends Middle School, Washington

The Middle School Building is the first K-12 school in the United States to have a LEED Platinum rating and the first LEED Platinum building in the District of Columbia. The landscape as a unifying context within which existing buildings and strategically sited additions form a purposeful and articulate whole is the focus point on re-establishing by development.

Figure 3.36. General view of the school [34]

By the existing school building renovation a new school building was designed as an addition to this building. In the design process of the new school building, the river basin in which the campus is situated was assumed as an ecological value and constituted the start point of the design. In this way, water management was addressed, primarily by the architect William McDonough and the educator David Orr, and an idea of designing a green building was generated.

The Middle School demonstrates that the sun is the primary source of energy and a renewable source through siting, orientation and reliance on natural lighting. Saving energy is the fundamental principle of the building renovation. The new Middle School uses 45% of the non-renewable energy that would be used by a normative building of the same size and in the same location and orientation.

Table 3.6. Fact sheet of Sidwell Friends School

Sustainable School Example 1 - Fact Sheet		
Project	**Building Name**	Sidwell Friends Middle School
	City	Washington, DC, USA
	Program	classrooms, library, art/music rooms, science labs, constructed wetland, rooftop container garden
Team	**Architect**	KieranTimberlake Associates
	Structure	CVM Engineers
	Services	Bruce E. Brooks & Associates
	Sustainability Consultants	GreenShape LLC (both projects) and Integrative Design Collaborative (Middle School only)
General	**Time -Line**	Completed in September 2006
	Floor Area	6,736 m²
	Cost	$28.5 million
	Plan	The old and new building wings meet to form a U-shaped courtyard
Site	**Site description**	Campus sits atop two watersheds, both of significant ecological value. Main areas at the site are existing middle school, middle school addition with green roof, trickle filter area, wetlands, rain garden, pond, outdoor classroom, meadow, woodland screen and play equipment area.
	Parking, cars	Parking is available in an underground lot, Bicycle storage and showers are available
Envelope	**Glass and glazing**	North windows are unscreened, screens at south windows are horizontal, screens at east and west are vertical
	Cladding	Exterior wood cladding was fabricated off-site to minimize site impact and embodied energy.
	Roof	Green roof with skylights and solar chimneys.
HVAC	**Equipment**	HVAC economizer, variable speed fans and pumps, high efficiency boilers and chillers, solar chimneys
	Special features	demand-controlled ventilation, passive and mechanically assisted ventilation, solar chimneys reduce the need for supplemental energy for heating and cooling
Interior	**Finishes**	Recycled, rapidly renewable and locally produced materials such as gypsum, linoleum, bamboo and agrofiber board are used as finishes; greenheart timber used for wood flooring; paints, carpets and adhesives are selected for low emissions of volatile organic compounds.
	Lighting	Photovoltaic panels generate %5 of the building's total electrical load, vertical sunscreens are oriented to balance thermal performance with daylighting, energy performance is optimized with daylighting and occupancy control.

Reclaimed materials include exterior cladding, flooring and decking, and the stone used for landscaping. Interior finishes were selected for their high levels of recycled content, low chemical emissions, and use of rapidly renewable materials [63].

The building was located within walking distance of a subway stop and several bus stops. Bicycle storage and showers are available and parking is available in an underground lot allowing the school to showcase more than 80 native species of plants instead of parked cars [67].

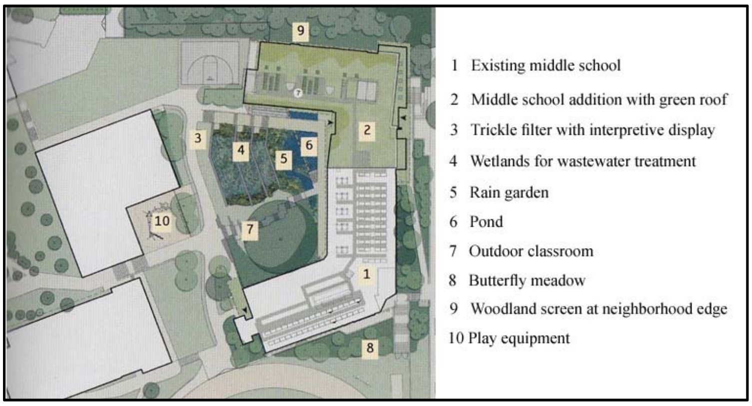


Figure 3.37. Site plan of Sidwell Friends Middle School [34]

In the campus, U-shaped courtyard is formed by the old and new wings that are connected one another with a spacious lobby and administrative offices in the primary entrance. Conventional classrooms are retained within the original building, while the new wing offers science labs, art studios, and other special-purpose rooms [68].

Figure 3.38. Reclaimed wood cladding was fabricated off-site in large sections [65]

The building is a compass, revealing orientation through the configuration of exterior sunscreens with the reclaimed wood cladding. North windows are unscreened, screens at south windows are horizontal; screens at the east and west windows are vertical. To minimize site impact and the embodied energy of on-site fabrication, the wood cladding was fabricated off-site in large sections [47].

Figure 3.39. View from southwest overlooking wetlands courtyard [65]

Housing a central energy plant in the basement of the addition, recycles building waste water on site for gray water used in the building; allows greater control of energy resources and provides a demonstration of responsible energy use to students. Green roof vegetation holds and filters rainwater, gutter and downspot direct water to a biology pond. This plant uses extremely-high-efficiency pulse boilers and modular chillers sized to take advantage of diversity factors in supplying other campus buildings [65].

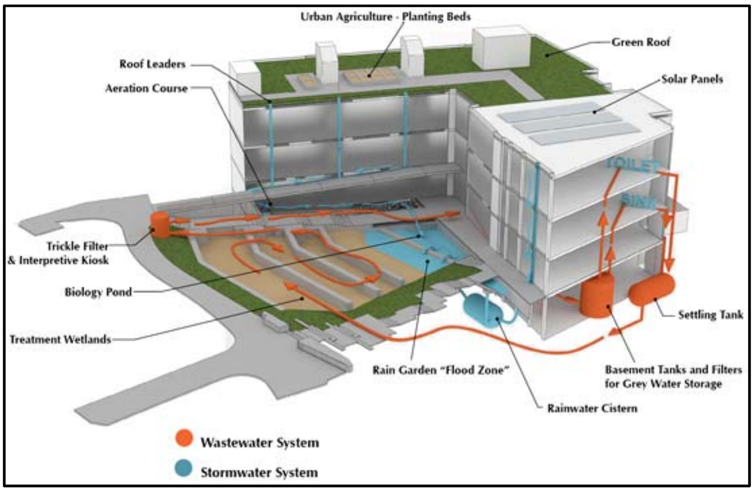


Figure 3.40. The wetland machine of Sidwell Friends School [68]

In the building, mechanically assisted natural ventilation is used to minimize the need for artificial cooling. In the new building, classrooms are oriented to optimize natural lighting. To reduce energy consumption, photovoltaic panels and solar thermal technologies are used on the existing school building. Five percent of the overall building electrical load will be generated by photovoltaic panels located on the roof of the existing

Middle School wing. Also 24% reduction in energy use in existing school is provided by efficient technologies.

Figure 3.41. Abundant use of daylight in library; artificial illumination is controlled by sensors [47]

The solar chimneys serving the specialty classrooms in the addition are intended to be used in mechanical ventilation and air conditioning modes, demonstrating the responsiveness of both passive and active systems to the local climate. South-facing glazing at the tops of the shafts heats the air and creates a convection which draws cooler air in through north-facing open windows [64].

Figure 3.42. View of planted roof, garden, and solar chimneys [34]

Generally, the facility demonstrates a responsible relationship between the natural and the built environment to foster an ethic of social and environmental responsibility in each student. Students witness natural and human created systems at work in which the building acts as the central teacher in an environmental curriculum.

Figure 3.43. Bridge to second level entry [64]

The landscape and building co-exist within, and demonstrate, a broader network of systems. Human systems - our inter-relationships with resources - are embodied by the landscape and building as natural systems. The project has been recognized by AIA's Committee on the Environment and Committee on Architecture for Education, but the building is emphasized as a beginning with its green features. Many of the teachers at all grade levels have designed lessons around the building system's opportunity [66].

3.3. CHAPTER RESULT

If the planning principles of educational buildings were examined in the historical process when the sustainability has not become a current issue as a concept yet; it was seen that the passive design principles were become a current issue in design by pointing them out occasionally. The sustainable design principles determined initially by discovering the significance of the sustainable design concept. Then these principles were adapted to educational buildings after the importance of sustainable learning environment was understood. Obviously, the passive methods, those are being used by not being evaluated under a major topic as "sustainable school design principle" in the historical process were defined as a certain design principle at that time.

It was seen that two approaches were mentioned while designing school buildings in terms of sustainability as re-evaluating the existing schools or designing the new schools. When the school examples determined with these approaches in this chapter were examined, features that are considered in all projects are as follows:

- Sustainable design of the site (Designing the open areas that allow sustainable education),
- Providing to reduce energy expenses,
- Selecting the building materials those of which are green and recyclable and also that do not emit toxic substances,
- Using passive design methods to provide indoor air quality,
- Utilizing the stormwater control systems and rainwater storage systems for the effective usage of water,
- Supplying the participation of local government and the community to the design and occupation process.

Besides these features of the sustainable school design, it has been pointed out that the building is a tool that teaches sustainability with efficient building components. With this topic, also it has been seen that the social aspect of the sustainability has been discussed. Beside these, in the green certification systems that assess sustainable school design such as LEED and CHPS, it can be easily seen that the title "energy and atmosphere" brings up the most point between other assessment titles. The examples examined in this chapter generally focus on this topic and aim to minimize the energy expanses. By having an important percentage of the school buildings in all other buildings, it would be appropriate to say that the title "energy" comes to the fore; and renovation of the school buildings for the energy reduction is pointed out.

4. EVALUATION OF ELEMENTARY SCHOOL BUILDINGS IN TERMS OF SUSTAINABILITY

The spatial features and benefits of school buildings that are designed by taking the sustainable design principles into account, were examined in the previous chapter. This chapter reviews the educational buildings in Turkey and discusses sustainable intervention opportunities of typified elementary school buildings through a case study.

4.1. TYPIFIED ELEMENTARY SCHOOL PROJECTS IN TURKEY

When education buildings in Turkey are examined from the early period to the present, it could generally be seen that spatial organizations underwent a change according to the social and political structure of that period. Nowadays, students receive education in buildings that have similar problems and similar spatial features because public schools have been applied as “typified projects” since The Ministry of National Education introduced 8-year compulsory primary education to Turkey in the beginning of the summer in 1997, with law no. 4306.

As it is seen in the Table 4.1., elementary schools constitute the largest proportion of educational buildings in Turkey. So, the study area was restricted with the elementary school buildings in Turkey and also with İstanbul Anatolian side.

Table 4.1. Data related to the number of educational institutions in Turkey [69]

Educational Institutions	2005/'06	2006/'07	2007/'08	2008/'09	2009/'10
Pre-school Number of schools	18 539	20 675	22 506	23 653	26 681
Primary education Number of schools	**34 990**	**34 656**	**34 093**	**33 769**	**33 310**
General high schools Number of schools	3 406	3 690	3 830	4 053	4 067
Vocational and technical high schools Number of schools	4 029	4 244	4 450	4 622	4 846
Higher educational institutions Number of schools	1 306	1 339	1 387	1 495	_

For the beginning of 8-year compulsory primary education, the government rallied to make elementary schools ready for the compulsory education. Istanbul Technical University, Mimar Sinan University of Fine Arts, Yıldız Technical University, Gazi University and Erciyes University were requested to prepare typified projects for the new elementary schools by The Ministry of National Education as with the number in Table 4.2. Under the leadership of Ministry of National Education, in 2000, the MEB published a catalogue of sample projects, conducted with the cooperation of Universities. These were ranked as typified projects for elementary schools with 240, 480, 720, 960 or 1200 students; regional primary boarding schools with 480, 720, 960 or 1200 students; and boarding schools with 480, 720, 960 students.

Table 4.2. Number of projects the universities produced [70]

	Elementary Schools with 240 students	Elementary Schools with 480 students	Elementary Schools with 720 students	Elementary Schools with 960 students	Elementary Schools with 1200 students
ITU	1	2	2	2	2
METU	1	1	1	1	-
YTU	-	1	1	-	-
MSFAU	1	-	1	1	-
Gazi Univ.	2	2	-	2	1
Erciyes Univ.	-	-	1	-	1

Universities generally emphasized that it is inappropriate to design school buildings as “typified projects”. However, there has been no positive development in this field so as to produce characteristic designs according to different climate regions. Thereupon, the emphasis was put on flexibility, functional distribution, natural lighting, multi-purpose uses, outdoor organizations and spatial organizations. However, it was noted that these typified projects are lack of important design inputs such as geographical, topographical, geological and climatic data. Ministry of National Education (MEB) continued the application of these typified projects in various regions of Turkey until 2000. However, the application areas of these projects were restricted as they are not suitable for the sites reserved by the municipality.

Within the framework of the protocol signed between the MEB and Istanbul Stock Exchange (IMKB) on 29.06.2000, the project called *Physical Contribution to Education 1* (EFİKAP) was developed; this was followed in 2004 by the project *Physical Contribution to Education 2* (EFİKAP). Within the scope of these projects, MEB had a private company to prepare new elementary school projects suitable for 240, 480, 660, 720, 960 and 1200 students. These projects were prepared by consulting companies and controlled by the architects in the institution, taking into consideration the suggestions of architects and education divisions in the MEB Directorate of Investments and Facilities.

Over time, these projects underwent a change after İstanbul Provincial Directorate of Public Works and İstanbul Special Provincial Administration made them revised by certain firms. According to information obtained from the Special Provincial Administration, elementary school buildings are currently constructed in eight different plan types. However, due to the frequent revisions, it is not clear when and in accordance with which decisions these projects were designed; and which company and architect played role in the design of these projects.

Ranging according to the number of classrooms and students, these projects are applied in all climate regions of Turkey. As spatial organizations and openings do not change in accordance with the climatic conditions, application of a “typified project” approach to the elementary schools is proved to be inappropriate. Interviews with MEB Istanbul Department of Investment and Facilities indicated that only practice used to adapt a typified school to different climatic regions is the selection of exterior insulation materials according to climate regions. But it could be said that this application, is not a special application for school buildings, it is only related with the *Regulation of Heating Insulation in Buildings*.

When the architectural drawings of these types were examined, it was seen that some alterations could be made in these projects according to the topographical characteristics of the site that could change the circulation diagram, including:

- 180º Rotation of the projects on the horizontal axis (mirror),
- Changing of location of the entrance depending upon slope differences across the site as from the basement floor,
- Changing the number of main entrances, depending on the site location,
- Changing the location of the service entrance depending upon the topographic conditions.

These alterations are supported due to the interview with Mr. Karaşahin, branch chief in İstanbul Special Provincial Administration in 20^{th} of July, 2010.

When data were compiled pertaining to typified elementary school buildings such as architectural drawings of these project types in the İstanbul region, it was seen that five of the eight standardized typified elementary school projects that have the types of 10025R-480, 10025R-720, 2000-41, 2000-42, Ragıp Akın, are commonly applied. The codes of these types and the data of numbers of classrooms and students are shown in Table 4.3., compiled with the information taken from İstanbul Special Provincial Administration and from İstanbul Provincial Directorate of Public Works and Settlement.

Although the building programs of these typified elementary schools met the need of the educational curriculum, spatial organizations show that these projects could not create effective learning environments.

Table 4.3. Commonly applied elementary school project types

School Type	**Number of classrooms**	**Number of Students**	**Number of floors**	**Floor area (m²)**	**Total Floor Area(m²)**
2000-41	17+(2)	240	B+G+3	591	2955
2000-42	23+(6)	720	B+G+3	1258	6328
10 025R-480	24+(3)	660	B+G+3	864	4325
10 025R-720	29+(3)	810	B+G+3	1121	5100
RAGIP AKIN	21+(4)	720	B+G+3	789	3985

Despite the proliferation of energy efficient building design and the abundance of international research on sustainability, sustainable design principles have not been encountered in typified schools as they produce rapidly to meet the needs.

When elementary school buildings constructed as typified projects are examined, it is seen that these buildings are lack of sustainable school design principles as follows:

- For selecting the site, proximity to transportation infrastructure and housing settlement is rarely an important matter.
- Especially in urban schools, buildings generally cover the entire site and remaining areas are generally used as paved playgrounds. This situation increases the heat island effect. There is no precaution for reducing this effect on site.
- Efficient water usage is not achieved, either via water management or by rainwater storage systems.
- To reduce heating costs in different climate regions, energy conservation is only facilitated through the selection of appropriate insulation materials. Furthermore, energy efficiency is not provided through the use of passive design methods or active systems.
- While selecting the building materials for these elementary schools, proximity to the resource is not considered and green or natural materials with minimum toxic emissions are not specified.
- Indoor air quality cannot be ensured by using efficient mechanical equipment or selecting the materials from ecological building materials.

Abovementioned situations show that the educational buildings that are constructed as typified projects, do not meet the physical needs of growing children and these learning environments do not serve the physical well-being of the users. Moreover, it was seen that the spatial organization similarities between these types are also evident as the architectural drawings shown in the Appendix C were examined. In all projects, the classrooms those are arranged bi-directionally on a single corridor axis results in thermal balance variations and causes uncomfortable learning environments.

Examination of current elementary school projects shows that it is necessary to re-evaluate existing elementary schools in order to reduce their energy costs and to create better learning environments. Accordingly, in the following section, progressive interventions are defined to research sustainability opportunities for typified elementary school projects through a case study of a typified existing elementary school building.

4.2. CASE STUDY: ŞEHİT ÖĞRETMEN MEHMET FİDAN ELEMENTARY SCHOOL

When the project types of existing elementary school buildings in Anatolian side of İstanbul that were obtained from İstanbul Special Provincial Administration and İstanbul Provincial Directorate of Public Works and Settlement were examined, it was seen that spatial configurations and building components of these projects were similar. Accordingly, as anticipating the similarity of sustainable intervention opportunities; the most implemented project type, 10 025R-480 type, was chosen for the study through 5 commonly applied elementary school project types.

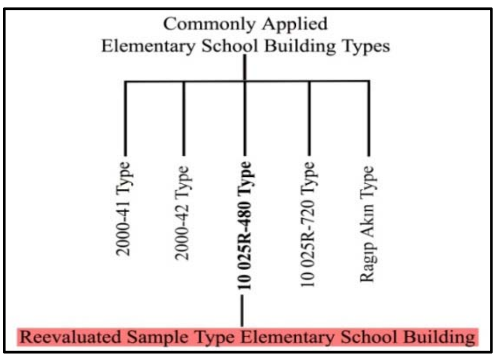


Figure 4.1. Project type of the case study

In this section, data on 10 025R-480 type case study, Şehit Öğretmen Mehmet Fidan elementary school building in the Anatolian side of İstanbul were presented and sustainability of this school building is discussed through a check list generated taking into account LEED and CHPS green school rating systems below.

4.2.1. Description of ŞÖMF Elementary School Building

After the 10025R-480 type elementary school project was chosen, an elementary school building in regard to which the most information was reached, was determined as case study. The location of the ŞÖMF elementary school is shown in Figure 4.2. and the school's project type and its construction year information are as in Table 4.4.

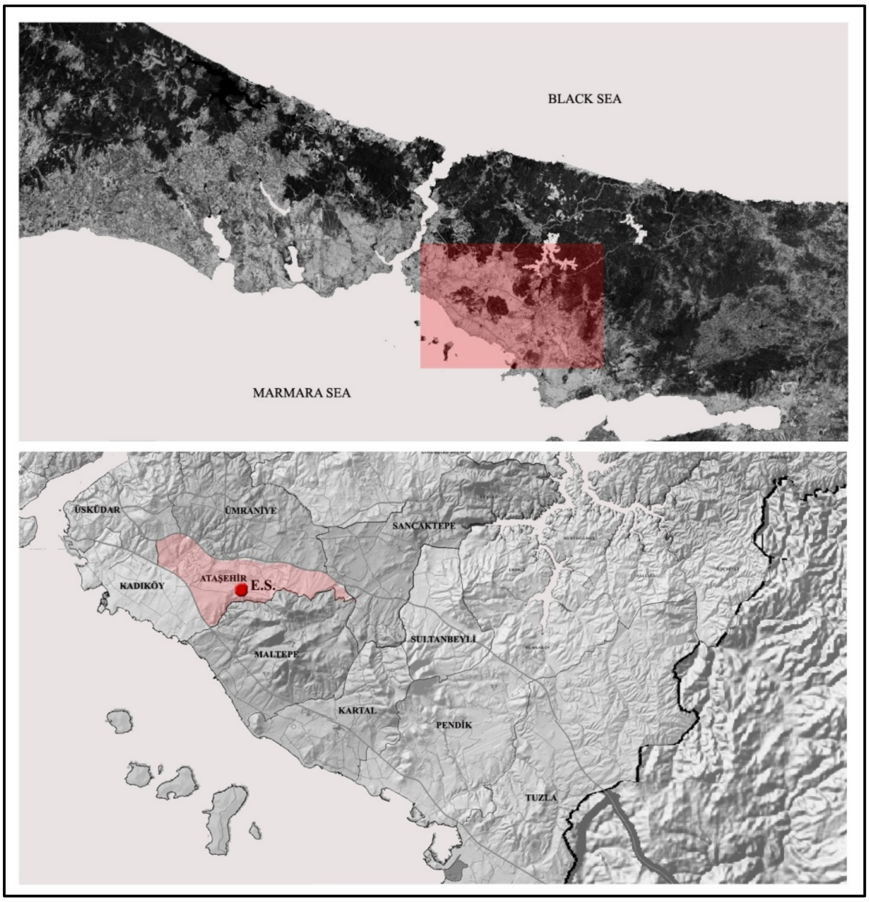


Figure 4.2. Scope area of the study and selected elementary school building (illustrated via *İstanbul Şehir Rehberi*)

Table 4.4. Information on the case study

Project Type	School		Date Built	Location
10025R-480	Şehit Öğretmen Mehmet Fidan E.S.	ŞÖMF	2007	Ataşehir

The 10025R-480 type ŞÖMF elementary school building is located in Ulusu Street in Ataşehir. The construction of the school was finished in 2007. It was constructed because an existing elementary school on the site did not meet the student capacity need of the region. The site that the ŞÖMF elementary school shared with the other school is 7778 m². A hard soil field of 2200 m², which belongs to the existing school, is used for playing and school ceremonies. The school is located on two levels, with a retaining wall constructed to balance the 5 m slope difference across the site. The service entrance is on the lower level and the slope difference on the site caused an extra basement floor as an addition to the standart typified 10 025R-480 school project.

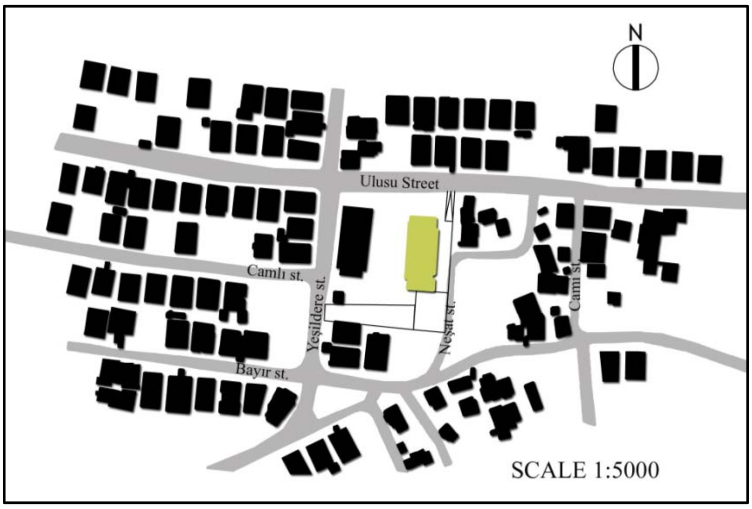


Figure 4.3. 10 025 R-480 Type ŞÖMF elementary school site plan

The building consists of 6 floors in total, 2 basement floors, a ground floor and three upper floors. It consists of 24 classrooms, 1 science, 1 computer sciences, 1 music laboratory, administrative rooms and service areas. There is an elevator in the school and also a circulation stairway and an emergency stairway. There is a green area that is not converted into hard soil within the school site but this green area remains idle.

Figure 4.4. 10 025 R-480 Type sample school general view

As shown in Figure 4.5., in the standard MEB 10025R-480 project with 24 classrooms, the classrooms are arranged bi-directionally on a single corridor axis. The number of classrooms generally meets the needs of the chosen region.

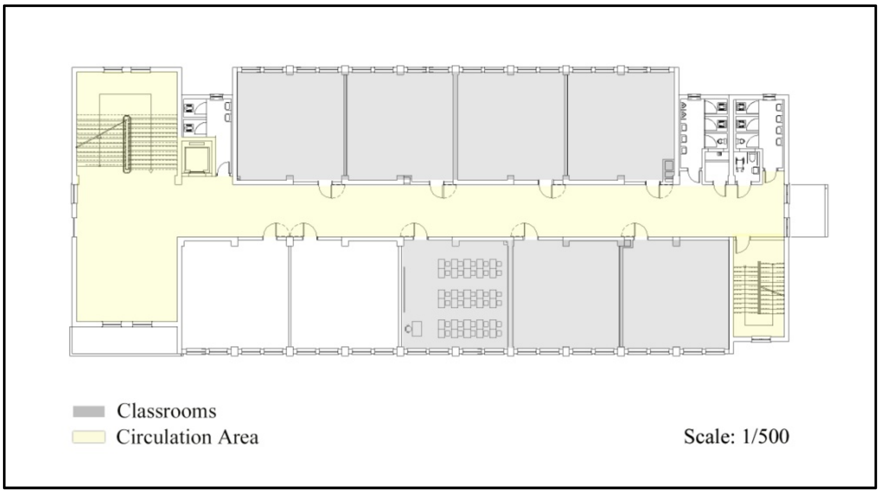


Figure 4.5. Typified floor plan of MEB 10025R-480 Type Elementary School

As the classrooms are located on different sides, thermal conditions also vary in these spaces. Therefore, physical quality of the classrooms is changed and students receive education in environments with different physical conditions lack of comfort, as the essential measures were not taken to ensure a comfortable and controlled indoor environment. In the Table 4.5., building component materials can be seen.

Table 4.5. 10 025 R-480 Type School Fact Sheet

ŞEHİT ÖĞRETMEN MEHMET FİDAN ELEMENTARY SCHOOL	Ataşehir, İstanbul
Project type:	10 025R-480
Classroom number:	24
Laboratory:	1 science, 1 Music, 1 Computer Laboratory
Storey height x number of floors:	(3.45 m x 6) 2 Basement floors + Ground floor + 3 floors
Design Date :	2007
Architectural Preliminary Project:	T.C. Ministry of Public Works and Settlement - Building Operation 6th Region Management
Construction Project:	TEMPO-Project Management-ODTM and MEB Project collaboration
Load bearing system :	Reinforced concrete
Classroom span axes:	7.30 m x 7.44 m
Building Envelope:	internal plaster 2.8 cm Brick wall 29 cm Exterior plaster 2 cm Adhesive Mortar Extruded Polystyrene Plate 3cm Elastic plaster 4 mm Heat insulating filet with 3.5 mm x3.5 mm interocular distance Siding
Roof covering materials:	Rafter 5/10 cm Clapboard minimum 18 mm coating wood Partition joint 4/3 cm bar Waterproofing Tile

The building program of the ŞÖMF elementary school project is shown in Table 4.6. As one can see in this table, these typified schools provide the needs of a learning environment. However, these projects were examined to determine whether these elementary schools create a healthy and comfortable learning environment that might facilitate improved academic performance.

Table 4.6. 10 025R-480 type elementary school project's architectural program

BUILDING PROGRAMME		
10 025 R-480 Type Elementary School **Space Name**	**Space Number**	**Total m²**
Classroom	24	1200
Science Laboratory	1	50
Computer Laboratory	1	50
UPS	-	-
Social Science Laboratory	-	-
Music Laboratory	1	52
Drawing Room	-	
Manager's Room	1	50
Assist. Manager's Room	1	33
Teacher's Room	1	50
Official Room	-	-
Medical Room	-	-
Preschool Kitchen	1	50
Preschool Activity-Play Area	2	50+50
Multi-purpose room	1	154
Employee Room	1	50
Atelier	-	-
School Council	-	-
Guidance Room	-	-
Administrative office	-	-
Canteen	1	100
Library	1	80
Archive	-	
Stationery	1	20
Photocopy room	1	6
Gymnastics Saloon	1	58
Boys' Changing Room	1	37
Girls' Changing Room	1	37
Storage	2	35
Cloakroom	-	-
Heating System Center	1	100
Central control room	1	24
Shelter	1	42

4.2.2. Examining the Sustainability of ŞÖMF Elementary School Building

After ŞÖMF elementary school building was described in the previous section, in this section, sustainability of this school building was evaluated through a checklist which contains the main subjects of sustainable design principles that a sustainable school must acquire.

First, LEED, CHPS, and other school and university leveling systems as sustainable building rating systems were examined. The fundamental subjects of a sustainable school were determined as in the Chapter 3. Then, ŞÖMF elementary school building evaluated under these subjects which satisfy the need to define sustainability determining "LEED for schools" as basis. By the help of this sustainability checklist, the goals that a school should meet as focusing on site, energy, materials, indoor air quality, water and construction were checked for the ŞÖMF elementary school as following Table 4.7.

Table 4.7. Sustainability checklist of ŞÖMF elementary school building

Requirements for Schools		Check
Sustainable Site	Construction Activity Pollution Prevention	Required
	Environmental Site Assessment	Required
	Site Selection	☒
	Development Density and Community Connectivity	☒
	Brownfield Redevelopment	☐
	Alternative Transportation – Public Transportation Access	☒
	Alternative Transportation – Bicycle Storage and Changing Rooms	☐
	Alternative Transportation – Low-Emitting and Fuel-Efficient Vehicles	☐
	Alternative Transportation – Parking Capacity	☐
	Site Development – Protect or Restore Habitat	☐
	Site Development – Maximize Open Space	☐
	Stormwater Design – Quantity Control	☐
	Heat-Island Effect – Nonroof	☐
	Heat-Island Effect – Roof	☐
	Heat-Island Effect – Paving	☐
	Light-Pollution Reduction	☒
	Site Master Plan	☐

Table 4.7. Sustainability checklist of ŞÖMF elementary school building (continued)

Requirements for Schools		Check
	Joint Use of Facilities	☐
	Sustainable practices on site	☐
Water Efficiency	Water Use Reduction	Required
	Water-Efficient Landscaping	☐
	Innovative Wastewater Technologies	☐
	Water-Use Reduction	☐
	Process Water-Use Reduction	☐
Energy and Atmosphere	Fundamental Commissioning of Required Building Energy Systems	Required
	Minimum Energy Performance	Required
	Fundamental Refrigerant Management	Required
	Optimize Energy Performance	☐
	On-site Renewable Energy	☐
	Enhanced Commissioning	☐
	Enhanced Refrigerant Management	☐
	Insulation materials	☒
	Green Power	☐
Materials and Resources	Storage and Collection of Recyclables	Required
	Building Reuse – Maintain Existing Walls, Floors, and Roof	☐
	Building Reuse – Maintain Existing Interior Nonstructural Elements	☐
	Construction Waste Management	☐
	Materials Reuse	☐
	Recycled Content	☐
	Regional Materials	☐
	Rapidly Renewable Materials	☐
	Certified Wood	☐
Indoor Environmental Quality	Minimum Indoor-Air-Quality Required Performance	Required
	Environmental Tobacco Smoke (ETS) Required Control	Required
	Minimum Acoustical Performance	Required
	Outdoor-Air Delivery Monitoring	☐
	Increased Ventilation	☐
	Construction Indoor-Air-Quality Management Plan – During Construction	☐
	Construction Indoor-Air-Quality Management Plan – Before Occupancy	☐
	Low-Emitting Materials	☐
	Indoor Chemical and Pollutant Source Control	☐
	Controllability of Systems – Lighting	☐

Table 4.7. Sustainability checklist of ŞÖMF elementary school building (continued)

Requirements for Schools		Check
	Controllability of Systems – Thermal Comfort	☐
	Thermal Comfort – Design	☐
	Thermal Comfort – Verification	☐
	Daylight and Views – Daylight	☐
	Daylight and Views – Views	☐
	Enhanced Acoustical Performance	☐
	Mold Prevention	☐
Innovation in Design	Innovation in Design	☐
	School as a Teaching Tool	☐
	Using Building Energy Performance Simulation Tools	☐

As it is seen in the Table 4.7., ŞÖMF school corresponds 5 elements in total in the checklist, one of which is site selection, the others are public transportation access, development density and community connectivity, and light pollution reduction under the title of sustainable sites. Also an element is insulation material under the title of energy and atmosphere. In this situation, in accordance with the rating system of LEED, the school could not being assessed with silver, platinum, bronze or gold ratings.

For the site selection process of the ŞÖMF elementary school building, an erosion and sedimentation control plan for the project's development was formulated during the design phase. It can be said that the building location is suitable if the topographical conditions of the site are considered. Although the building was not designed with minimal footprint to minimize site disruption of those environmentally sensitive areas, during the site-selection process, urban and urbanized sites were given to preference and direct development of urban areas with existing infrastructure was encouraged. So meeting the many necessary conditions of site selection, this title was marked.

The ŞÖMF school was constructed on previously developed land in a community with a development density. And also it was constructed on previously developed land which is within 800 m of a residential area or neighborhood and is within 800 m of at least

10 basic services, and has pedestrian access between the building and the services. So, development density and community connectivity was satisfied.

The ŞÖMF school is not on a brownfield area or there is no brownfield site near the school determined by the local government. So, as site selection did not give preference to brownfield sites, the title brownfield redevelopment cannot be assessed. The school was designed within 400 m walking distance of at least one stop for at least two public bus lines that can be used by building occupants. So alternative transportation – public transportation access was provided as it was marked in the checklist. The other alternative transportation as bicycle storage and changing rooms, low-emitting and fuel-efficient vehicles and parking capacity titles were not considered in the design process. For the site development, there is no enterprise for protecting or restoring habitat and maximizing open space. And under the other titles as stormwater design, heat-island effect, site master plan, joint use of facilities, sustainable practices on site, there are no precautions or design applications. For the light pollution reduction, light trespass from the building and site was minimized, sky glow to increase night-sky access was reduced and nighttime visibility through glare reduction was improved. For this title, necessary conditions were satisfied so, it can be marked but these applications were made by not considering the importance of these subjects.

For the water efficiency title, non of the subjects that are water-efficient landscaping innovative wastewater technologies, water-use reduction process and water-use reduction were taken into consideration, so the ŞÖMF school cannot be scored under this title.

Also, under the title of energy and atmosphere, only application is the usage of insulation materials. Except this, there is no application or precaution about optimizing energy performance, on-site renewable energy, enhanced commissioning, enhanced refrigerant management, measurement and verification or green power. So, only “insulation materials” was marked under this title.

In the ŞÖMF school, no green, non-toxic, rapidly renewable, regional materials or recycled content were used. So the title of materials and resources cannot be scored in the checklist.

Indoor environmental quality is provided randomly without any construction indoor-air-quality management plan, outdoor-air delivery monitoring, low-emitting materials, indoor chemical and pollutant source control, controllability of systems, enhanced acoustical performance or mold prevention. So the ŞÖMF elementary school cannot be assessed under this title.

Also innovation in design could not be mentioned because of the typified project of the school which is applied in all climate regions with the same architectural design.

While examining the sustainability of the ŞÖMF elementary school through the checklist, department manager Mr. Demirel from İstanbul Directorate of National Education in 17th of June, 2010, and branch chief Mr. Karaşahin from İstanbul Special Provincial Administration in 18th of August, 2010 were interviewed; general architectural features of typified projects were asked and the information if the projects have the 5 major subjects in the checklist were obtained.

From the checklist, it is understood that typified schools are lack of sustainability. So there is a need to research sustainable intervention opportunities to typified school buildings.

4.3. SUSTAINABLE INTERVENTION STEPS FOR THE CASE STUDY

In this section, sustainable intervention steps were defined as sustainable site, water efficiency, energy and atmosphere, materials and resources and indoor environmental quality as in the Section 3.2.3 that includes sustainable design principles for existing school buildings. ŞÖMF elementary school building is evaluated under these titles in order to provide sustainability. In the LEED and CHPS rating systems the subject “Energy and Atmosphere” is rated with the highest points. So, in this section, a proposed intervention to building envelope under this subject was also assessed by using “DesignBuilder” building energy performance simulation tool.

First, in order to develop sustainable intervention opportunities, “Autodesk Ecotect Analysis” building energy simulation tool was used to visualize and simulate the daylight shadow values on the ŞÖMF school building by following the sun’s hourly, monthly and yearly path.

The school itself was modeled in the software. As there were no other buildings adjacent to the school and the buildings that were situated around the school were not so high to affect the daylight of the school building; the modeling process was based on the school building itself and interactions with surrounding buildings were not modeled. The model that shows daylight-shadow values of the building is shown in the Figure 4.6.; measured on 21st of June which is the day of the year with the longest hours of daylight in the northern hemisphere, and on 21st of December which is the day of the year with the shortest hours of daylight in the northern hemisphere.

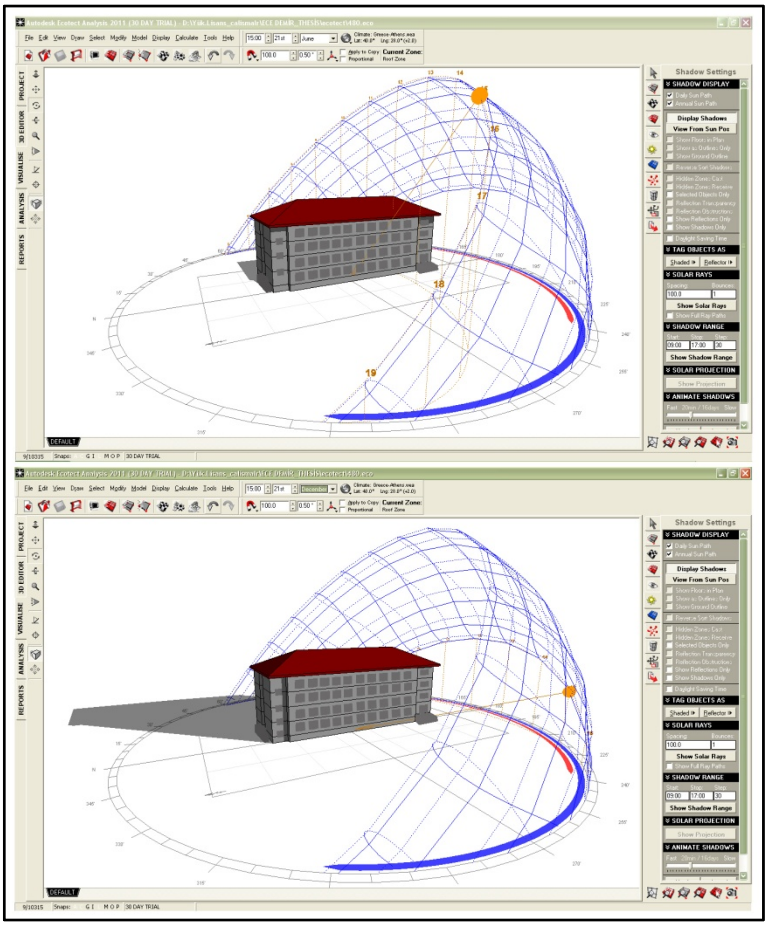


Figure 4.6. Sun path diagram of the 10 025R-480 type ŞÖMF school building

After the site and orientation information were inserted into the program for the school, corresponding values show that classrooms situated on the front side and back side of the school receive the maximum amount of sunlight equivalently. However, as the classrooms on the front side are oriented to west, these spaces potentially overheat. Also the ceremony and playground of the children receives direct sunlight after midday.

After simulating and visualizing the daylight shadow values of school in different spaces, the following intervention opportunities were discussed.

4.3.1. Sustainable Site

In conventional urban schools, a multistory building occupies much of a school site, with paved playground adjacent, surrounded in a courtyard or entirely absent. Besides, as ŞÖMF elementary school is in a developing region, the site has large areas of paved playground and space between the schools in site. This case causes different problems. Sites of the schools must be evaluated considering these problems.

According to the observations and documentation processes conducted on ŞÖMF school building (10 025R-480 typified elementary school), information on the site plans obtained from the Special Provincial Administration was confirmed. And, as it is understood from the Figure 4.7., it was found that 93% of the school site is covered with hard soil. All playgrounds are covered with asphalt, including the playground of the nursery school. In addition, the limited green areas within the borders of the school site are not utilized as mentioned before. As the elevation of this green zone is 5 m lower than the ceremony and playground area, water from the hard soils is drained into this green zone.

As this building shares the site with another elementary school, intervention opportunities are proposed to improve sustainability, were made by considering this situation. The following interventions could be carried out to improve sustainability across the entire site:

- Integration of water harvesting systems to use the gray drainage water on the green site.

- Protection of green fields and providing the opportunity to have classes and to conduct sustainable practices in this area, which could help create environmental awareness of such issues as native vegetation.
- Planting the playgrounds and minimizing hard soils, thus decreasing the heat island effect is possible.
- Covering the playground of the kindergarten with a soft and natural-component material instead of asphalt to improve safety.

Figure 4.7. Site definition of ŞÖMF elementary school building

There is a powerful synergy between sustainable site design and progressive educational thinking. A variety of environments such as planted water courses and detention areas, slopes and rocky areas can support more kinds of social spaces, imaginative play, and environmental study opportunities [45]. So, it can be said that including more naturalistic areas introduces another level of interest and activity to the campus and also increased planting increases habitat and frees the soil. Tree planting creates shade that further moderates local heat islands. For ŞÖMF school building, some green field proposals that help children develop new activities in the kinds of alternative environments can be seen in Figure 4.8.; and these proposals could be diversified. The proportion of green playgrounds to the hard soils should be at least 50%.

Figure 4.8. Planting the play environment for sustainable site

When ŞÖMF elementary school building evaluated with the subject of "Sustainable Site", intervention opportunities can be compiled in the Table 4.8. for this subject.

Table 4.8. Sustainable intervention opportunities to the sustainable site

Intervention Subject	**Intervention Steps**	
Site	**1.** Conservation of existing hardsoil areas	**a.** Covering hardsoil areas with permeable pavement for water disposal
		b. Evaluation of existing natural ground to give the opportunity of sustainability activities
	2. Re-evaluation of open areas	**a.** To create sustainable and green environments toward the opportunities that the site serves
		b. To observe the proportion of hardsoil areas and green areas in the site by considering the heat island effect
	3. Water management	**a.** Providing stormwater management by evaluating the topography of the site
		b. Integration of rainwater storage systems

There can be three intervention steps for sustainable site, as conservation of existing hardsoil areas, re-evaluation of open areas and water management. In the subtitle of conservation of existing hardsoil areas; two main applications can be done such as covering hardsoil areas with permeable pavement for water disposal and evaluation of existing natural ground to give the opportunity of sustainability activities.

In the subtitle of re-evaluation of open areas; creation of sustainable and green environments toward the opportunities that the site serves and observation of the proportion of hardsoil areas and green areas in the site by considering the heat island effect can be the main applications.

Also, in order to manage the water usage on site, stormwater management by evaluating the topography of the site and integration of rainwater storage systems must be provided on site.

4.3.2. Water Efficiency

The sustainable school reduces or eliminates potable water use for irrigation and cuts of potable water in the building [45]. After the interviews with the institutions which projected the typified schools as mentioned before, there is no application of water-efficient landscaping, water-use reduction and using innovative wastewater technologies in ŞÖMF elementary school. When the applications for the efficient use of water in sustainable schools were examined, the Table 4.9. was created to provide water efficiency of ŞÖMF elementary school building.

Table 4.9. Sustainable intervention opportunities to provide water efficiency

Intervention Subject	Intervention Steps	
Water	**1.** Water management on site	**a.** Rainwater harvesting on site
		b. Stormwater management
	2. Water management in building	**a.**Efficient plumbing fixtures
		b. Rooftop rainwater harvesting
		c. Gray water collection

In the table above, two main intervention opportunities were discussed for the water efficiency such as water management on site and water management in building. For ŞÖMF elementary school building, rainwater harvesting system can easily be adopted on site because of the slope difference to the back side of the building. Also slope difference at the back side of this school site, extends (at a decreasing rate) along an inclined service area heading towards the green area, requires to install a stormwater management plan on site. Ensuring water management on site and recycling of this water are important parts of providing water efficiency of ŞÖMF elementary school. In case, water management in building can be provided by using efficient plumbing fixtures, by harvesting rainwater on rooftop and by collecting gray water for the recycled usage.

Besides all these interventions, making visible the collection of rainwater and its ultimate use to water gardens can be a part of sustainable curriculum.

4.3.3. Energy and Atmosphere

When the sustainable renovations of existing school examples were examined, it was seen that sustainable integrations especially focus on reducing energy consumptions. Besides, in LEED and CHPS sustainable school rating systems, the subject of “Energy and Atmosphere” has the highest point as mentioned before. So it is meaningful to analyze ŞÖMF elementary school building in terms of energy consumption after a sustainable intervention. In this section, after the intervention opportunities in this title were discussed, energy performance simulation of ŞÖMF elementary school building was explained and data generated by the software was presented.

First, in order to research sustainable intervention opportunities to ŞÖMF elementary school building under the title of energy and atmosphere, the building was modeled in the Autodesk Ecotect Analysis simulation tool. The observed changes in the daylight-shadow values from the September, when the schools start education, to the end of the school year in June, show that classrooms at the front side of the building did not receive direct sunlight until 13:00 pm, whereas classrooms at the back side of the building receive sunlight before 13:00 pm. It was seen that classrooms on two sides receive direct sunlight at certain times of the day, but no measures were taken against the glare in classrooms as mentioned before.

To incorporate ideal lighting principles into the school design, the following practices should be conducted in both ŞÖMF elementary school building and other typified elementary schools whose long axis is in the north-south direction:

- Using of louvers and overhangs on the building envelope to control the direct sunlight on east and west facades and to prevent glare,
- Vertical positioning of these louvers, to benefit from the sunlight on the east and west facades,
- It is important to expand the openings on the south facade, which receives most sunlight all day long and where there are few windows; and to integrate photovoltaic panels on this facade.

As it is seen in the Figure 4.9., it can be anticipated that the energy consumption of the building will reduce if these interventions are applied.

Figure 4.9. Intervention on the building envelope of the sample school building

When the intervention opportunities are discussed for ŞÖMF elementary school building, the following table was created considering the sustainable integration applications for the existing school buildings.

Table 4.10. Sustainable intervention opportunities to provide energy efficiency

Intervention subject	Intervention steps		
Energy and Atmosphere	**1.** Building envelope	**a.**Conservation of building envelope	1. Integration of louvers, sunshades to control heating and lighting energy
			2. Integration of PV panels for electrical energy production
			3. Using insulation materials
		b. Renovation of building envelope	1. Window renovation
			2. Building envelope material renovation
			3. Integration of double skin facade
			4. Expanding or decreasing the size of openings
	2. Roof applications	**a.** PV panel integration	
		b. Green and cool roof	

Energy efficient interventions were classified in two main titles such as intervention on building envelope and integration of roof applications. The subtitles of intervention on building envelope evaluated in 2 parts such as conservation of building envelope and renovation of building envelope. When the building envelope is conserved without any sustainable renovations, louver, sunshade applications can be done in order to control heating and lighting energy. Also integration of PV panels on building envelope can reduce electrical energy consumption. Using insulation materials to provide thermal comfort can be served as vapor barrier. In the renovation of building envelope title, 4 main subtitle were discussed in order to provide energy efficiency. Window or glazing renovation can reduce heating energy consumption if the components are chosen from appropriate materials to the regional climate. Building envelope material renovation, integration of double skin façade and expanding or decreasing the size of openings can also reduce energy consumption.

Also, in order to provide energy efficiency, roof applications such as PV panel integration and green and cool roofing can be done.

In the following section, as it is seen in the Table 4.10., 1.a.3., 1.b.1 and 1.b.4. intervention steps were evaluated by the help of a building energy performance simulation tool and the effects of these interventions were presented.

4.3.3.1. Energy Performance Simulation of the Case Study

For the energy performance analysis, Energy Plus based “DesignBuilder” building energy performance simulation tool was used. DesignBuilder was preferred due to its interface that reduces potentially incorrect inputs and the convenience it provided in the modeling process. This tool was used to determine how abovementioned interventions to the building envelope could affect the heating energy consumption.

First, the ŞÖMF school building was modeled within DesignBuilder as in the Figure 4.10. Then, zones, architectural elements, materials, working schedules etc. were defined. Within this model, Istanbul was selected as the basis for appropriate regional climatic data. The orientations of the buildings were then defined in the program.

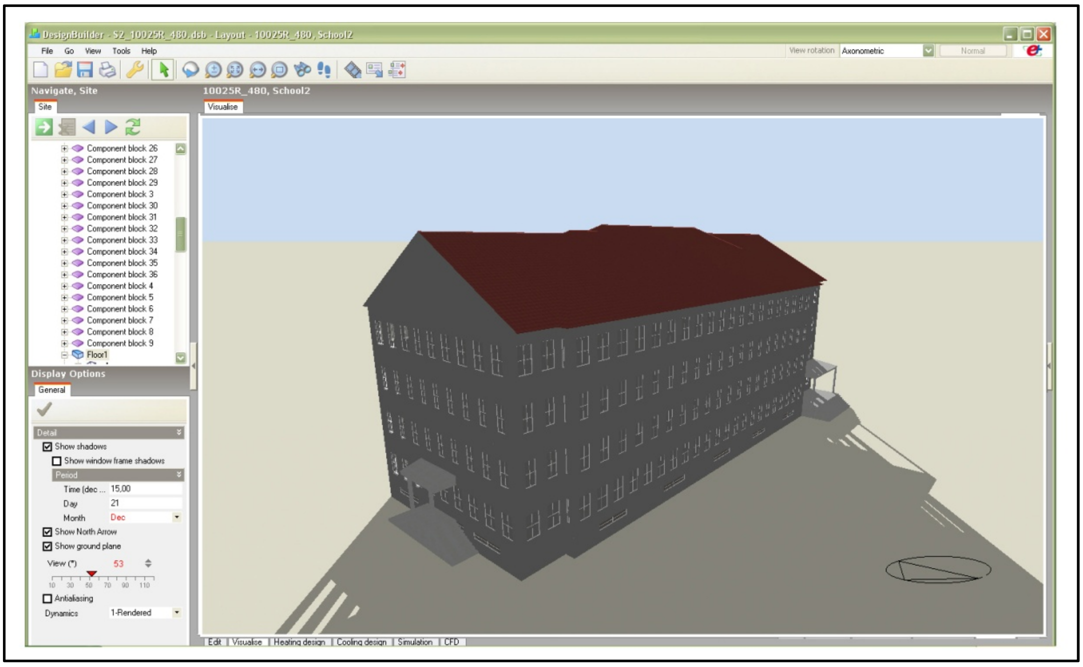


Figure 4.10. Form of the 10025R-480 type ŞÖMF school modelled in DesignBuilder

Every zone within the schools was modeled and all building materials that determine the thermo-physical features of the building envelope were processed within the program, as shown in Table 4.5. The physical features of window components of ŞÖMF elementary school building are shown in Table 4.11.

Table 4.11. Physical properties of windows

Windows	Light Transmission	Direct Solar Transmission	Total Solar Transmission
UPVC window frame (polyvinlychloride) Double Clear Glazing 3mm/13mm Air	0,812	0,705	0,758

Also, data related with occupants were inserted into software and occupancy hours are as Monday to Friday from 9:00-16:00 pm. Holidays per the year data was determined as 92 days as seen in Figure 4.11. Comfort temperature in classrooms defined as 20ºC. After inserting all of the physical features of the building into the program, the heating energy consumption of the building was determined by the simulation. The predicted heating energy consumption was then compared with the results of the simulation after the intervention to building envelope.

Simulation calculations were made after the intervention to building envelope in terms of the renovation strategies of, increasing insulation thickness, window glazing renovation and using shading devices as louvers.

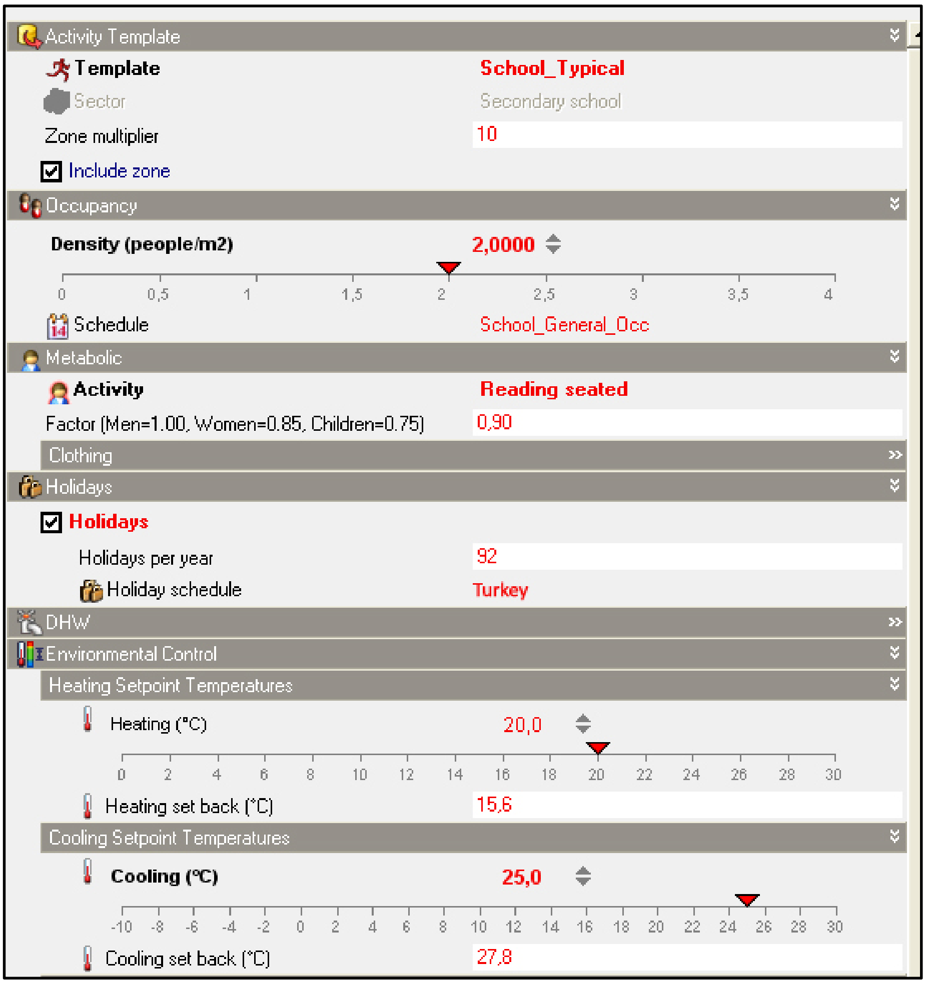


Figure 4.11. Activity sheet for the sample school in DesignBuilder

The following section presents the data generated by software after the input files of the software were defined as above.

4.3.3.2. Data Generated by Software

After the examination of sustainable design interventions to ŞÖMF elementary school building, and simulation process in the DesignBuilder software; the program output was produced in order to get the following results:

- Heating energy consumption during December, which has the highest rate in total energy consumption before the intervention (defined as case 1)
- Heating energy consumption during December, after the intervention to the building envelope (defined as case 2)

The study estimated how much energy could be gained in the school building without using high-cost energy efficient systems- by means of interventions to the building envelope, by increasing insulation thickness, renovating the window glazing, or expanding the openings to increase the daylight gain and integrating sunshade devices.

Window openings were expanded on the facades for ŞÖMF school building as proposed in the previous section. This proposal aims to decrease heating energy consumption by benefitting from sunlight on these facades. The window dimensions of the classrooms were determined according to the movement of daylight simulated within Autodesk Ecotect Analysis and to the optimum level heat gains determined in DesignBuilder. Also, during the modeling process, louvers were integrated on the facades of the school, as proposed in Section 4.3.3. The shading devices such as louvers that the software offered are as in the Figure 4.12.

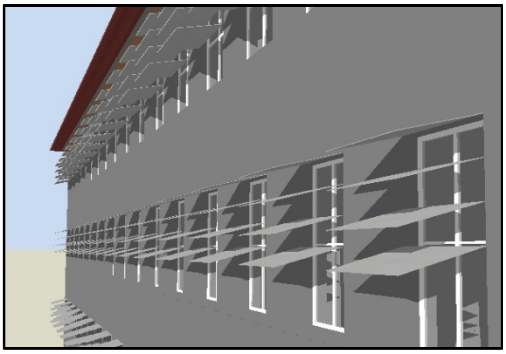


Figure 4.12. Louvers that the software offers

Besides, together with this study, using trombe wall, double skin integration and using active systems as PV panels are some other interventions to building envelope in order to reduce energy demand.

Table 4.12. shows building envelope components before and after the intervention, defined above as case 1 and case 2. As the heating energy demand has the highest ratio in all energy demands of a school in a temperate and humid climate, İstanbul, so the evaluation emphasized heating energy. Table 4.12. shows the data generated by software after simulation for December because maximum heat gain is achieved during that month.

Table 4.12. Components of building envelope inputs for the simulation and heating energy consumption results before and after

	Case	Building envelope materials				Window components and classroom opening sizes			Heating energy consumption
The ŞÖMF School Building (10025R-480 Type)	**1**	Internal plaster 0.02	Brick wall 0.29	external plaster 0.02	EPS(Expanded polystyrene lightweight) Insulation	UPVC Window frame	Dbl Clr 3mm/13mm Air glazing	122x175	6317 kW
	2	Internal plaster 0.02	Brick wall 0.24	external plaster 0.02	EPS(Expanded polystyrene heavyweight) Insulation	UPVC Window frame	Dbl Clr 6mm/13mm Air glazing Louver integration	140x190	5980 kW

As it is seen from the Table 4.12., in the first and second cases, the internal plaster has the thickness of 0.02 cm, brick wall has the thickness of 0.29 cm and 0.24 cm and external plaster has the thickness of 0.02 cm. Only the insulation material, EPS (Expanded polystyrene lightweight) is changed with EPS (Expanded polystyrene heavyweight) in the second case. Window frame of the school is the same for both cases. But window glazing with the features of double clear 3mm/13mm air glazing was changed with the glazing of double clear 6mm/13mm air glazing. Also, louvers were integrated to east and west facades of ŞÖMF elementary school building. In the first case, window openings are 122x175 cm and in the second case 140x190 cm.

For the first case, before the interventions, the heating energy consumption in December was 6317 kW. After the interventions, ŞÖMF elementary school building was simulated and heating energy consumption was calculated as 5980 kW.

The energy demand of ŞÖMF elementary school building during December shows that there is a reduction of 5% in the heating energy after the intervention. Energy consumed for the heating in the school is shown in Figure 4.13.

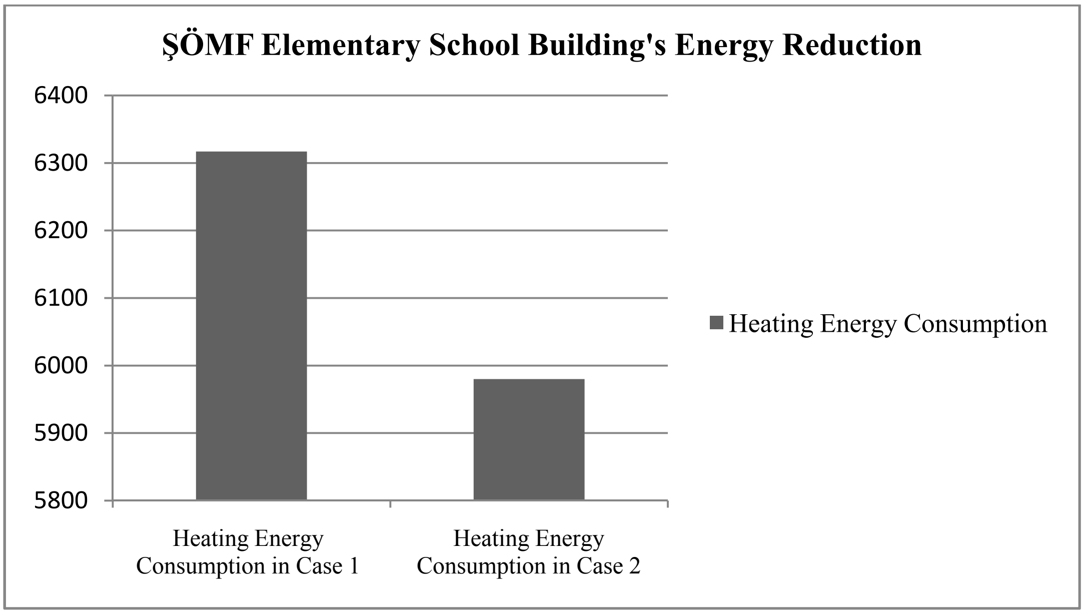


Figure 4.13. Comparison of heating energy consumption according to the intervention

From this point of view, changing building materials or renovation of building envelope could reduce the energy costs of the building. Although this case is confirmed, heating energy calculation showed that the gain is not very high as the existing materials were changed with similar materials. This proposal was made according to the minimum cost intervention scenario. It should therefore be considered that building life cycle costs would compensate the first expenses soon. In this situation, the use of insulation materials and window components with better thermal performance is suggested.

4.3.4. Materials and Resources

When the school was examined in terms of materials and resources title in the sustainability checklist, it was seen that none of the sustainable principles in the title of “materials and resources” are used. Therefore in this subject, there exists materials that were not reached the end of life in the ŞÖMF elementary school building, intervention steps are limited as in the Table 4.13.

Table 4.13. Sustainable intervention opportunities for the "Materials" subject

Intervention Subject	**Intervention Steps**
Materials and Resources	**1**. Recycling building materials those ended their life and reusing of these materials
	2. Using renewable, non-toxic, low VOC and green materials

So, in ŞÖMF elementary school building, building materials which reached the end of their economic life, can be recycled or reused. If the new materials will be used, renewable, non toxic, low VOC, green materials should be preferred.

4.3.5. Indoor Environmental Quality

Indoor environmental quality is the third important subject in the sustainability rating systems. There are many subtitles to provide indoor environmental quality such as increasing the ventilation, using low emitting materials, controllability of systems, indoor chemical and pollutant source control, enhanced acoustical performance and mold prevention. There is no application or precaution in the ŞÖMF elementary school building to provide indoor environmental quality.

For the reason that there are many subtitles as being evaluated, the intervention opportunities can be classified in two subtitles under the main title of indoor environmental quality as in the Table 4.14. First title is indoor air quality and second title is acoustics.

Table 4.14. Sustainable intervention opportunities for the "Indoor environmental quality"

Intervention Subject	**Intervention Steps**	
Indoor Environmental Quality	**1.** Indoor air quality	**a.** Providing natural ventilation
		b. Integration of mechanical systems which have systems to provide healthy environments
		c. Changing the materials if necessary with which do not emit toxic substances
	2. Acoustics	Providing good acoustics for indoor environmental quality

In order to provide required performance of indoor air quality, first, natural ventilation must be increased. New approaches such as heat or energy recovery ventilation can bring 90% outside air into the space continuously, flushing out pollutants without losing energy efficiency [45]. So, HVAC equipments that promote this situation and provide healthy environments can be used to keep the occupants comfortable. Also, indoor air quality is tied to the materials in the spaces, maintenance procedures and ventilation. Further, if necessary, the materials should be changed with non toxic, renewable, green materials with no added formaldehyde.

In the Brundtland Commission's sustainability definition, good acoustics is mentioned as a part of meeting the need of the present [24]. As an integrated approach to design, acoustic performance is part of the envelope, the HVAC system, the finishes in the room, and the choice of natural ventilation system [45]. So, improved acoustics must be a part of the sustainable intervention to the ŞÖMF school. To do this, the classes must cut reverberation times, which interfere with the intelligibility of speech, by installation of sufficient absorptive surfaces, typifiedly the ceiling and the walls.

4.4. EVALUATING THE SUSTAINABILITY OF THE CASE STUDY AFTER THE INTERVENTIONS

After the sustainable intervention opportunities were researched for the ŞÖMF elementary school, it is meaningful to control the sustainability checklist for the second time. In the following, the new sustainability checklist for the school is presented.

Table 4.15. Sustainability checklist of ŞÖMF elementary school building

Requirements for Schools		Check
Sustainable Site	Construction Activity Pollution Prevention	Required
	Environmental Site Assessment	Required
	Site Selection	☒
	Development Density and Community Connectivity	☒
	Brownfield Redevelopment	☐
	Alternative Transportation – Public Transportation Access	☒
	Alternative Transportation – Bicycle Storage and Changing Rooms	☐
	Alternative Transportation – Low-Emitting and Fuel-Efficient Vehicles	☐
	Alternative Transportation – Parking Capacity	☐
	Site Development – Protect or Restore Habitat	☒
	Site Development – Maximize Open Space	☐
	Stormwater Design – Quantity Control	☒
	Heat-Island Effect – Nonroof	☐
	Heat-Island Effect – Roof	☐
	Heat-Island Effect – Paving	☒
	Light-Pollution Reduction	☒
	Site Master Plan	☐
	Joint Use of Facilities	☐
	Sustainable practices on site	☒
Water Efficiency	Water Use Reduction	Required
	Water-Efficient Landscaping	☒
	Innovative Wastewater Technologies	☒
	Water-Use Reduction	☒
	Process Water-Use Reduction	☐

Table 4.15. Sustainability checklist of ŞÖMF school building (continued)

Requirements for Schools		Check
Energy and Atmosphere	Fundamental Commissioning of Required Building Energy Systems	Required
	Minimum Energy Performance	Required
	Fundamental Refrigerant Management	Required
	Optimize Energy Performance	☒
	On-site Renewable Energy	☐
	Enhanced Commissioning	☐
	Enhanced Refrigerant Management	☐
	Insulation materials	☒
	Green Power	☐
Materials and Resources	Storage and Collection of Recyclables	Required
	Building Reuse – Maintain Existing Walls, Floors, and Roof	☐
	Building Reuse – Maintain Existing Interior Nonstructural Elements	☐
	Construction Waste Management	☐
	Materials Reuse	☐
	Recycled Content	☒
	Regional Materials	☒
	Rapidly Renewable Materials	☒
	Certified Wood	☐
Indoor Environmental Quality	Minimum Indoor-Air-Quality Required Performance	Required
	Environmental Tobacco Smoke (ETS) Required Control	Required
	Minimum Acoustical Performance	Required
	Outdoor-Air Delivery Monitoring	☐
	Increased Ventilation	☒
	Construction Indoor-Air-Quality Management Plan – During Construction	☐
	Construction Indoor-Air-Quality Management Plan – Before Occupancy	☐
	Low-Emitting Materials	☒
	Indoor Chemical and Pollutant Source Control	☐
	Controllability of Systems – Lighting	☐
	Controllability of Systems – Thermal Comfort	☒
	Thermal Comfort – Design	☒
	Thermal Comfort – Verification	☐
	Daylight and Views – Daylight	☒
	Daylight and Views – Views	☒
	Enhanced Acoustical Performance	☒
	Mold Prevention	☐

Table 4.15. Sustainability checklist of ŞÖMF school building (continued)

Requirements for Schools		Check
Innovation in Design	Innovation in Design	☐
	School as a Teaching Tool	☒
	Using Building Energy Performance Simulation Tools	☒

As in the section of sustainable site intervention, protecting and restoring habitat before the integration of sustainable practices on site was offered. In addition, stormwater management and changing the pavement to reduce heat island effect were emphasized. So, 4 more sustainable elements were marked in the new case. Accordingly, in total, 8 elements in the checklist under the sustainable site title were satisfied.

For the first case, there are no sustainable design elements for the efficient use of water. Sustainable intervention opportunities for this subject are to use water efficient landscaping systems, wastewater technologies so that reducing the water use. Thus, for the new case, 3 elements were marked under this title.

In the existing ŞÖMF elementary school, only insulation materials are used for energy efficiency. After sustainable interventions for the title of energy and atmosphere, energy performance was optimized. So in total, 2 elements related to this title were marked for the second case.

If there is a need to change and renew the materials in the school, recycled, regional and renewable materials were offered to be used. So, 3 elements were marked in the checklist after sustainable intervention opportunities were presented under the title of materials and resources.

Increased ventilation, using low emitting materials and using systems to control thermal comfort were offered for the indoor environmental quality. Also with the sustainable interventions to building envelope such as expanding openings, using louvers or sunshades to control daylight in order to provide thermal comfort with design implementations, were assessed under this title. In addition, enhanced acoustical performance was offered for the indoor environmental quality. So in the second case, 7 elements were marked in the checklist, whilst there are no design elements under this title for the first case.

Also, if the sustainable intervention implementations are made visible to students, it can be said that the school serves as a teaching tool of sustainability. Further, using building energy performance simulation tools in the energy performance analysis process, are assessed as innovation in design. After the interventions, 2 elements are marked for the innovation in design which is a must for a sustainable design.

As it is understood from the sustainability checklist, after the sustainable opportunities to the ŞÖMF elementary school were assessed, 20 more sustainable design elements were marked while there is only 5 markings before the interventions. So implementing the sustainable interventions to typified school buildings can be assessed to increase sustainability in the green building certification and rating systems.

5. CONCLUSION

The following conclusions were reached as a result of this study in which sustainable intervention opportunities were researched for the typified elementary school buildings through a case study:

- When sustainable design principles for school buildings were examined, it was seen that sustainable intervention steps can be classified under 5 major subjects such as sustainable site, energy and atmosphere, water efficiency, materials and resources and indoor environmental quality. Accordingly, these sustainable intervention steps collectively including subtitles, were proposed for the case study and also for all elementary school buildings that have typified projects by considering different climate regions in Turkey, as in the Table 5.1.

Table 5.1. Sustainable intervention opportunities to typified schools

<table>
<tr><th>Intervention Types</th><th>Intervention Subjects</th><th colspan="2">Intervention Steps</th></tr>
<tr><td rowspan="6">Type A</td><td rowspan="6">Site</td><td rowspan="2">1. Conservation of existing hardsoil areas</td><td>a. Covering hardsoil areas with permeable pavement for water disposal</td></tr>
<tr><td>b. Evaluation of existing natural ground to give the opportunity of sustainability activities</td></tr>
<tr><td rowspan="2">2. Re-evaluation of open areas</td><td>a. To create sustainable and green environments toward the opportunities that the site serves</td></tr>
<tr><td>b. To observe the proportion of hardsoil areas and green areas in the site by considering the heat island effect</td></tr>
<tr><td rowspan="2">3. Water management</td><td>a. Providing stormwater management by evaluating the topography of the site</td></tr>
<tr><td>b. Integration of rainwater storage systems</td></tr>
<tr><td rowspan="5">Type B</td><td rowspan="5">Water</td><td rowspan="2">1. Water management on site</td><td>a. Rainwater harvesting on site</td></tr>
<tr><td>b. Stormwater management</td></tr>
<tr><td rowspan="3">2. Water management in building</td><td>a.Efficient plumbing fixtures</td></tr>
<tr><td>b. Rooftop rainwater harvesting</td></tr>
<tr><td>c. Gray water collection</td></tr>
</table>

Table 5.1. Sustainable intervention opportunities to typified schools (continued)

Intervention Types	Intervention Subjects	Intervention Steps		
Type C	**Energy and Atmosphere**	**1.** Building envelope	**a.** Conservation of building envelope	1. Integration of louvers, sunshades to control heating and lighting energy
				2. Integration of PV panels for electrical energy production
				3. Using insulation materials
			b. Renovation of building envelope	1. Window renovation
				2. Building envelope material renovation
				3. Integration of double skin facade
				4. Expanding or decreasing the size of openings
		2. Roof applications	**a.** PV panel integration	
			b. Green and cool roof	
Type D	**Materials Resources**	**1**. Recycling building materials those ended their life and reusing of these materials		
		2. Using renewable, non-toxic, low VOC and green materials		
Type E	**Indoor Environmental Quality**	**1.** Indoor Air quality	**a.** Providing natural ventilation	
			b. Integration of mechanical systems which have systems to provide healthy environments	
			c. Changing the materials if necessary with which do not emit toxic substances	
		2. Acoustics	Providing good acoustics for indoor environmental quality	

- In the case study, ŞÖMF elementary school was assessed through a sustainability checklist before the interventions and it was seen that the school fulfilled the requirement of 5 sustainable design criteria; after the sustainable intervention to the elementary school, the school fulfilled the requirement of 20 sustainable design criteria. Therefore, it can be said that it is meaningful to use these sustainable intervention opportunities for increasing sustainability of the schools.
- Before any intervention to ŞÖMF elementary school building, the building was modeled and simulated in “DesignBuilder” building energy performance simulation tool. For this first case, simulation inputs were as EPS (Expanded polystyrene lightweight) insulation material, double clear 3mm/13mm air window glazing and window openings were 122x175cm. In order to generate simulation outputs in this

direction, the heating energy consumption was calculated as 6317 kW in December for this case.

- ŞÖMF school building modeled and simulated in "DesignBuilder" building energy performance simulation tool, after intervention to building envelope. For this second case, simulation inputs were as EPS (Expanded polystyrene heavyweight) insulation material, double clear 6mm/13mm air window glazing in the building envelope and the openings were 140x190 cm. Also, on the west and east facades of the school, louvers were integrated to control daylight. In order to generate simulation outputs in this direction, the heating energy consumption was calculated as 5980 kW in December for this second case.
- Abovementioned sustainable interventions that assessed in "Energy and Atmosphere" subject showed that heating energy reduction is about 5% for a month which was December. It can be anticipated if materials that have higher insulation values are used, the energy consumption will decrease in higher amounts.
- Also, after intervention steps have been suggested by discussing the typified school buildings related to the sustainability concept, it could be said that evaluating the same method for different building types would be beneficial. Obviously, if the existing building did not reach its end of life, this kind of renovations could be possible to provide better physical conditions. If the intervention opportunities in this study are provided to be implemented, this study could be re-evaluated for social aspects that how the users are affected from these interventions.

Almost all present studies about sustainability and efficient use of energy are supported by building energy simulation calculations or sustainability assessment systems. Within the scope of this study, many restrictions guided the energy performance analysis. Hence all of the intervention subjects are a study area in itself, it was not possible to assess all of the intervention steps comprehensively. In this regard, the other intervention steps should be studied for future works. Moreover, determination of the total gain can be provided by calculating the lighting energy consumption and cooling energy consumption. Furthermore, by using other renovation methods like trombe wall, double façade, PV panels, thermal mass; how much energy consumption can be gained from those methods can be determined for the further studies.

APPENDIX A: STATISTICAL DATA OF EDUCATIONAL BUILDINGS

Table A.1 The number of buildings by use of buildings according to the year 1984 to 2000 in Turkey

Use of building, 1984 - 2000														
Provinces	Year	Total Number of Building	Residential Building	Mostly Residential Building	Mostly out of Residential Building	Completely commercial	Education Culture	Health	Administrative	Religious	Mixed out of residential building	Other	Unknown
Turkey	1984	4 387 971	3 515 110	326 499	59 158	424 217	**13 485**	2132	18 795	13 494	12 209	812	2060
	2000	7 838 675	5 872 808	863 005	84 926	804 662	**30 349**	6600	33 124	26 952	37 598	74 788	3863
İstanbul	1984	510 979	374 868	80 408	8 274	42 853	**1023**	173	1038	1030	804	60	448
	2000	869 444	612 280	165 136	9 534	67 618	**2839**	707	2084	2216	3702	2612	716

Table A.2 Financier of building by use of educational buildings

Financier of building by use of building, 2000								
	Number of building	Residential building	Mostly residential building	Mostly out of residential building	Commercial	Industrial	Eduaction	Culture
Turkey	7 838 675	5 872 808	863 005	84 926	470 524	143 209	**28 820**	1529
Private	7 185 169	5 515 765	834 030	82 411	386 007	92 545	4321	422
Public	278 624	88 240	16 473	1 650	43 441	11 118	**24 235**	1061
Construction cooperative	350 327	258 665	9 967	493	37 608	38 832	206	6
A foreign country	2 494	830	71	10	560	97	58	14
Unknown	22 061	9 308	2 464	362	2 908	617	-	26
İstanbul	869 444	612 280	165 136	9 534	49 870	14 510	**2558**	281
Private	826 687	588 742	162 566	9 139	45 217	11 337	965	149
Public	15 553	5 355	660	65	1983	343	**1527**	119
Construction cooperative	22 548	16 138	1 170	255	2047	2648	44	2
A foreign country	527	216	42	5	81	26	22	4
Unknown	4 129	1 829	698	70	542	156	-	7

APPENDIX B: OBTAINED LIST OF THE ELEMENTARY SCHOOL PROJECTS

Whole typified elementary school projects in the Anatolian side of İstanbul are listed in Table B.1 that were obtained from İstanbul Provincial Directorate For National Education, İstanbul Special Provincial Administration, and İstanbul Provincial Directorate of Public Works and Settlement.

Table B.1 Whole elementary school projects’ lists that were obtained

Town	School Name	Site plan	Construction Project	2000-41 type	2000-42 type	10 025R-480 type	10 025R-720 type	Ragıp Akın type	2000-10 type
Ataşehir	Ümraniye-Ataşehir Yeni Çamlıca(Lemanana) E.S.	X							
Beykoz	Beykoz Çavuşbaşı Gündoğdu E.S.	X			X				
	Beykoz Çukurçayır 60. Yıl E.S. Special Type	X	X						
	Beykoz Şahinkaya E.S.	X	X						
Kadıköy	Kadıköy Şehit Öğretmen Mehmet Fidan E.S.	X	X			X			
	Kadıköy Leman Kaya E.S.	X	X					X	
	Kadıköy 29 Ekim E.S.	X				X			
	Kadıköy İnönü E.S.	X					X		
	Kadıköy Kemal Berktan E.S.	X	X					X	
	Kadiköy Halil Atamavcı E.S.	X							
Kartal	Kartal Paşaköy Samandıra E.S.	X				X			
	Kartal Saffet Simavi E.S.	X						X	
	Kartal Ibni Sina E.S.	X			X				
	Kartal Şehit Üsteğmen Gökhan Yavuz E.S.	X				X			
	Kartal Şakir Demir E.S.	X						X	
	Kartal Veysel Karani E.S.	X			X				
Maltepe	Maltepe Mürüvet Hanım E.S.	X						X	
	Maltepe Yılmaz Mızrak E.S.	X						X	
	Maltepe Hasan Şadoğlu E.S.	X				X			
	Maltepe Kadir Rezzan Has E.S.	X				X			
	Maltepe Kazım Tunç E.S.	X				X			
	Maltepe Orhangazi E.S.	X				X			
	Maltepe Suzan Ahmet Yalkın E.S.	X				X			
	Maltepe Bağlarbaşı E.S.	X					X		
	Maltepe Binbaşı Necati Bey E.S.	X		X					
	Maltepe Ahmet Rasim E.S. (Special type)	X	X						
	Maltepe Altay Çeşme E.S.	X						X	
Pendik	Pendik Kavakpınar E.S.	X	X		X	X			
	Pendik Cemile Çopuroğlu E.S.	X	X						X
	Pendik Abdurrahman Gazi E.S.	X				X			
	Pendik Ahmet Kutsi Tecer E.S.	X						X	
	Pendik Ayazma E.S.	X				X			

Table B.1 Whole elementary school projects' lists that were obtained (continued)

Town	School Name	Site plan	Construction Project	2000-41 type	2000-42 type	10 025R-480 type	10 025R-720 type	Ragıp Akın type	2000-10 type
	Pendik Süreyya Paşa E.S.	X						X	
	Pendik Erol Türker E.S.	X	X		X				
	Pendik Yıldırım Beyazıt E.S.	X	X			X			
	Pendik Şeyhli E.S.	X			X				
	Pendik Esenyalı Mah. E.S.	X				X			
	Pendik Fuat Köprülü E.S.	X							
	Pendik Kurtköy Çamlık Mah. E.S.	X			X				
Sultan-beyli	Sultanbeyli Orhangazi Mah. E.S.	X	X			X			X
	Sultanbeyli Hasanpaşa E.S.	X			X	X		X	
	Sultanbeyli Mimar Sinan Mah. E.S.	X							
Ümraniye	Ümraniye Çekmeköy İsmihan İsmet Süzer E.S.	X	X			X			
	Ümraniye Taşdelen Beldesi E.S.	X				X			
	Ümraniye 60.yıl Sarıgazi E.S.	X				X			
	Ümraniye TEV Zahide Zehra Garring E.S. (special type)	X	X						
	Ümraniye Nisantepe E.S.	X					X		
	Ümraniye Yeniçamlıca E.S.	X				X			
	Ümraniye Alemdar Ekşioğlu Mah. E.S.	X	X		X				
	Ümraniye Sarıgazi Mah. 1. Bölge E.S.	X	X		X				
	Ümraniye Çakmak Mah. E.S.	X						X	
	Ümraniye Çekmeköy Merkez Mah. E.S.	X				X			
	Ümraniye Mehmetçik High School Garden Addition E.S.	X	X						X
Üsküdar	Üsküdar Ihsan Kurşunoğlu E.S.	X				X			
	Üsküdar Belma Güde E.S. (special type)	X	X						
Tuzla	Tuzla Aydınlı E.S.	X				X			
	Tuzla Evliya Çelebi E.S.	X					X		
	Tuzla Avni Yukarıuç E.S.	X					X		
	Tuzla İbni Sina E.S.	X	X				X		

APPENDIX C: ARCITECTURAL DRAWINGS OF COMMONLY APPLIED TYPIFIED ELEMENTARY SCHOOLS

Commonly applied typified elementary school projects are presented in Figure C.1, Figure C.2, Figure C.3, Figure C.4, Figure C.5.

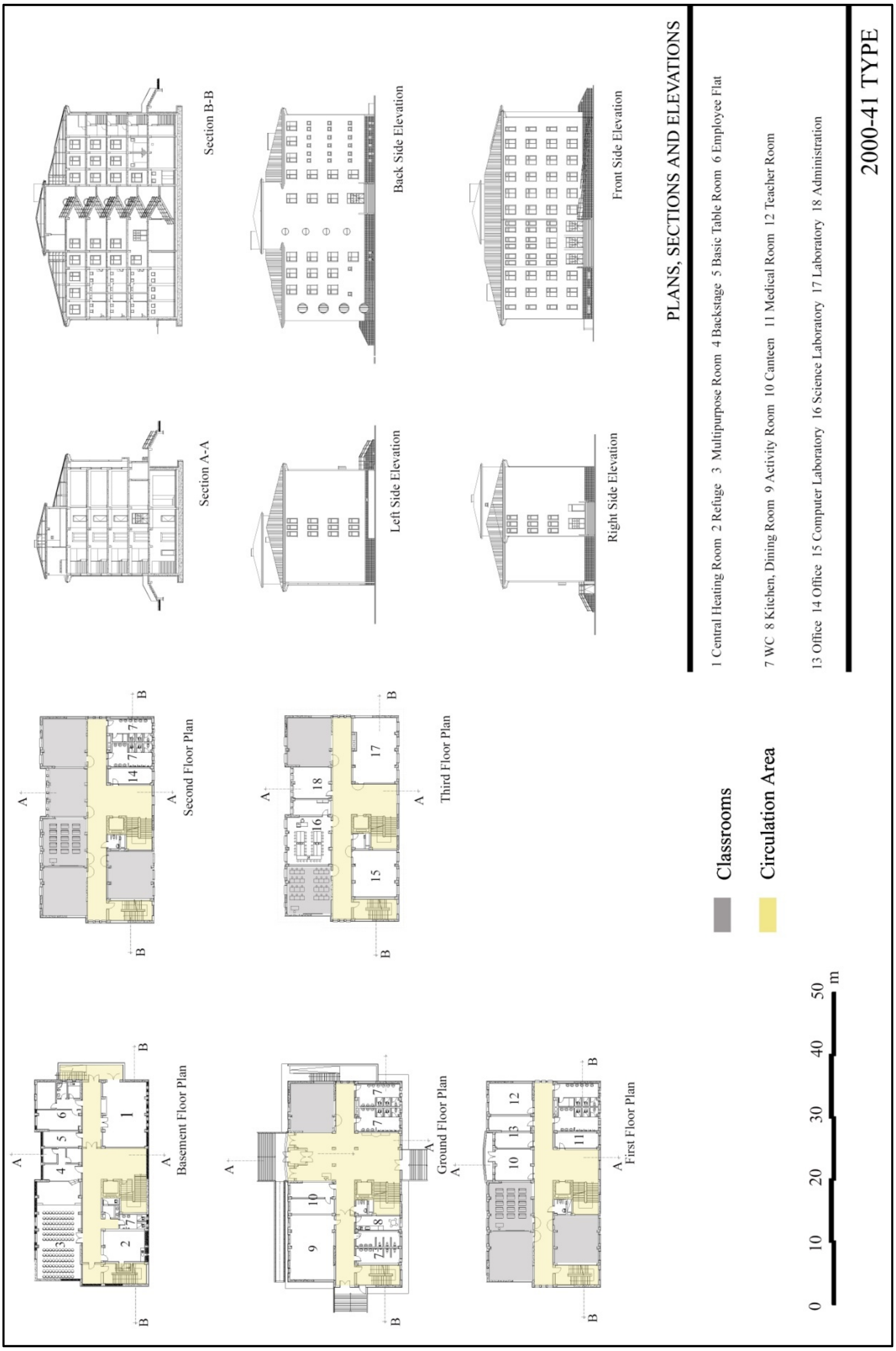


Figure C.1 2000-41 type architectural drawings

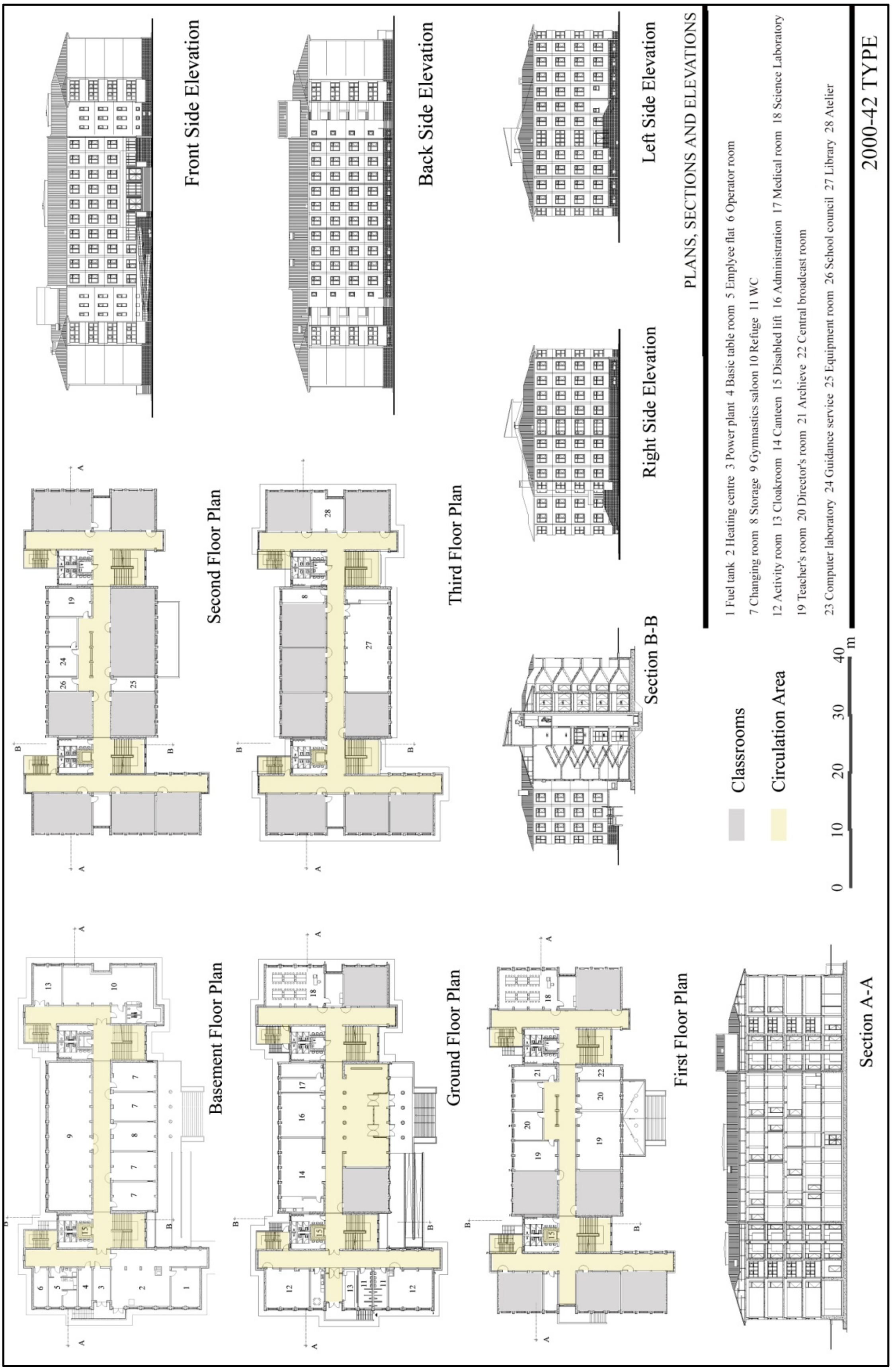


Figure C.2 2000-42 type architectural drawings

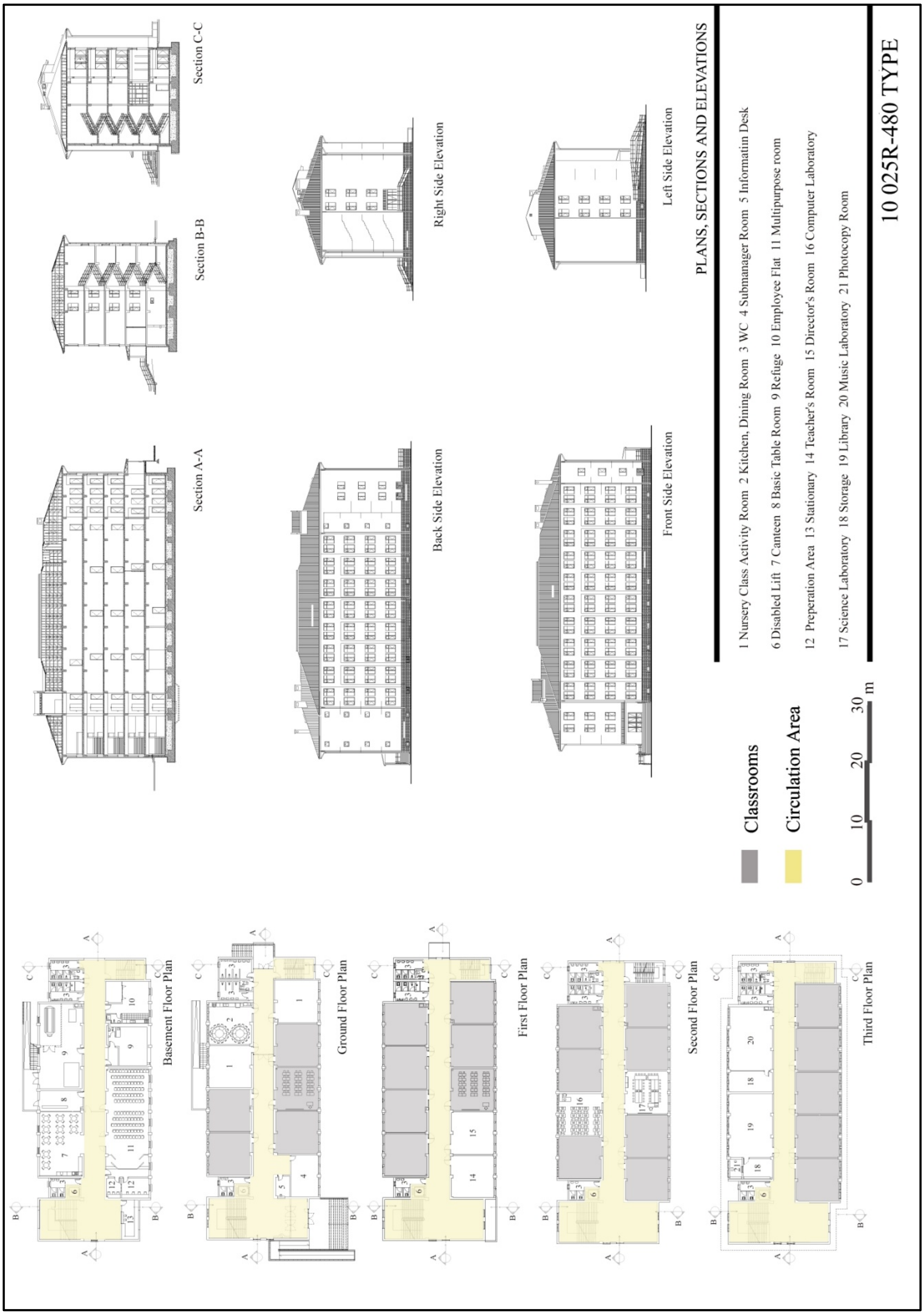


Figure C.3 10025R-480 type architectural drawings

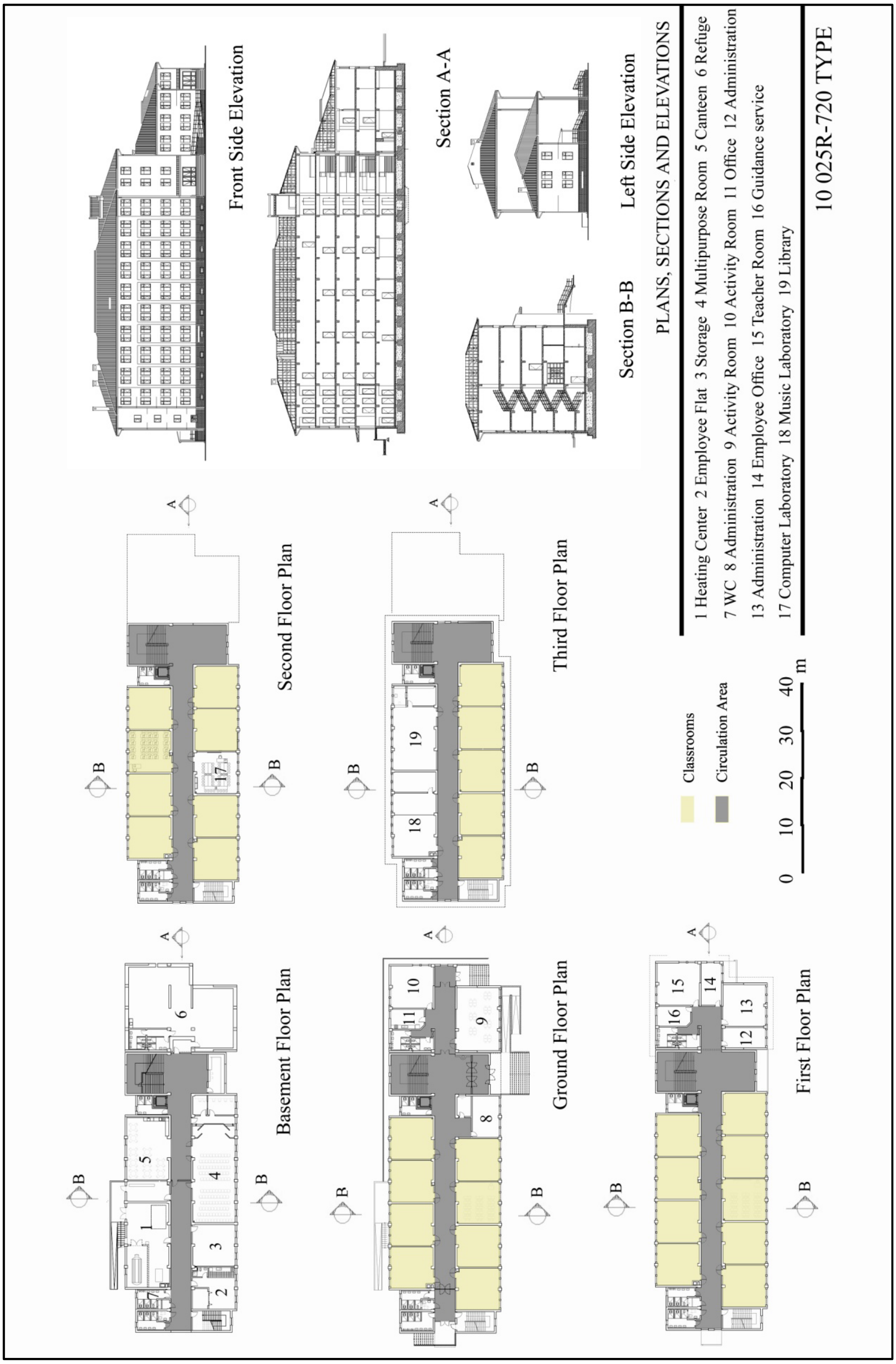


Figure C.4 10025R-720 type architectural drawings

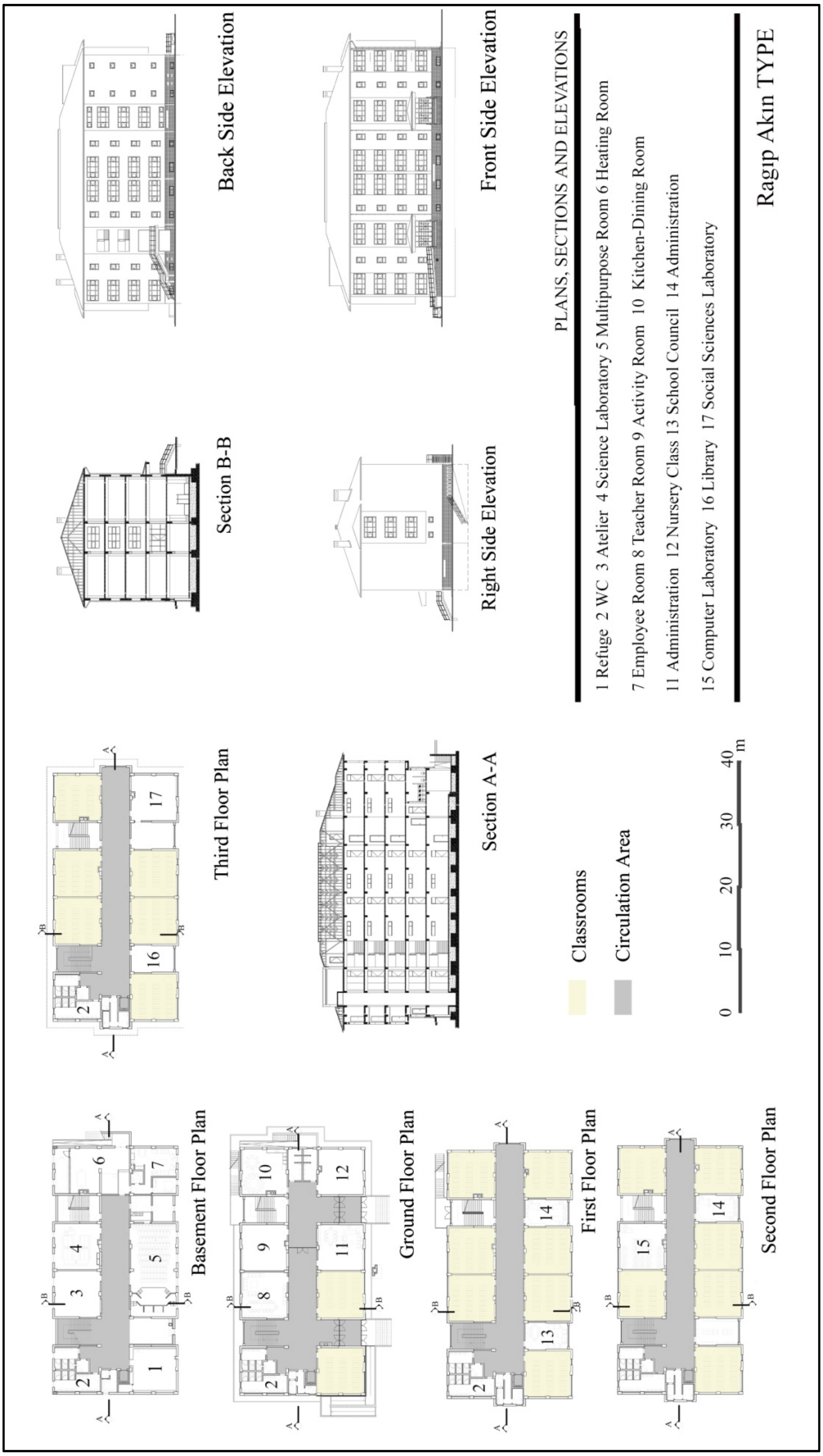


Figure C.5 Ragıp Akın type architectural drawings

APPENDIX D: DATA GENERATED BY DESIGNBUILDER

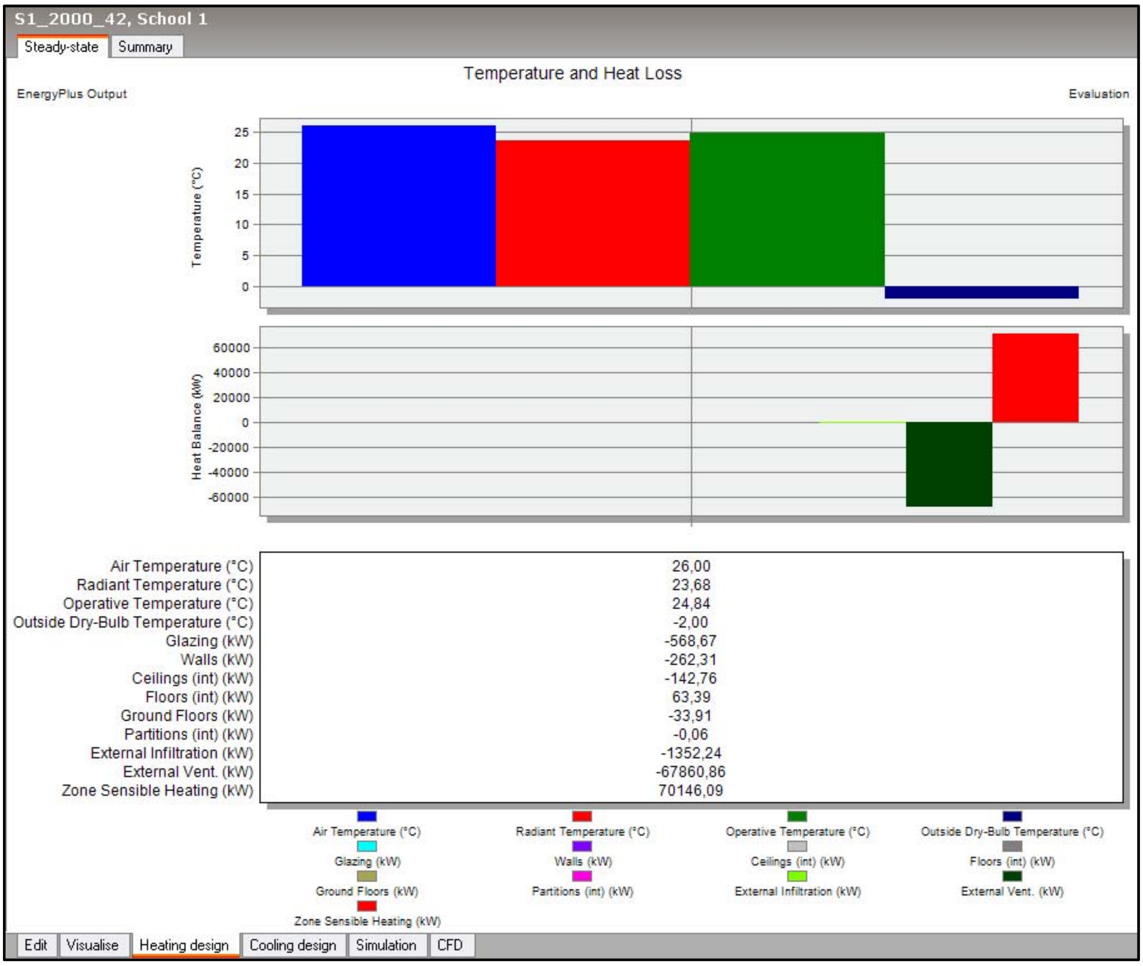


Figure D.1 Data generated before intervention to the building envelope of ŞÖMF elementary school

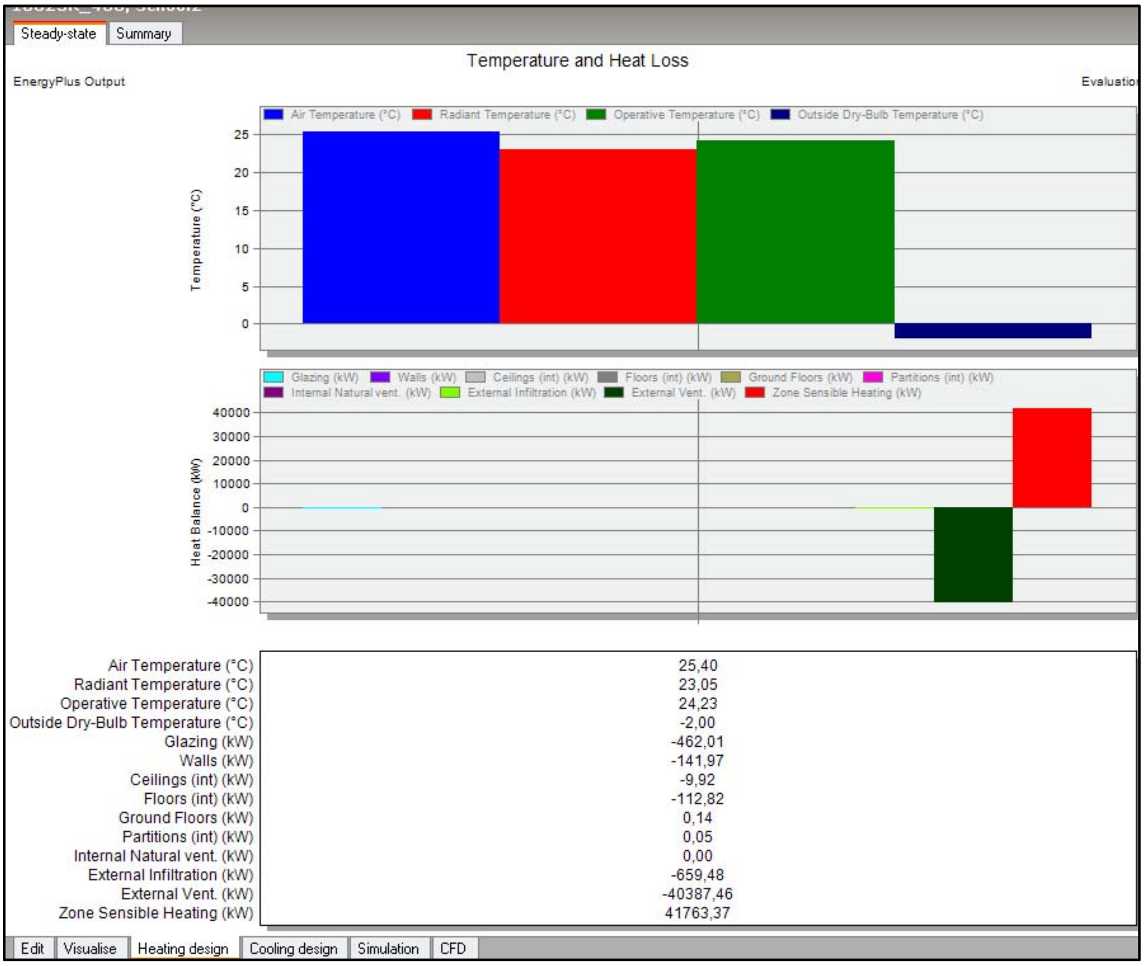


Figure D.2 Data generated after intervention to the building envelope of ŞÖMF elementary school

REFERENCES

1. U.S. Energy Information Administration (EIA), *International Energy Outlook,* Washington, www.eia.gov/oiaf/ieo/index.html, 2010.

2. Bachman, L. R., *Integrated Buildings: The Systems Basis of Architecture,* John Wiley & Sons, New Jersey, 2003.

3. Brunoro, S., "*An Assessment of Energetic Efficiency Improvement of Existing Building Envelopes in Italy"*, Management of Environmental Quality*,* Vol. 19, issue 6, p.718, 2008.

4. Berkes, F., & Kışlalıoğlu, M., *Ekoloji ve Çevre Bilimleri,* Remzi Kitabevi, İstanbul, 2009.

5. Freeman, S., *Biological Science,* Pearson Benjamin Cummings, San Francisco, 2008.

6. Holliday, J. C., *Design for Environment: Social Change and the Need for New Approaches in Planning,* Charles Knight, London, 1977.

7. Karabey, H., "*Ülkemiz Açısından Çevre Sorunlarına Bir Yaklaşım ve Bilimin Görevi" Makale*, DGSA Yayını, Ankara, 1977.

8. Cain, M. L., Bowman, W. D., Hacker, S. D., *Ecology,* Sinauer Associate, Sunderland, 2008.

9. Fanchi, J. R., *Energy Technology and Directions for the Future,* Elsevier Academic Press, London, 2004.

10. Behling, S., & Behling, S., *Solar Power: The Evolution of Sustainable Architecture,* Prestel*,* London, 2000.

11. McKinney, M. L., Schoch, R. M., & Yonavjak, L., *Environmental Science: Systems and Solution,* Jones and Bartlett, London, 2007.

12. “Kyoto Protocol”, United Nations Framework Convention on Climate Change (UNFCCC), http://unfccc.int/kyoto_protocol/items/2830, 1997, accesced in September, 2010.

13. Williams, D. E., *Sustainable Design: Ecology, Architecture and Planning,* John Wiley & Sons, Canada, 2007.

14. Odum, E. P., & Barrett, G. W., *Fundamentals of Ecology,* Thomson Brooks/Cole*,* Toronto, 2005.

15. Manuel, C., & Molles, J., *Ecology: Concepts and Applications,* McGraw Hill*,* Newyork, 2002.

16. Mcharg, I. L., *Design with Nature,* John Wiley & Son, Washington, 1992.

17. Van der Ryn, S., & Cowan, S., *Ecological Design,* Island Press, Washington, 1996.

18. Weber, H., *Energiebewusst planen,* Verlag Georgy D.W. Callwey, München, 1983.

19. Halloway, D. R., *“A Simple Design Methodology For Passive Solar Houses”*, http://www.dennisrhollowayarchitect.com/, 2009, last accessed in December.

20. Todd, N., & Todd, J., *From Eco-Cities to Living Machines: Principles of Ecological Design,* North Atlantic Books*,* California, 1993.

21. Chahroudi, D., “*Buildings as Organisms,*. CoEvolution Quarterly, Vol.16, pp.110-115, 1977-1978.

22. Lee, P. B., “*The Ekose'a House*”, CoEvolution Quarterly*,* Whole Earth Catalog, Vol.20, pp. 33-34, 1978.

23. Madge, P., "*Ecological Design: A New Critique"*, Design Issues, Vol. 13, Issue 2, pp. 44-54, 1997.

24. World Commission on Environment and Development, *"Our Common Future Report*", Oxford University Press, London, 1987.

25. Mebratu, D., "*Sustainability and Sustainable Development: Historical and Conceptual Review",* Environmental Impact Assessment Review, pp. 493-520, 1998.

26. Button, J., *Dictionary of Green Ideas,* Routledge, London, 1988.

27. Brown, B. J., Hanson, M. E., Liverman, D. M., Merideth, R. W., "*Global sustainability: Toward definition*", Environmental Management *,* Vol. 11, issue 6, pp. 713-719, 1987.

28. Keeler, M., & Burke, B., *Fundamentals of Integrated Design for Sustainable Building,* John & Wiley Sons, Canada, 2009.

29. Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W., *The Limits to Growth,* Universe Books*,* NewYork, 1974.

30. Pisani, J. A., *"Sustainable development:, Historical roots of the concept"* Environmental Sciences*,* Vol.3, issue 2, pp. 83-96, 2006.

31. Wheeler S. M., Beatley T., *The Sustainable Urban Development Reader*, Routledge, Newyork, 2007.

32. Wackernagel, M., & Rees, W., "*What is an Ecological Footprint*", The Sustainable Urban Development Reader, Routledge, pp. 211-219. Newyork, 2007.

33. Dorsey, J., & L'Esperance, C., *Sustainable Design Guidelines for the Construction of New Facilities and the Renovation of Existing Structure*, Education Resources Information Center (ERIC), http://www.eric.ed.gov/PDFS/ED454689.pdf, 2000.

34. LPA., *Green School Primer: Lessons in Sustainability,* Images Publishing, Victoria, 2009

35. "*Guiding Principles of Sustainable Design",* National Park Service, http://www.nps.gov/dsc/d_publications/d_1_gpsd_1_ch1.htm, 2010.

36. Prowler, D., FAIA, & Vierra, S., "*The Role of Buildings and the Case for Whole Building Design",* WBDG National Institute of Building Science, http://www.wbdg.org/, 2008, accessed in 2010, February.

37. Tönük, S., *Bina Tasarımında Ekoloji,* YTÜ Basın Yayın Merkezi, İstanbul, 2001.

38. Douglas, J., *Building Adaptation,* Butterworth-Heinemann, Elsevier, Burlington, 2006.

39. Gevorkian, P., *Alternative Energy Systems in Building Design,* McGraw-Hill Professional, Newyork, 2009.

40. "Hydrogen Benefits", tech. report., Hydrogen Energy Center, http://www.hydrogenenergycenter.org, 2010, accessed in 2010, March.

41. Fuchs, H., & Zeumer, S., *Energy Manual: Sustainable Architecture,* Birkhauser Verlag, Münich, 2008.

42. Taylor, A., *Linking Architecture and Education: Sustainable Design of Learning Environments,* University of New Mexico Press, China, 2009.

43. Earthman, G. I., *School Facility Conditions and Student Academic Achievement,* UCLA's Institute for Democracy, Education and Access., Williams Watch Series, Los Angeles, 2002

44. Dudek, M., *Architecture of Schools: The New Learning Environments,* Architectural Press, London, 2000.

45. Gelfand, L., *Sustainable School Architecture: Design for Primary and Secondary Schools,* John Wiley & Sons, Canada, 2010.

46. Dudek, M., *Schools and Kindergartens,* Birkhauser. Berlin, 2007

47. Ford, A., *Designing the Sustainable School,* Images Publishing, Victoria, 2007.

48. "*Green Existing Schools Implementation Workbook",* LEED USGBC report, Washington, http://www.usgbc.org/ShowFile.aspx?DocumentID=6427, 2009.

49. "*Heat Island Effect"*, US Environmental Agency Report*, http://www.epa.gov/, 2010.*

50. Santamouris, M., "*Heat-Island Effect"*, Energy and Climate in the Urban Built Environment, pp. 48-68, James & James, London, 2001.

51. Olgyay, V., *Design with Climate: Bioclimatic Approach to Architectural Regionalism,* Princeton University Press, New Jersey, 1963.

52. Patkau Architects, *Strawberry Vale Elementary School report*, http://www.patkau.ca/, 2009.

53. Kayıhan, K. S., *Sürdürülebilir Mimarlığın Yarı Nemli Marmara İkliminde Tasarlanacak Temel Eğitim Binalarında İrdelenmesi ve Bir Yöntem Önerisi,* Yıldız Teknik Üniversitesi, Doktora Tezi, İstanbul, 2006.

54. McDonough, W., & Braungart, M., *Cradle to Cradle: Remaking the Way We Make Things,* North Point Press, New York, 2002.

55. Berge, B., *The Ecology of Building Materials,* Architectural Press, Oxford, 2009.

56. Sev, A., *Sürdürülebilir Mimarlık*, Yapı Endüstri Merkezi, İstanbul, 2009.

57. Slessor, C., *"Primary School",* The Architectural Review, Vol. 1352, pp. 66-69, 2009.

58. Kere Architecture, *Primary School report,* http://www.kere-architecture.com/bf/bf_001.html, 2007, accessed in March, 2010.

59. Network, A. K., *Gando Primary School, Gando, Burkina Faso*, http://www.akdn.org/photos_show.asp?Sid=3, 2002, accessed in March, 2010.

60. *AIA/COTE Top Ten Green Projects*, tech. report, AIA/The American Institute of Architects, http://www.aiatopten.org/, 2007, accessed in July, 2010.

61. Boehland, J., *Projects: Nueva School*, GreenSource The Magazin of Sustainable Design, http://greensource.construction.com/projects/0807, 2008, accessed in March, 2010.

62. *Certified Project List: Neuva School,* USGBC - U.S. Green Building Council,. http://leedcasestudies.usgbc.org/,2008, last accessed in March, 2010.

63. Leddy Maytum Stacy Architects projects, http://www.lmsarch.com/, 2000, accessed in June, 2010.

64. *Sidwell Friends Middle School*, project presentation, KieranTimberlake Architects, http://kierantimberlake.com/featured_projects/, 2010, accessed in August, 2010.

65. *Sidwell Friends Middle School,* project definition, USGBC, http://www.usgbc.org/, 2007, accessed in August, 2010.

66. Bauer, M., Mösle, P., & Schwarz, M., *Green Building: Guidebook for Sustainable Architecture,* Springer, Berlin, 2010.

67. Malin, N., *Sidwell Friends Middle School*, project definiton, GreenSource, http://greensource.construction.com/projects/0707_sidwell.asp, 2010, accessed in August, 2010.

68. Andropogon Landscape Architecture, *Ecological planning and design, sustainable Works*, http://www.andropogon.com/work, 2010, accessed in August, 2010.

69. *Sayısal Veriler-2009*, T.C. İstanbul Valiliği, İ. M., Express Basımevi, İstanbul, 2009.

70. Gökmen, G. P., Özsoy, A., Çağdaş, G., Esin, N., & Erkök, F., "*Çağdaş ilköğretim Okulu Tasarım ve Uygulamalarında Bağlam Tartışmaları"* Mimar-ist, issue: 2, pp. 29-34, 2007.

71. *Building Census 2000,* State Institute of Statistics Prime Ministery Republic of Turkey, http://www.turkstat.gov.tr/Kitap.do?metod=KitapDetay&KT_ID=9&KITAP_ID=64, Ankara, 2001, accessed in June, 2010.

REFERENCES NOT CITED

Eicker, U., *Solar Technologies for Buildings,* John Wiley & Sons, Stuttgart, 2003.

Gonzalo, R., Habermann K. J, *Energy Efficient Architecture: Basics for planning and construction*, Birkhauser, Boston, 2006.

Haeckel, E., *General Morphology of Organisms,* Reimer, Berlin, 1866.

Healh K., *Vernacular Architecture and Regional Design: Cultural Process and Environment Response,* Architectural Press, London, 2009.

Melby, P., *Regenerative Design Techniques*, John Wiley & Sons, New York, 2002.

Stein, R. G., *Architecture and Energy*, Anchor Press, New York, 1977.

Wines, J., *Green Architecture,* Taschen, Köln, 2008.

Zeisel, J., *Inquiry by design: environment/behavior/neuroscience in architecture, interiors, landscape, and planning,* W.W. Norton Company, New York, 2006.